

Sept. 18, 1945.

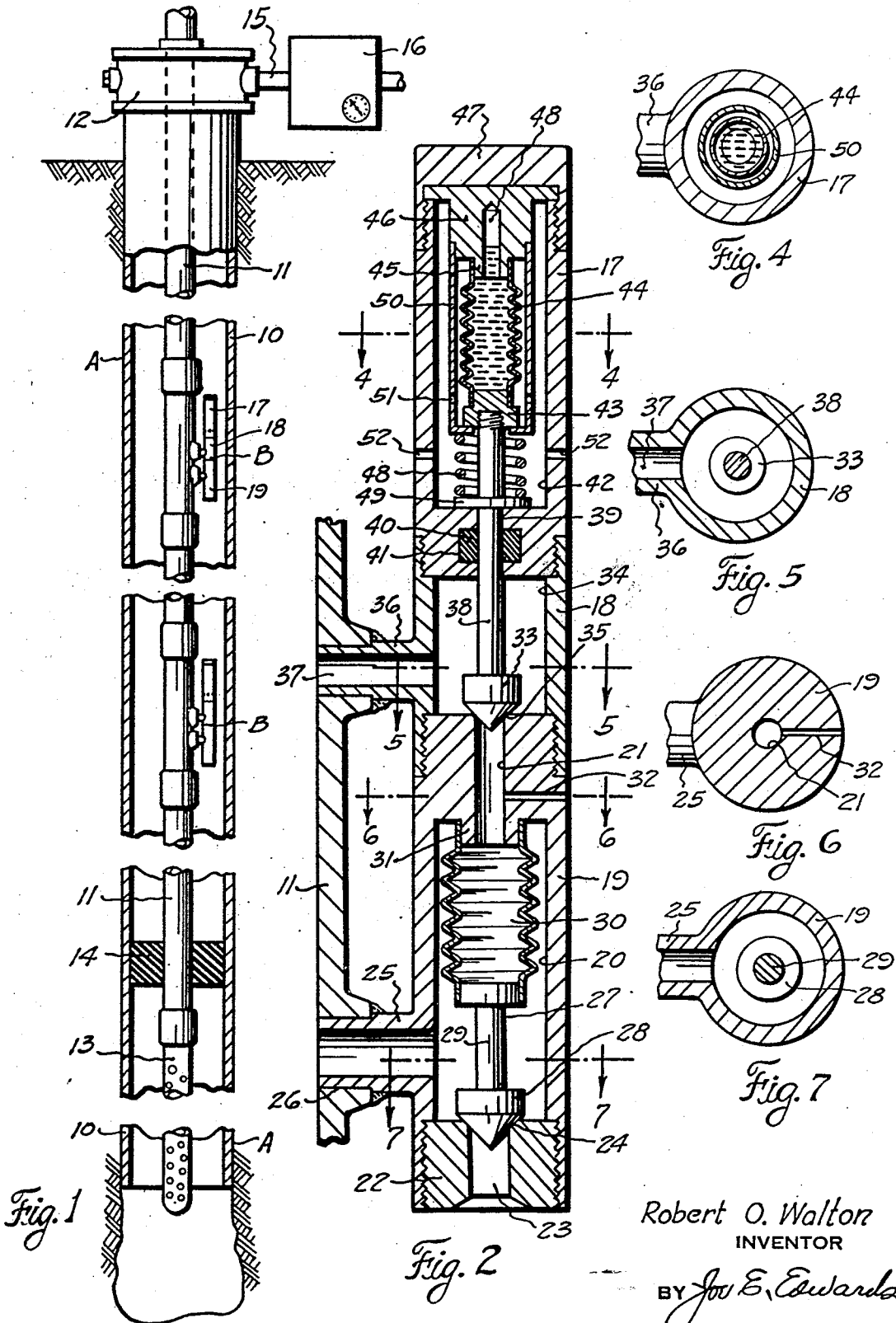
R. O. WALTON

2,385,316

WELL FLOW DEVICE

Filed June 9, 1944

2 Sheets-Sheet 1



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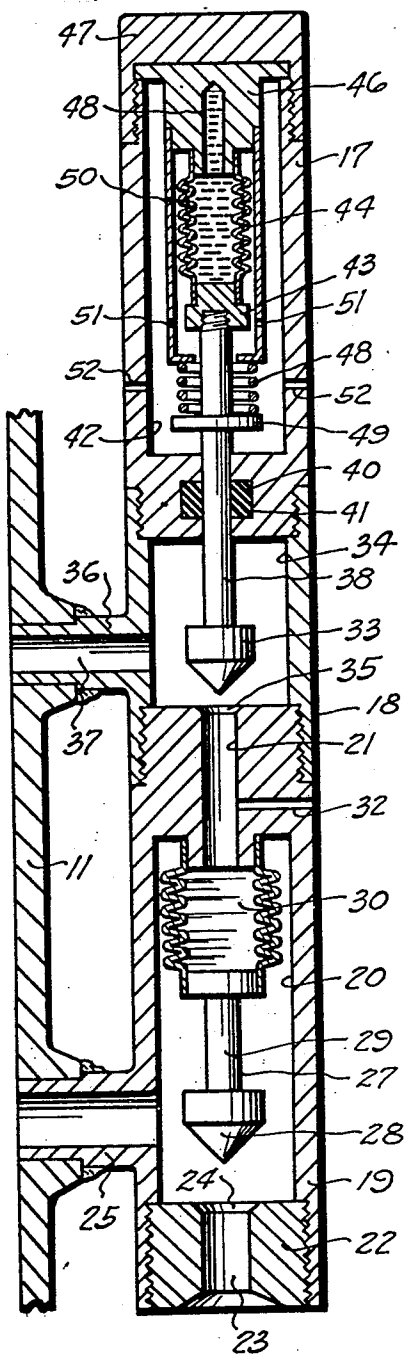


Fig. 3

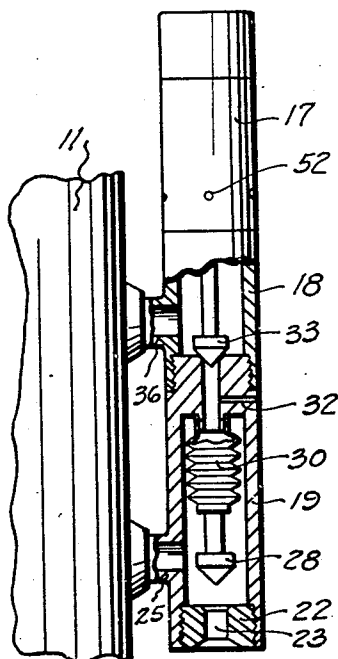


Fig. 8

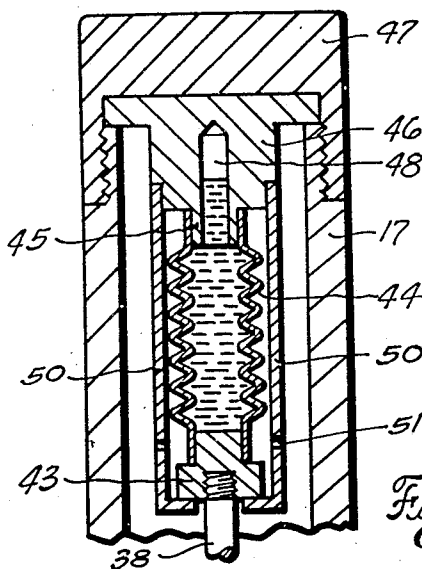


Fig. 9

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2,385,316

WELL FLOW DEVICE

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Application June 9, 1944, Serial No. 539,424

18 Claims. (Cl. 103—233)

This invention relates to new and useful improvements in well flow devices.

The invention is a modification of and improvement on the device shown in my co-pending application, Serial No. 451,570, filed July 20, 1942.

One object of the invention is to provide an improved device for controlling the admission of a lifting fluid, such as gas, into a liquid column within a well tubing or conductor for lifting or raising the liquid to the surface, said device being particularly adapted for use as an intermitter to intermittently admit the lifting gas at predetermined intervals in accordance with well conditions.

An important object of the invention is to provide a simple and efficient flow device which is constructed of a minimum number of parts, said device being actuated solely by the pressure of the lifting gas, whereby a differential in pressures across the valve element of the device is not depended upon to operate said valve and also whereby lifting gas is admitted into the liquid column in the well tubing only when said lifting gas has attained the desired predetermined pressure necessary to effect lifting of the well fluid in said tubing.

A particular object of the invention is to provide an improved device, of the character described, having a main valve for controlling admission of the lifting gas into the well liquid column, said valve being normally held in a closed position by the pressure of the lifting gas; the device also including a pilot valve which is actuated when the lifting gas reaches a predetermined pressure, said pilot valve upon actuation, relieving the pressure acting to hold the main valve closed, whereby said main valve may move to an open position and thereby admit gas to the liquid column.

Another object of the invention is to provide an improved flow device which includes a main control valve having an enlarged bellows attached thereto, both the valve head and the interior of said bellows being exposed to the pressure of the lifting gas so that the larger cross-sectional area of the bellows is utilized to normally hold the valve in its closed position; the device also including means for "bleeding off" the pressure within said bellows to allow opening of the main valve when the lifting gas reaches a predetermined desired pressure.

Still another object of the invention is to provide an improved flow device, of the character described, wherein the gas pressure acting upon

the main valve bellows is bled off into the well tubing and also wherein the means for permitting the escape of said pressure is a pilot valve which is itself actuated by the pressure of the lifting gas.

A specific object of the invention is to provide an improved pilot valve arrangement for controlling actuation of the main valve, said pilot including a depressible bellows which has its exterior exposed to the pressure of the lifting gas so as to be actuated thereby, the interior of said bellows having means for limiting its movement, whereby a positive stop for movement of the valve is had and rupturing of the bellows by an excessive lifting gas pressure is prevented.

A still further object of the invention is to provide an improved pilot valve arrangement for a flow device, wherein the actuating bellows of said valve has a suitable liquid contained therein, said bellows functioning as a positive stop to limit movement of the valve and also acting to prevent collapse or rupturing of said bellows by excessive external pressures.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings, wherein an example of the invention is shown, and wherein:

Figure 1 is a view, partly in section and partly in elevation of a well bore having a well tubing extending therethrough showing a plurality of flow devices, constructed in accordance with the invention, mounted in said tubing.

Figure 2 is an enlarged, transverse, vertical sectional view of the flow device, with the main valve and pilot valve closed.

Figure 3 is a similar view, with the main valve closed and the pilot valve open.

Figures 4 to 7 are enlarged, horizontal, cross-sectional views, taken on the lines 4—4, 5—5, 6—6, and 7—7, respectively, of Figure 2.

Figure 8 is a view, partly in section and partly in elevation of the flow device and showing the pilot valve closed with the main valve open, and

Figure 9 is an enlarged, transverse sectional view of the bellows which actuates the pilot valve.

In the drawings, the letter A designates a well bore having a well casing 10 mounted therein. A well tubing 11 extends downwardly through the casing 10 and has its upper end supported in the usual casing head 12 which is mounted on the upper end of said casing. The lower end of the well tubing has the conventional well screen 13, through which the well fluids are admitted into said tubing, attached thereto. A suitable well

packer 14 which is schematically illustrated packs off between the tubing and casing above the perforated screen 13.

A plurality of valve devices B, constructed in accordance with the invention, are connected in the tubing 11 and are located at various elevations or levels therein. As will be hereinafter described, each device B is adapted to control the admission of a lifting fluid, such as gas, into the well tubing string and such fluid is utilized to lift the well liquids upwardly through the well tubing to the surface. The invention will be herein described as operating with an auxiliary lifting fluid such as gas, but it is noted that the lifting fluid may be gas from a sub-surface formation which enters the well casing. When auxiliary lifting fluid is employed, said lifting fluid or gas is conducted to the annular space between the well casing 10 and the well tubing through an inlet pipe 15 which is connected to the casing head 12, the admission of said gas being controlled by a time-controlled intermitting device 16. The time controlled intermitter 16, as is well known, controls the admission of gas to admit the same in predetermined volumes at desired intervals and said device is adjusted in accordance with the particular conditions of each well.

The devices B are all of identical construction and each device includes a tubular housing which is constructed of three sections, an upper section 17, an intermediate section 18 and a lower section 19 (Figure 2). The lower section is provided with an axial bore 20 and a reduced counterbore 21 which communicates with the main bore is formed at the upper portion of the section. A collar 22 having an inlet port 23 extending therethrough is threaded into the lower end of the bore 20 and the extreme upper end of the port has an annular beveled valve seat 24 surrounding the same. Manifestly, the inlet port 23 establishes communication between the well casing 10 and the bore 20 of the lower section 19 of the device.

Communication between the bore 20 of said section and the interior of the well tubing 11 is established by means of a tubular nipple 25 which extends radially from the lower portion of the section 19 and which is suitably secured within an opening 26 in the tubing. Thus a flow of fluid from the annular space between the casing 10 and tubing 11 may occur through the port 23, bore 20 and nipple 25 into the interior of the well tubing.

For controlling the flow of fluid through the port 23, a main valve 27 is mounted within the section 19 and is adapted to engage the annular valve seat 24. The valve includes a valve head 28 and valve stem 29, the latter having its upper end secured to the lower end of a main valve bellows 30. The upper end of the bellows is fastened to an annular collar 31 which surrounds the lower end of the counterbore 21 and the bellows is constructed so that its spring action normally urges it toward a collapsed or depressed position, whereby the bellows tends to hold the main valve in a raised or unseated position, as shown in Figure 8. For expanding the bellows to move the valve downwardly to a seated or closed position, the interior of said bellows is exposed to the pressure exteriorly of the device through a gas supply passage 32 which extends radially through the upper portion of the section 19 and which communicates with the counterbore 21. With this arrangement, the pressure of the

fluid within the casing outside of the tubing acts against the interior of the bellows 30 and also acts against the valve head 28 when the latter is seated; however, since the cross-sectional area of the bellows is greater than the exposed portion of the valve head, it is evident that the valve will be held in a closed or seated position.

The pressure within the casing which is acting upon the bellows 30 is that of the lifting fluid or gas and when this pressure reaches a predetermined point, it is desirable to open the main valve to admit the lifting fluid into the well tubing to effect raising of the well liquid within said tubing. In order to actuate the main valve 27 and move it to its unseated or open position when the lifting fluid reaches a predetermined pressure, a pilot valve 33 is mounted within the bore 34 of the intermediate section 18. The pilot valve is adapted to engage a valve seat 35 which surrounds the upper end of the counterbore 21 and when said valve is seated the pressure is trapped within the bellows 30 to hold the main valve 28 in its lowered or closed position. Upward movement of the pilot valve 33 opens the counterbore 21 and permits the pressure within the bellows 30 to escape upwardly into the section 18; the section 18 communicates with the interior of the well tubing through a tubular nipple 36 and it is noted that the bore 37 of the nipple is of considerably larger diameter than the supply passage 32 through which the fluid pressure is admitted to the bellows.

Therefore, as soon as the pilot valve 33 is opened, the pressure may escape from the interior of the bellows through the counterbore 21 and nipple 36 at a faster rate than such pressure can be replenished through the relatively small passage 32, with the result that the pressure acting on the interior of the bellows is reduced to the point where the main valve 27 is opened. This opening of the main valve is effected by the normal collapsing action of the bellows and also by the lifting fluid acting against the lower end of said valve.

In order to open the pilot valve 33 when the pressure of the lifting fluid reaches the predetermined desired point, said valve is actuated solely by the lifting fluid pressure. As is clearly shown in Figures 2 and 3, the pilot valve includes a stem 38 which extends upwardly through a reduced counterbore 39 formed in the lower portion of the upper section 17. A suitable packing ring 40 is disposed within a recess 41 in the counterbore and surrounds the stem to seal off around said stem. The upper end of the stem extends upwardly into the main bore 42 of the section 17 and has its extreme upper end fastened to a plug 43. The plug 43 is attached to and closes the lower end of an operating bellows 44 which is disposed within the upper portion of the section 17. The upper end of the bellows is fastened to a depending collar 45 which is formed integral with a cap member 46, the latter being mounted in position between the upper end of the section 17 and a closure 47 having threaded connection with said section.

The bellows 44 is constructed so that its normal spring action tends to expand the bellows whereby the pilot valve attached to its lower end is normally urged toward its seated position.

The interior of the bellows is filled (Figures 2 and 9) with a suitable fluid such as water or oil and the upper end of said bellows communicates with a recess 48 in the cap member 46. When the bellows is expanded and the pilot valve seated

(Figures 2 and 9) the fluid does not completely fill the recess, whereby the bellows may be depressed until this recess is completely filled as illustrated in Figure 3. The volume of fluid within the bellows will determine the amount of movement which the bellows may undergo and thus the fluid acts as a positive stop to limit the travel of the pilot valve. Also, it is apparent that when the bellows is fully depressed the fluid completely fills said bellows and recess and since said fluid is non-compressible, rupturing or breaking of the bellows by an excessive external pressure on said bellows cannot occur. Thus, the fluid not only acts as a stop for limiting movement of the pilot valve but also acts to prevent rupturing of said bellows by external pressure and this is an important feature of the invention.

In addition to the normal action of the bellows urging the pilot valve to its seated position, a coiled spring 48 surrounds the pilot valve stem 38 within the upper section 17. This spring has its lower end engaging an external annular flange or ring 49 which is secured to the stem, while its upper end is confined against the lower end of a fixed sleeve 50. The sleeve 50 has its upper end fastened to the cap member 46 and encircles the pilot bellows 44. The plug 43 which closes the lower end of the bellows and has the stem attached thereto is arranged to engage the flanged lower end of the sleeve when the pilot valve is in a lowered or closed position (Figure 2). The sleeve 50 has a plurality of ports or openings 51 therein while the upper section is provided with inlet ports 52 whereby the pressure of the lifting fluid in the casing may enter the section and then the sleeve to act upon the bellows 44 to depress the same. It is noted that the sleeve 50 could be replaced by elongate stop arms which would serve the same purpose.

The spring 48 which urges the pilot valve to its closed position is of a predetermined tension and obviously, the pressure of the lifting fluid acting against the pilot bellows 44 must reach a predetermined pressure before the pilot valve will open. By changing the tension of this spring, the pilot valve may be arranged to open at any desired lifting fluid pressure. No differential of pressure across the valve is depended upon because the spring exerts a constant fixed pressure on the valve which can be overcome only when the lifting fluid pressure exceeds such constant.

In operation, a plurality of valve devices B are connected in the tubing string 11 and are disposed at various elevations therein. Each valve device has its spring 48 properly adjusted so as to exert a predetermined pressure upon its pilot valve 33, it being preferable that the uppermost device be set for the highest pressure. For example, the uppermost valve device in the tubing may be set to open the pilot valve at 450 pounds per square inch, the next set to open at 425 pounds, the third at 400 and so on progressively to the lowermost device in the tubing which would, of course, be operated by the lowest pressure.

With no or insufficient pressure in the well casing, each valve device is in the position shown in Figure 8 with the main valve 27 open and the pilot valve 33 closed. To initially start the devices in operation, the lifting fluid is introduced into the casing until sufficient pressure to extend the main valve bellows 30 has been introduced. It is noted that the pilot valve spring 48

exerts a greater pressure than the main valve bellows 30 so that said bellows is extended to close the main valve before the pilot valve opens. The introduction of the initial lifting fluid may be accomplished either by closing in both tubing and casing and equalizing pressures throughout and then bleeding off the tubing pressure to hold a sufficient pressure in the casing to maintain the main valve 27 seated, or by admitting the lifting fluid pressure into the casing in a volume greater than the fluid can escape into the tubing through the open main valves of the various devices. In this latter method, it is apparent that the pressure will be built up in the casing until it becomes sufficient to close the main valve through its action on the main valve bellows 30. When this point is reached, no additional lifting fluid is admitted except at the proper intervals by the intermitter.

As explained, the pressure of the lifting fluid acts through the passage 32 and counterbore 21 and against the interior of the main valve bellows 30 to hold the main valve 27 seated or closed. At this time, the pilot valve 33 is also closed since the spring 48 has a greater pressure than the spring action of the main bellows.

The liquid column in the well tubing is permitted to build up to its standing level after which the intermitter 16 actuates to admit a charge of lifting fluid to increase the pressure of said fluid within the casing. As this pressure reaches the point at which the uppermost valve is set, said pressure acting through the ports 52 in the section 17 and ports 51 in the sleeve 50 overcomes the tension of the spring 48 and depresses the pilot valve bellows 44 to raise the pilot valve 33 from its seat. As soon as this occurs the pressure within the main valve bellows 30 may escape through the counterbore 21 and nipple 36, with the result that the main valve 27 is unseated (Figure 3) to admit the lifting fluid into the tubing through inlet port 23 and nipple 25. This lifting fluid will lift the well liquid to the surface in the usual manner. The main valve 27 will remain open so long as the pressure acting upon the pilot bellows 44 is sufficient to hold the pilot valve open against the pressure of the spring 48. However, when the fluid pressure in the casing drops below the pressure of the spring 48 the pilot valve closes to again trap the pressure within the main valve bellows and thereby close the main valve.

The particular adjustment of the valve devices which sets the uppermost valve to operate at the highest pressure with each valve device therebelow set for progressively lower pressures also makes it possible to effect a lowering of the working level of the well, whereby a lower lifting fluid pressure is required for lifting purposes. When utilized in this manner, the tubing string having the valve devices connected therein is lowered into the well and for purposes of illustration, it will be assumed that the well is 5,000 feet deep with a normal standing liquid level of 4,000 feet, which means that the normal level is 1,000 feet below the surface. The well packer 14 is then set within the well casing and obviously, a column of liquid is trapped in the annular space between the well tubing and casing. Due to the construction of the valve devices, those devices which are subjected to a pressure greater than that for which their respective pilot bellows are adjusted are held open by the pressure exerted by the liquid column. Those devices nearer the upper end of the column which are not subjected to sufficient

pressure to open their pilot valves may be held in a closed position or if such pressure is insufficient to extend the main bellows 30, the valve may be open.

After the packer is set, the auxiliary lifting fluid pressure is introduced into the annular space between the tubing and casing and the admission of the initial pressure will be sufficient to effect closing of all of the uppermost valves above the point at which the liquid column exerts a pressure sufficient to hold the valves therebelow in a closed position, with the uppermost valve device adjusted to be opened when the pressure in the annular space between casing and tubing reaches 450 pounds, the lifting fluid is admitted into the casing until this pressure is reached; since all of the valve devices below the uppermost one are adjusted to open at lower pressures, it is apparent that when 450 pounds pressure is reached, all of said devices will be open. When the uppermost valve device opens, the lifting fluid is admitted to the well tubing and lifts the well liquid in the tubing above this valve device to the surface, whereby the upper portion of the liquid column in said tubing is raised. This removal of a portion of the liquid column lightens the load in the well tubing and allows the well liquid to flow from the annular space between the casing and tubing and into the tubing, thereby lowering the liquid level in the annular space and raising the level in the tubing above the uppermost valve, so that as the intermitter shuts off flow, the uppermost valve closes. As the intermitter periodically admits lifting fluid, the uppermost valve continues to operate until the liquid level in the casing or annular space has been lowered to permit the lifting fluid to reach the next below valve device.

After this next device is reached, it will continue to pass lifting fluid until the intermitter 16 shuts off the admission of lifting fluid, at which time the pressure within the tubing and casing will equalize back to the operating pressure of said second valve which, as presumed, is 425 pounds. Because the uppermost valve is set at 450 pounds, said valve will close and will remain so. Subsequent admission of lifting fluid will actuate the second valve to lift additional liquid from the tubing and thereby further lower the level in the annular space until such time as the next below valve device is reached, after which the lifting of liquid is accomplished at the operating pressure of the latter valve device. The operation is continued until the bottom or lowermost valve device, which operates at the lowest pressure is reached and from this point on, the lowermost valve will function to admit the lifting fluid into the tubing to raise the well liquids entering the tubing from the formation. Thus, operation will continue from the lowermost valve at its operating pressure and the upper valves will remain closed. The arrangement permits the working level of the well to be lowered and thereby allows the well liquids to be lifted to the surface with a minimum operating pressure.

It is pointed out that the pilot bellows 44 is filled with a fluid which as explained, acts as a stop or limiting means to limit upward movement of the pilot. The bellows completely seals its interior and the adjacent recess 48 to a constant pressure within the pressure range of the valve's operation. It is pointed out that when the valves are first run into a well having well fluid therein the bellows are subjected to the pressure of the liquid column which of course reflects the bottom

hole pressure. When the necessary gas or lifting fluid pressure is applied to actuate the valves, the bellows is subjected to the combined pressure of the well liquid and gas and unless some means such as the liquid within said bellows is provided, the bellows might be ruptured prior to operation of the apparatus. With the arrangement shown, damage to the bellows by excessive pressures is prevented. When in its extreme depressed position (Figure 3) the fluid completely fills the bellows and thus regardless of the pressure which may be acting on the exterior of said bellows, there is no danger of said bellows being ruptured.

The device is simple in construction and involves a minimum number of parts. It is actuated solely by the pressure of the lifting gas and eliminates the necessity of depending upon a pressure differential across the valves for its actuation. The use of the spring 48 which controls the pressure at which the device operates makes it possible to easily adjust the device to adapt it to particular well conditions. Although the invention has been described as operated by an auxiliary lifting fluid or gas, some wells may have sufficient gas entering the casing from a sub-surface formation and it is within the scope of the invention to actuate the valve devices with such gas. In such instance, the intermitter 16 would be omitted.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made, within the scope of the appended claims, without departing from the spirit of the invention.

What I claim and desire to secure by Letters Patent is:

1. A flow device adapted to be connected in a well tubing and including, a housing having a flow passage for establishing communication between the exterior and interior of the well tubing, a main valve element for controlling the flow through said passage, movable means acted upon by the pressure of the fluid exteriorly of the tubing for normally holding the main valve in a seated or closed position shutting off flow through the passage, and pilot valve means arranged to be actuated when the pressure exteriorly of the tubing reaches a predetermined point for releasing the pressure acting on the movable means, whereby the main valve is opened to admit flow into the tubing upon the establishment of a predetermined pressure exteriorly of said tubing.

2. A well flow device adapted to be connected in a well tubing and including, a housing having a flow passage extending therethrough for establishing communication between the exterior and interior of the tubing, a main valve element within the passage and movable to open and closed positions within said passage for controlling the flow therethrough, pressure actuated means connected with the valve and having one side exposed to the pressure exteriorly of the tubing for imparting movement to the valve, said pressure actuated means moving the valve to a closed position when acted upon by said pressure, and operating means also actuated solely by the pressure exteriorly of the tubing for releasing the pressure acting on the pressure actuated means to effect opening of the main valve to permit a flow through the passage and into the tubing.

3. A well flow device as set forth in claim 2, wherein the operating means is actuated only

when the pressure exteriorly of the tubing attains a predetermined point.

4. A well flow device as set forth in claim 2, wherein the operating means is a pilot valve arrangement which is normally closed to prevent escape of the pressure acting on the pressure actuated means and when opened releases such pressure to permit opening of the main valve.

5. A well flow device adapted to be connected in a well tubing and including, a housing having a flow passage establishing communication between the interior and exterior of the tubing, a main valve within the passage and movable to open and closed positions therein for controlling flow therethrough, a flexible operating element connected with the main valve and having its interior exposed to the pressure exteriorly of the tubing whereby said element is actuated to hold the main valve in a closed position, the housing having an enlarged escape port extending from the element to permit escape of the pressure acting thereon to allow opening of the main valve, and a pilot valve actuated solely by the lifting fluid pressure for controlling the flow through said escape port, whereby said pilot must open before the pressure acting on the operating element can be released to open the main valve and admit flow into the tubing.

6. A flow device as set forth in claim 5, wherein the pilot valve is normally in a closed position and is moved to an open position only when the pressure exteriorly of the tubing reaches a predetermined point.

7. A well flow device adapted to be connected in a well tubing and including, a housing having a flow passage establishing communication between the interior and exterior of the tubing, a main valve within the passage and movable to open and closed positions therein for controlling flow therethrough, a flexible operating element connected with the main valve and having its interior exposed to the pressure exteriorly of the tubing whereby said element is actuated to hold the main valve in a closed position, the housing having an enlarged escape port extending from the element to permit escape of the pressure acting thereon to allow opening of the main valve, a pilot valve for controlling the flow through said escape port, whereby said pilot must open before the pressure acting on the operating element can be released to open the main valve and admit flow into the tubing, and a pressure operated means exposed to and actuated by the pressure exteriorly of the tubing for moving the pilot valve to an open position.

8. A well flow device adapted to be connected in a well tubing and including, a housing having a flow passage establishing communication between the interior and exterior of the housing, a main valve within the passage and movable to open and closed positions therein for controlling flow therethrough, valve actuating means connected with said valve and having one side thereof exposed to the pressure exteriorly of the tubing whereby such pressure holds the main valve seated, the housing having a release port for permitting escape of the pressure acting upon the valve actuating means whereby the main valve is opened when said pressure is released, a pilot valve normally closing the release port, and an operating bellows connected to the pilot valve and exposed to the pressure exteriorly of the tubing so as to be actuated thereby.

9. A well flow device adapted to be connected in a well tubing and including, a housing having

a flow passage establishing communication between the interior and exterior of the housing, a main valve within the passage and movable to open and closed positions therein for controlling flow therethrough, valve actuating means connected with said valve and having one side thereof exposed to the pressure exteriorly of the tubing whereby such pressure holds the main valve seated, the housing having a release port for permitting escape of the pressure acting upon the valve actuating means whereby the main valve is opened when said pressure is released, a pilot valve normally closing the release port, and means exerting a predetermined pressure on the pilot valve and urging it to a closed position, whereby the pressure exteriorly of the tubing must reach a predetermined point before the pilot is opened to permit opening of the main valve.

10. A well flow device adapted to be connected in a well tubing and including, a housing having a flow passage establishing communication between the interior and exterior of the housing, a main valve within the passage and movable to open and closed positions therein for controlling flow therethrough, valve actuating means connected with said valve and having one side thereof exposed to the pressure exteriorly of the tubing whereby such pressure holds the main valve seated, the housing having a release port for permitting escape of the pressure acting upon the valve actuating means whereby the main valve is opened when said pressure is released, a pilot valve normally closing the release port, an actuating bellows connected to the pilot valve for imparting movement thereto, said bellows being normally expanded to hold the pilot valve closed and being depressed by the external pressure to open the valve, and a liquid within said bellows, said liquid partially filling the interior of the bellows when the latter is expanded and completely filling said interior when depressed, whereby the liquid functions as a stop to limit depression of the bellows and also acts to prevent rupturing of the bellows by excessive external pressure.

11. A flow device as set forth in claim 9, together with a liquid within the operating bellows, said liquid completely filling the interior of the bellows after the same has been actuated, whereby said liquid not only limits the movement of the bellows but also protects the same from collapse and rupture due to excessive external pressures.

12. A flow device as set forth in claim 9, wherein the means exerting a predetermined pressure on the pilot valve is a spring.

13. A well flow device as set forth in claim 7, wherein the pressure operated means is an operating bellows, together with a liquid within said bellows, said liquid completely filling the interior of the bellows after the same has been actuated, whereby said liquid not only limits the movement of the bellows but also protects the same from collapse and rupture due to excessive external pressure.

14. A well flow device as set forth in claim 1, wherein the pilot valve means is connected to a bellows which is exposed to and actuated by the pressure exteriorly of the tubing, said bellows having its interior partially filled with liquid when in an extended position and having said interior completely filled when in a retracted position, whereby said liquid functions to limit movement of the bellows and also to prevent rupturing thereof by external pressures.

15. A well flow apparatus including, a well cas-

ing, a well tubing extending axially through the casing and having a well liquid inlet at its lower end, means for introducing a lifting gas under pressure into the annular space between the casing and tubing, and a plurality of flow devices mounted in the tubing, each device having a flow passage for establishing communication between the casing and tubing and having a movable main valve element and also having a movable pilot valve, said main valve element being held closed by the pressure in the well casing and being adapted to be opened solely by the casing pressure acting upon the pilot valve which pilot valve releases the pressure holding said movable main valve closed, each device having its pilot valve operable at a different pressure from the pressures at which the other devices operate, whereby the devices may be progressively operated by varying the pressure of the lifting gas being admitted to the casing.

16. A well flow apparatus as set forth in claim 15, wherein the flow devices are spaced throughout the length of the tubing and wherein the uppermost device is set to operate at the highest pressure with the remaining devices being set at successively lower pressures with the lowermost device operating at the lowest pressure.

17. A well flow apparatus as set forth in claim 15, wherein the movable valve element has an operating bellows connected therewith with the interior of said bellows exposed to the casing pressure.

18. A well flow apparatus as set forth in claim 15, wherein the pilot valve is connected with a bellows having its exterior exposed to the casing pressure, whereby when said pressure attains a predetermined point the bellows is compressed to actuate the pilot and thereby permit opening of the movable valve element.

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