

Nov. 10, 1953

L. F. DAVIS

2,658,460

ELECTRICALLY OPERATED GAS LIFT VALVE

Filed Feb. 9, 1950

4 Sheets-Sheet 1

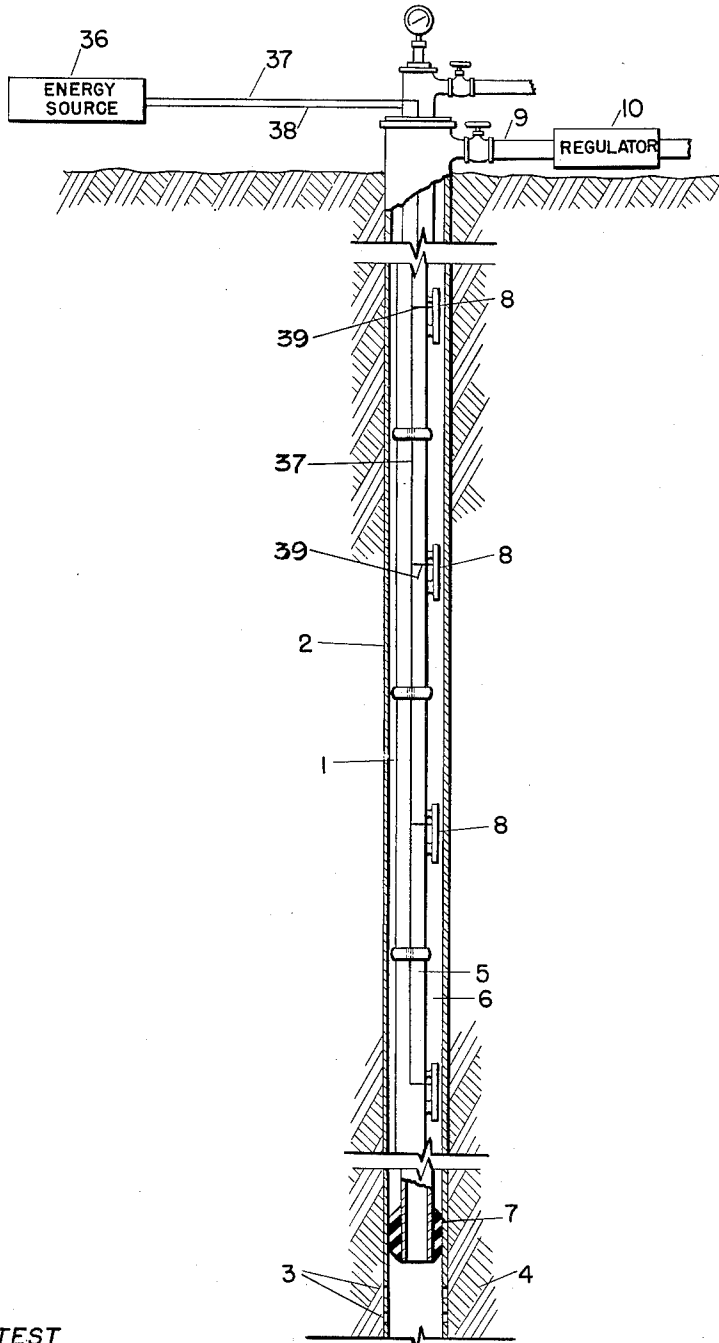


Fig. 1

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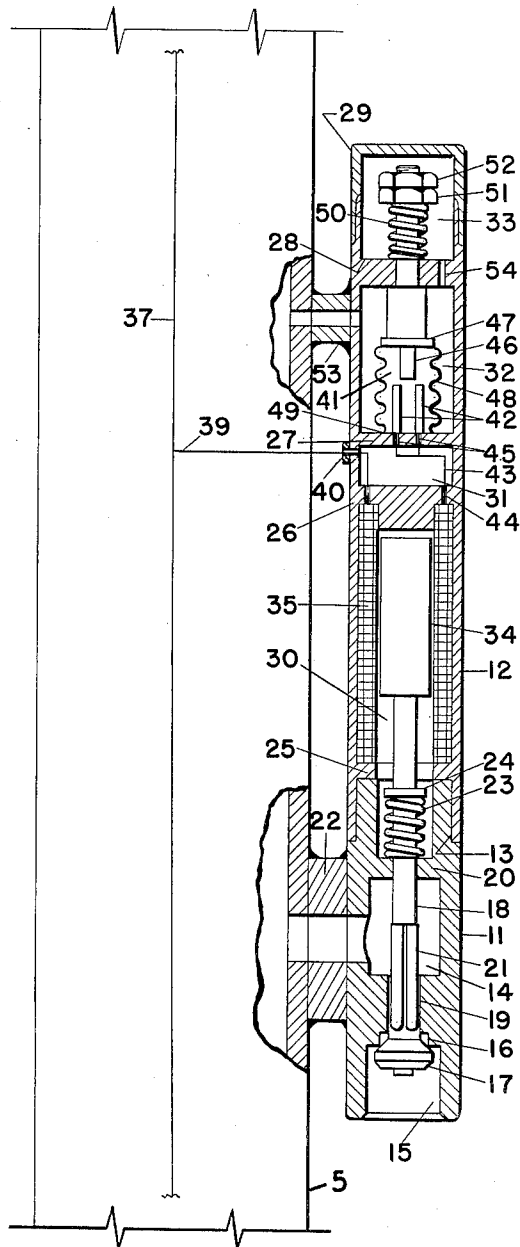
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4 Sheets-Sheet 2



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4 Sheets-Sheet 3

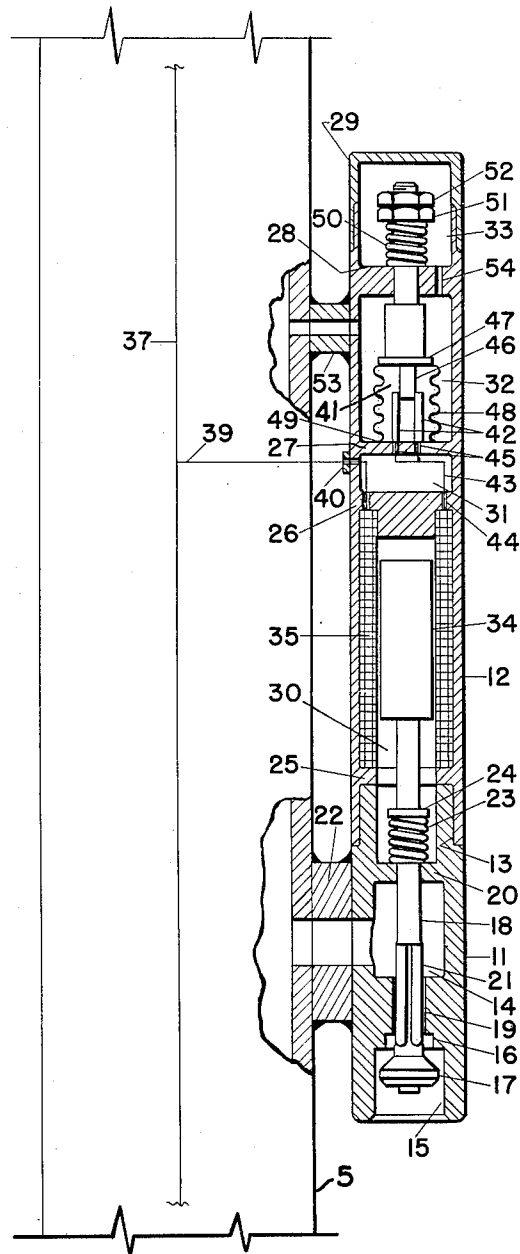


Fig. 3

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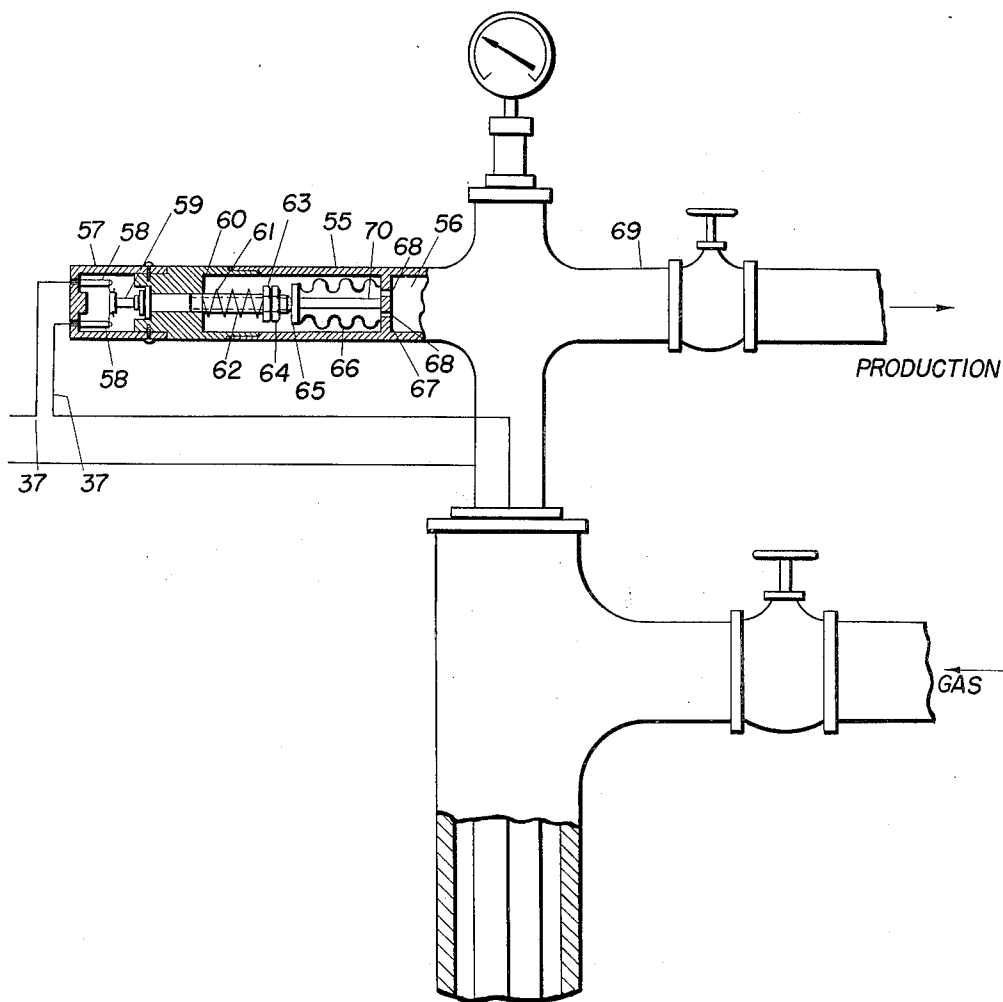
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ELECTRICALLY OPERATED GAS LIFT VALVE

Filed Feb. 9, 1950

4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,658,460

ELECTRICALLY OPERATED GAS LIFT VALVE

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Application February 9, 1950, Serial No. 143,328

11 Claims. (Cl. 103—233)

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This invention relates to improvements in flow devices for oil wells and the like, and more particularly to an electrically operated valve for controlling admission of fluid into a tubing string through which reservoir liquids flow to the surface of the earth.

In producing liquids from oil reservoirs, frequently the pressure within the reservoir initially, or after production of some of the oil, is below that required to cause the reservoir liquids to flow through a production tubing to the well head, and it becomes necessary to augment the natural reservoir pressure in order to recover the reservoir liquid. This is frequently accomplished by means of a fluid under high pressure which is injected into the liquid in the production tubing whereby the liquid above the point of admission is lifted to the well head under the force of the expanding fluid. The admission of fluid into the production tubing is controlled by means of a well flow device or valve.

Various types of valves have been proposed and used for this purpose, including an electrically operated valve, the operation of which is controlled entirely at the surface of the earth and is independent of conditions in the well. The valve is opened simply by the application thereto of an electrical potential and remains open until such potential is removed. Such valve is not entirely satisfactory for the reason that well conditions vary from time to time and since operation of the valve is independent of such conditions, inefficient operation results. For example, if the operation time cycle is too short, an excessive amount of lifting fluid will be employed to lift a given amount of well liquid. On the other hand, if the operation time cycle is too long, the lifting fluid may be insufficient to raise the reservoir liquid standing in the tubing to the well head.

Accordingly, it is one object of the present invention to provide an improved valve for controlling admission of fluid into a well tubing string and which will obviate the foregoing difficulties.

Another object is to provide such a valve wherein the operation of the valve is controlled electrically.

A further object is to provide an electrically operated well flow device adapted to be connected in the tubing string for controlling the admission of fluid thereinto and wherein the valve will be opened only when the hydrostatic head of well liquid within the tubing string has reached a predetermined amount.

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A further object is to provide an electrical well flow device wherein a pressure responsive element exposed to the pressure within the tubing string operates a switch for controlling the application of electrical energy to a valve actuating means.

A still further object of the invention is to provide an electrically operated well flow device adapted to be connected in the tubing string for controlling the admission of fluid thereinto and wherein the valve will be opened only when the hydrostatic head of the well liquid within the tubing has reached a predetermined amount and will remain open until the well liquid above the valve has been lifted to the surface of the earth and the pressure within the tubing string has fallen below said predetermined amount.

An additional object is to provide an electrically operated well flow device adapted to be connected in the tubing string for controlling the admission of fluid thereinto and wherein the valve will be opened only when the hydrostatic head of well liquid within the tubing string has reached a predetermined amount and will remain open only until the well liquid in the tubing string above the valve has been lifted to the well head.

Other objects and features of the invention will be apparent from the description and drawings which follow.

Figure 1 is an elevational view, partially in section, showing improved well flowing apparatus constructed in accordance with the invention.

Figure 2 is an elevational view, partially in section, showing the electrically controlled valve in its closed position and connected within the tubing string.

Figure 3 is a view similar to Figure 2 showing the valve in its open position.

Figure 4 is an elevational view, partially in section, showing another embodiment of the invention wherein a pressure responsive switch is connected in the tubing string at the upper end thereof and exposed to the pressure therein for interrupting the flow of electrical energy in the valve actuating means thereby to cause the valve to close when liquid within the tubing string above the valve has been lifted to the well head.

Broadly, this invention is concerned with a well flow device including a well tubing having flow passages for establishing communication between the exterior and interior thereof and through which reservoir fluid is conducted to the well head. A plurality of electrically operated valves are positioned at intervals along the length of the tubing for controlling flow through the passages.

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Each of the valves is adapted to be opened when the pressure within the tubing at the valve reaches a predetermined value and includes a valve element movable to open and closed positions, resilient means for continuously urging the valve element to one of the positions, actuating means adapted when energized to move the valve element to the other position against the force of the resilient means, and an electric circuit for energizing the actuating means. The electric circuit includes a source of electrical energy and switch means arranged to be operated when the pressure within the tubing at the valve reaches a predetermined point whereby the application of electrical energy to the actuating means is controlled.

Referring to the drawings, and at this time particularly to Figure 1, numeral 1 denotes generally a well bore having a well casing 2 therein with perforations 3 providing communication between the interior of casing 2 and the producing reservoir 4. A tubing string 5 is arranged within casing 2 so as to provide annular space 6 therebetween, which is closed adjacent the lower end of the tubing string by a suitable well packer 7, which packs off between the tubing string and the casing. Reservoir liquids entering casing 2 through perforations 3 are directed into tubing string 5.

A plurality of well flow devices or valves 8, constructed in accordance with the invention, are connected in tubing string 5 and are located at various elevations or levels therein. Each valve 8 is adapted to control the admission of a lifting fluid into tubing string 5 from annular space 6 and such fluid is utilized to lift the reservoir liquids upwardly through the tubing string to the surface. The invention will be herein described as operating with an auxiliary lifting fluid but it is to be understood that the lifting fluid may be obtained from a subsurface formation which is connected into the well casing. When auxiliary lifting fluid is employed, it is conducted to annular space 6 through valve controlled pipe 9, the admission of the fluid being controlled by a suitable regulator 10. The regulator, as is well known, controls the admission of fluid to admit sufficient fluid to maintain the pressure within the annular space 6 with desired limits.

The valves 8 are all of identical construction and referring particularly to Figures 2 and 3, which are similar views showing a valve 8 connected in tubing string 5, except that the valve is shown in its closed position in Figure 2 and in its open position in Figure 3, each valve includes a tubular housing which is constructed of two sections, a lower section 11 and an upper section 12, the two sections being connected, as at 13, by threading, welding, or in any other suitable manner. Section 11 is formed with an axial bore 14 communicating at one end 15 with annular space 6 and in which is provided a valve for controlling the flow of fluid in bore 14. The valve includes valve seat 16 formed integrally within section 11 and closure member 17 adapted to seat on valve seat 16, the closure member being provided on one end of valve stem 18 which extends upwardly through axial opening 19 in valve seat 16 and a corresponding opening in lateral partition 20 thereby to provide a guide for the valve stem. Partition 20 substantially seals the upper end of bore 14 against the flow of fluid. The lower portion 21 of valve stem 18 preferably is polygonal providing clearance between the valve stem and the wall of opening 19 for the passage of fluid when closure member 17 is unseated. Interme-

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diately of valve seat 16 and partition 20 axial bore 14 communicates with nipple 22 which is connected to section 11 of the housing by welding or other suitable means. The nipple is similarly connected at its other end with tubing string 5 and obviously bore 14 and nipple 22 form a fluid flow passage between annular space 6 and tubing string 5, flow through which is controlled by the valve provided in bore 14 and above described. Closure member 17 is normally maintained in a seated position by the force of helical spring 23 provided about valve stem 18 above partition 20 and compressed between the latter and a nut 24 threaded on the valve stem.

Lateral partitions 25, 26, 27, and 28, together with cap 29 threaded or otherwise connected to the upper end of section 12 of the valve housing, divide that section into four separate compartments 30, 31, 32, and 33. Partition 25, which abuts the upper end of section 11 of the valve housing, is provided with a suitable axial opening through which valve stem 18 extends into compartment 30. The valve stem terminates in compartment 30 and an enlarged end portion 34 functions as a plunger for a solenoid adapted to actuate the valve against the force of helical spring 23. The solenoid consists of plunger 34 and coil 35 disposed about the plunger and maintained in position in compartment 30 between partition 25 and partition 26, the latter having formed therein a circular groove to receive the end of the coil, as shown. The solenoid is arranged so that plunger 34, formed of a magnetizable material, such as iron, will be caused to move downwardly against the force of spring 23 upon energization of the solenoid by flow of electrical energy through coil 35, as described hereinafter, thereby to open the valve permitting lifting fluid to pass through axial bore 14 and nipple 22 into tubing string 5. The valve remains open until said flow of electrical energy is interrupted in the manner below pointed out. When such energy flow is terminated the force of spring 23 will cause closure member 17 to seat on valve seat 16 to cut off further flow of lifting fluid into tubing string 5 through nipple 22.

As explained, valve 8 is electrically operated and is caused to open when the solenoid is energized by the flow of electrical energy there-through. For supplying electrical energy to the valves 8 connected with tubing string 5, there is provided, in accordance with the invention, an electrical circuit including preferably a direct current source. The invention will be herein described as operating with a single energy source 36 (Figure 1) located at the surface, but it is to be understood that said source may take the form of a series of batteries, each of which is disposed in the well adjacent one of the valves 8, the operation of which it controls. When the single energy source 36, located at the surface, is employed, such source is connected with each of the valves 8 by means of electrically insulated conductors 37 and 38. One of the conductors 37 is clamped by any suitable means to the outside of tubing string 5 and extends downwardly to a point approximately adjacent the lowermost valve 8. Connected at suitable points along conductor 37 are a series of connecting conductors 39 to each of which, in turn, is connected one terminal of the solenoid coil 35 of one of the valves 8, as shown in Figures 2 and 3. Conductor 39 extends through a rubber insulator 40 in the wall of upper section 12 of the valve housing into compartment 31 and thence through a suitable opening in par-

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tion 26 where it connects with coil 35. The other conductor 38 is directly attached to tubing string 5 to provide a return path to the energy source 36 for the energy flowing through the solenoid, as described below in detail.

It is one purpose of the invention to provide an electrically operated well flow device or valve which will be opened only when the hydrostatic head of well liquid within the tubing string above the valve has reached a predetermined amount. To this end there is included in the electrical circuit, above mentioned, for supplying electrical energy to the solenoid a pressure actuated switch arranged to be actuated by the pressure within tubing string 5. The switch, denoted generally by numeral 41, is maintained in compartment 32 of the valve housing and preferably is a knife-type switch including a pair of stationary contacts 42 attached in an upright position to partition 27 from which they are electrically insulated by any suitable means, not shown, such, for example, by providing rubber gaskets therebetween. Contacts 42 are connected to the other terminal of coil 35 of the solenoid by means of insulated conductor 43 which extends through suitable openings 44 and 45, respectively, in partitions 26 and 27, as shown in Figures 2 and 3. A movable contact 46 of switch 41 is connected by welding or in any other suitable manner to floating head 47 of a pressure responsive element or bellows 48 enclosing contacts 42 and 46. Bellows 48 is sealed at one end 49 to partition 27 and is normally urged to a distended position by a coil spring 50 disposed in compartment 33 about the portion of bellows head 47 extending through a suitable axial bore in partition 28. Spring 50 is compressed, as shown, between partition 28 and adjustment nut 51 threaded on the end of bellows head 47 and maintained in place by lock nut 52. It is obvious that spring 50 continuously exerts a predetermined force on bellows head 47 through nut 51 which pressure may be controlled by proper adjustment of the latter. This force normally maintains bellows 48 in a distended position with contacts 42 and 46 apart, that is, with the switch open. The contacts are arranged, however, to be engaged closing the switch when sufficient pressure is exerted on the exterior of the bellows to compress the latter against the force of spring 50. When the switch is closed, a return path is completed from solenoid coil 35 to the energy source 36 through conductor 43, contacts 42 and 46, bellows head 47 formed of a suitable conducting material, such as iron, partition 28 with which bellows head 47 is in contact at all times, the valve housing, tubing string 5 and conductor 38. A suitable bore 54 may be formed in partition 28 to permit equalization of pressure in compartments 32 and 33.

Nipple 53 is welded or otherwise secured in the wall of upper section 12 of the valve housing and in the wall of tubing string 5 so as to establish communication between compartment 41 and the interior of the tubing string, thereby exposing bellows 48 to the pressure within the latter. When the pressure within the tubing string due to the hydrostatic head of liquid above the valve 8 reaches a predetermined pressure controlled by adjustment nut 51, as explained, bellows 48 will be compressed closing switch 41 to cause electrical energy to flow through the solenoid and thereby unseat closure member 17. Lifting fluid then will flow past valve seat 16, through axial bore 14 and nipple 22 into the tubing string where it will expand and lift reservoir fluid above the

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valve to the surface. The valve will remain open until the pressure in tubing string 5 falls below that necessary to maintain bellows 48 in compressed position, at which time the knife switch 41 will open interrupting the flow of electrical energy in the solenoid, at which time closure member 17 will be caused to be seated under the force of helical spring 23, and the cycle repeated.

In operation, a plurality of valves 8 are connected in the tubing string 5 and are disposed at various elevations therein. Each valve has its spring 50 properly adjusted so as to exert a predetermined pressure upon bellows 48 tending to maintain the latter in a distended position.

Although it is normally contemplated to set all valves to operate at the same pressure, they may be set with the uppermost valve at the highest operating pressure, the next valve at a lower pressure and so on progressively to the lowermost valve which would be set at the lowest pressure, or the uppermost valve may be set at the lowest pressure, the next succeeding valve at a higher pressure, and so on progressively to the lowermost valve which would be set at the highest pressure. For example, the uppermost valve in the tubing string may be set to open when the pressure within the tubing string acting on its bellows reaches 450 p. s. i., the next set to open at 425 p. s. i., the third at 400 p. s. i., and so on progressively to the lowermost valve in the tubing which would, of course, be operated at the lowest pressure, all of the valves may be set to operate at 450 p. s. i.

Normally each valve has its parts in the position shown in Figure 2 with bellows 48 distended and closure member 17 seated on valve seat 16. After the reservoir liquid within annular space 6 and above packer 7 has been replaced by the lifting fluid, the pressure of the lifting fluid is maintained at a point considerably above that required to lift the reservoir fluid standing in the tubing string to the surface. At this time the apparatus is ready for operation to control the admission of lifting fluid from annular space 6 into the tubing string through the lowermost valve. It is to be noted that the pressure within the tubing string is at all times acting through nipple 53 on the exterior of bellows 48.

The liquid column in the tubing string is then permitted to build up to a level such that the hydrostatic pressure thereof is sufficient to compress the bellows and close switch 41, thereby energizing the solenoid and unseating closure member 17. At this time the valve has its parts in the position shown in Figure 3 and lifting fluid is permitted to pass through axial bore 14 and nipple 22 into the tubing string wherein it serves to lift reservoir liquid above the valve to the surface. As the lifting fluid expands, the pressure thereof, which initially is of the order of 100 p. s. i. greater than the hydrostatic pressure necessary to operate the valve, decreases until it is no longer sufficient to maintain bellows 48 in a contracted position. At this time switch 41 will open interrupting the flow of electrical energy through the solenoid whereby closure member 17 will again be seated by the force of helical spring 23, and the cycle repeated.

In another embodiment of the invention a pressure actuated switch, inserted in tubing string 5 at the upper end thereof and exposed to the pressure therein, is connected in the electric circuit of the valve actuating means or solenoid of valve 8 in a manner so that the elec-

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trical energy actuating the solenoid will be interrupted and the valve closed as soon as the well liquid in the tubing standing thereabove has reached the well head, regardless of the pressure remaining in tubing string 5. Referring to Figure 4, there is shown an enlarged view of the well head wherein a tubular housing 55 for a pressure actuated switch is connected in tubing string 5 adjacent its upper end, the housing communicating at one end 56 with the interior of the tubing string and being closed at its other end by cap 57. On the inner wall of cap 57 is mounted a pair of stationary contacts 58 of the pressure actuated switch and the contacts are connected in conductor 37 which extends through suitable insulators in the end of cap 57, as shown. An elongated contact 59 is mounted within housing 55 for longitudinal movement into and out of contact with stationary contacts 58. Aperatured partition 60 in housing 55 serves as a guide for moving contact 59, which extends there-through. A coil spring 61 is provided about one end 62 of movable contact 59 and is compressed between partition 60 and adjustment nut 63 whereby movable contact 59 is continuously urged into engagement with stationary contacts 58 by the force of spring 61. It is to be understood that this force may be adjusted by manipulation of nut 63 which may be retained in a fixed position on contact 59 by means of lock nut 64. End 62 of movable contact 59 abuts floating head 65 of a pressure responsive member or bellows 66, the other end of the bellows being secured by any suitable means, such as by welding, to lateral partition 67 formed in housing 55. A pair of ports 68 in partition 67 provides communication between the interior of tubing string 5 and the interior of bellows 66.

In operation, normally the pressure within tubing string 5 is relatively low and therefore bellows 66 will be maintained in its compressed position by the force of contact 59 on floating head 65. Under such conditions it will be seen that electrical energy may flow from source 36 to valves 8 when knife switch 41 of valve 8 is closed. When electrical energy is flowing in the solenoid, valve 8 will open to admit lifting fluid into tubing string 5 wherein the fluid will cause well liquid standing above the valve to pass through the tubing string to the well head. When the liquid reaches the well head it will pass through valve controlled pipe 69 to a suitable storage tank, not shown. However, as the liquid passes from the tubing string into valve controlled pipe 69 it will exert pressure on the interior of bellows 66 through ports 68 in partition 67. Adjustment nut 63 is so manipulated that this pressure will cause the bellows to expand causing movable contact 59 to move out of engagement with contacts 58 under the force of spring 62 thereby to open the electrical circuit between energy source 36 and valves 8 resulting in deenergization of the solenoids and the closing of valves 8 notwithstanding that the pressure within tubing string 5 is still sufficient to maintain bellows 48 of valve 8 in a contracted position and knife switch 41 closed. Stud 70 secured to bellows head 65 limits the amount of contraction of bellows 66 by contact with partition 67 to prevent damage to the latter.

From the foregoing, it is seen that in this embodiment of the invention any one of the valves 8 will be opened when the hydrostatic head of well liquid within the tubing string at that particular valve has reached a predetermined value

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and will close when the well liquid above the valve has been lifted to the well head and bellows 66 expanded under the pressure thereof to open contacts 58 and 59.

It is to be understood that while it is preferable to employ natural gas as the lifting fluid, any other suitable gas may be employed for this purpose.

While in the foregoing there has been shown and described the preferred embodiment of this invention, it is to be understood that minor changes in the details of construction, combination, and arrangement of parts may be resorted to without departing from the spirit and scope of the invention as claimed.

I claim:

1. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the predetermined value, a housing enclosing the pressure responsive switch means, and passage means providing communication between the housing and the well tubing.

2. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, normally open pressure responsive switch means connected in the electric circuit and adapted to be closed upon the application thereto of a pressure equal to the predetermined value, a housing enclosing the pressure responsive switch means, and passage means providing communication between the housing and the well tubing.

3. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve ele-

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ment to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the predetermined value, said switch means having a pressure responsive operating element, a housing enclosing the pressure responsive switch means, and passage means providing communication between the housing and the well tubing for exposing said pressure responsive element to the pressure within the tubing.

4. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the predetermined value, said switch means comprising a switch having a fixed member, a movable member, and a pressure responsive element connected to said movable member, a housing enclosing the pressure responsive switch means, and passage means providing communication between the housing and the well tubing for exposing said pressure responsive element to the pressure within the tubing.

5. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the

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predetermined value, said switch means comprising a switch having a fixed member, a movable member, and a bellows connected to said movable member, a housing enclosing the pressure responsive switch means, and passage means providing communication between the housing and the well tubing for exposing said bellows to the pressure within the tubing.

6. In a well flow device including a well tubing, a housing adapted to be connected in the tubing, said housing having a valve compartment and a switch compartment, a flow passage comprising interconnecting openings in said tubing and said valve compartment for establishing communication between the interior and exterior of said tubing, a valve element mounted within the valve compartment and movable to open and closed positions for controlling flow through the passage, resilient means connected with the valve element for moving the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the predetermined value, said switch means being mounted in said switch compartment and having a pressure responsive element, and passage means providing communication between the switch compartment and the well tubing for exposing said pressure responsive element to the pressure within the tubing.

7. In a well flow device including a well tubing, a housing adapted to be connected in the tubing, said housing having a valve compartment and a switch compartment, a flow passage comprising interconnecting openings in said tubing and said valve compartment for establishing communication between the interior and exterior of said tubing, a valve element mounted within the valve compartment and movable to open and closed positions for controlling flow through the passage, resilient means connected with the valve element for moving the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the predetermined value, said switch means being mounted in said switch compartment and comprising a fixed member, a movable member, and a pressure responsive element connected to said movable member, and passage means providing communication between the switch compartment and the well

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tubing for exposing said pressure responsive element to the pressure within the tubing.

8. In a well flow device including a well tubing, a housing adapted to be connected in the tubing, said housing having a valve compartment and a switch compartment, a flow passage comprising interconnecting openings in said tubing and said valve compartment for establishing communication between the interior and exterior of said tubing, a valve element mounted within the valve compartment and movable to open and closed positions for controlling flow through the passage, resilient means connected with the valve element for moving the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing the actuating means when the pressure within the tubing at the valve reaches a predetermined value comprising an electric circuit including a source of electrical energy connected with the actuating means, pressure responsive switch means connected in the electric circuit and adapted to be operated upon the application thereto of a pressure equal to the predetermined value, said switch means being mounted in said switch compartment and comprising a fixed member, a movable member, and a bellows connected to said movable member, and passage means providing communication between the switch compartment and the well tubing for exposing said bellows to the pressure within the tubing.

9. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing and deenergizing the actuating means comprising an electric circuit including a source of electrical energy for the actuating means, a first housing mounted on said tubing at the approximate level of said flow passage, a first switch means connected in said circuit and arranged to be operated when the pressure within the tubing at the valve reaches a predetermined point for controlling the application of electrical energy to the actuating means, said first switch means being mounted in said first housing and having a pressure responsive operating element, passage means providing communication between said first housing and said tubing for exposing the pressure responsive element of said first switch means to the pressure within the tubing at the level of said first housing, a second housing mounted on said tubing at the upper end thereof, second switch means mounted in said second housing and adapted to interrupt the application of electrical energy to the actuating means when the pressure within the tubing at said upper end reaches a predetermined value, said second

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switch means having a pressure responsive operating element, and passage means providing communication between said second housing and the upper end of said tubing for exposing the pressure responsive element of said second switch means to the pressure within the upper end of said tubing.

10. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing and deenergizing the actuating means comprising an electric circuit including a source of electrical energy for the actuating means, a first housing mounted on said tubing at the approximate level of said flow passage, first switch means connected in said circuit and arranged to be actuated when the pressure within the tubing at the valve reaches a predetermined point for controlling the application of electrical energy to the actuating means, said first switch means being mounted in said housing and comprising a switch having a fixed member, a movable member, and a pressure responsive element connected to said movable member, passage means providing communication between said first housing and said tubing for exposing the pressure responsive element of said first switch means to the pressure within the tubing at the level of said first housing, a second housing mounted on said tubing at the upper end thereof, second switch means mounted in said second housing and adapted to interrupt the application of electrical energy to the actuating means when the pressure within the tubing at said upper end reaches a predetermined value, said second switch means having a pressure responsive operating element, and passage means providing communication between said second housing and the upper end of said tubing for exposing the pressure responsive element of said second switch means to the pressure within the upper end of said tubing.

11. In a well flow device including a well tubing having a flow passage for establishing communication between the exterior and interior thereof, a valve element positioned in said flow passage movable to open and closed positions for controlling flow through the passage, resilient means for continuously urging the valve element to one of the positions, a magnetizable plunger connected with said valve element, and actuating means comprising an electromagnetic coil adapted, when energized, to move said plunger whereby to shift the valve element to the other position against the force of the resilient means; the combination therewith of means for automatically energizing and deenergizing the actuating means comprising an electric circuit including a source of electrical energy for the actuating means, a first housing mounted on said tubing at the approximate level of said flow passage, first switch means connected in said circuit and arranged to be actuated when the pressure within the tubing at the valve reaches a predetermined point for con-

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trolling the application of electrical energy to the actuating means, said first switch means being mounted in said housing and comprising a switch having a fixed member, a movable member, and a bellows connected to said movable member, passage means providing communication between said first housing and said tubing for exposing the bellows of said first switch means to the pressure within the tubing at the level of said first housing, a second housing mounted on said tubing at the upper end thereof, second switch means mounted in said second housing and adapted to interrupt the application of electrical energy to the actuating means when the pressure within the tubing at said upper end reaches a predeter-

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mined value, said second switch means having a pressure responsive operating element, and passage means providing communication between said second housing and the upper end of said tubing for exposing the pressure responsive element of said second switch means to the pressure within the upper end of said tubing.

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