Aug. 6, 1946. J. D. NIXON 2,405,323

SYSTEM AND APPARATUS FOR FLOWING WELLS

Filed June 29, 1944 2 Sheets-Sheet 1

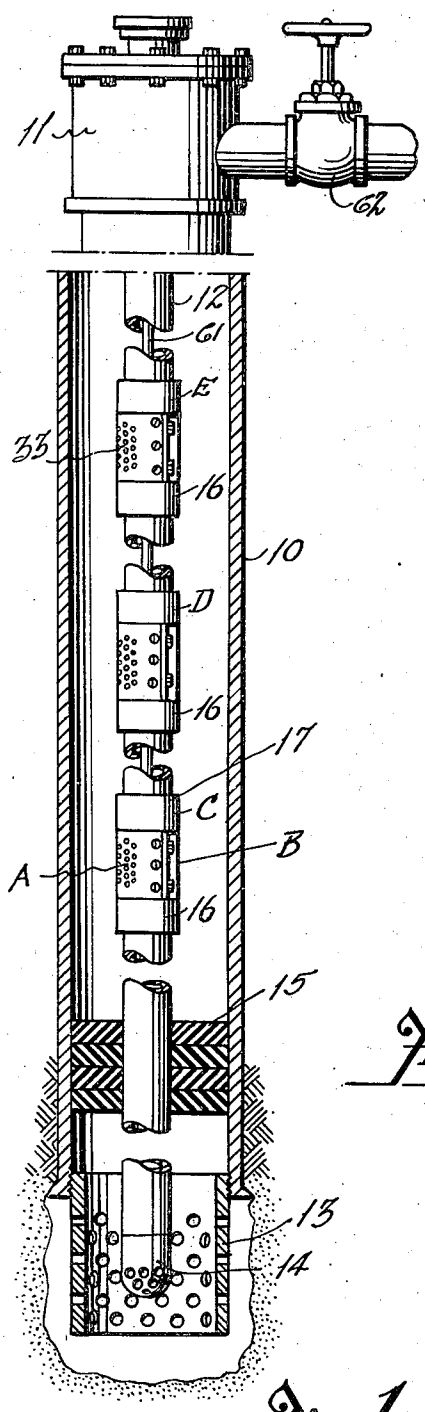



Fig. 1

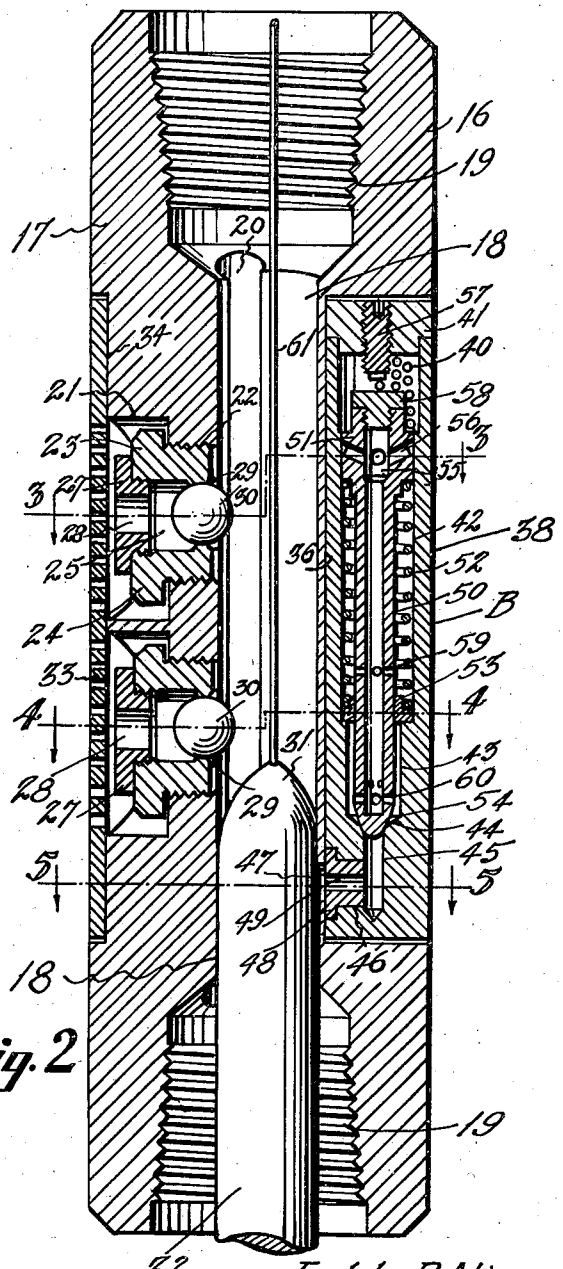



Fig. 2

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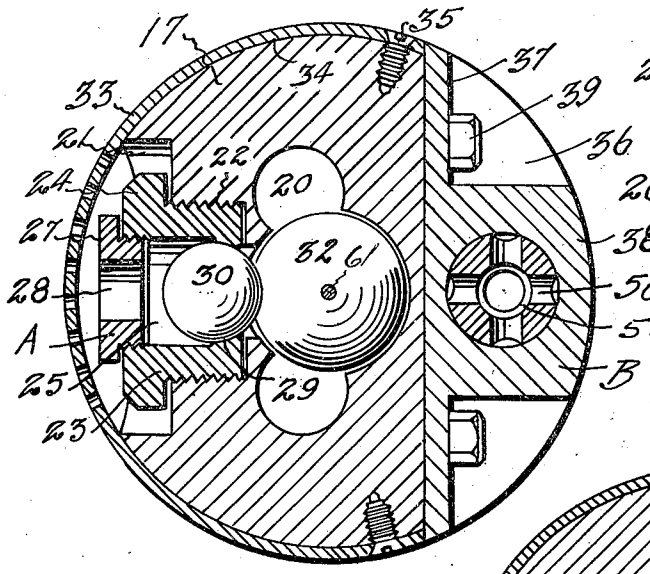



Fig. 3

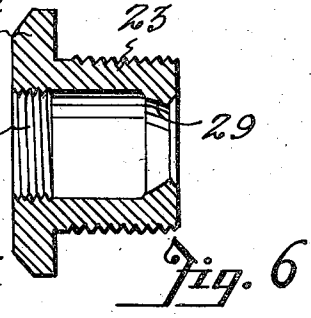



Fig. 6

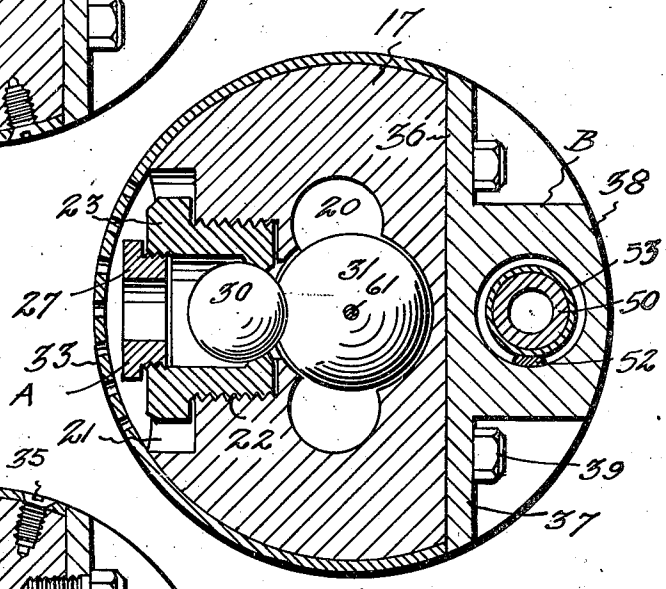



Fig. 4

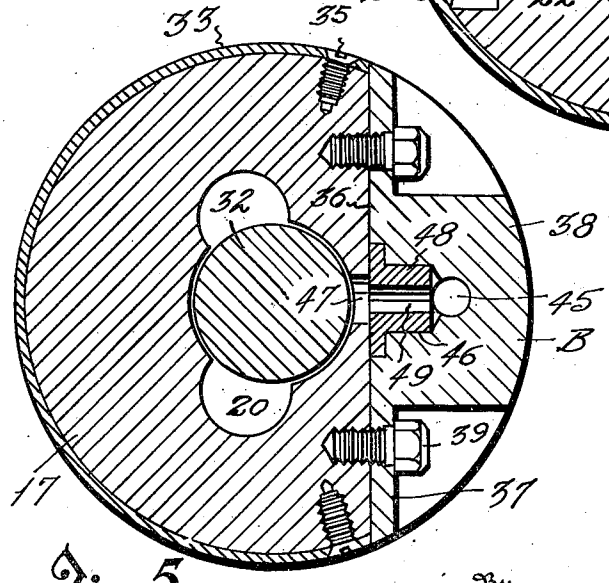



Fig. 5

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2,405,323

# UNITED STATES PATENT OFFICE

2,405,323

## SYSTEM AND APPARATUS FOR FLOWING WELLS

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Application June 29, 1944, Serial No. 544,397

18 Claims. (Cl. 103—233)

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This invention relates to new and useful improvements in systems and apparatuses for flowing wells.

In producing wells by the gas lift method wherein mechanically operated means and/or automatically operated or pressure differential means are employed, there are certain occurrences and operating phases which present fluid lifting problems, as well as requiring considerable manual supervision. These occurrences are due primarily to a number of factors. Oil and gas wells vary considerably in their rate of flow, as well as in producing characteristics and therefore, the flow of any given flowing well is more or less unstable. Further, where a head of lifting fluid is carried in the casing or annular space surrounding the tubing, the pressure is subject to wide variations, ranging from a complete shut-off to pressure drops which may be of small consequence, or which may fall below the working pressure, required to lift the column or head of well fluid accumulated in the tubing, above the point of entry of the lifting fluid.

Where intermittent lifting is installed, it is customary, in some systems, to carry the lifting fluid in the casing, under a substantially predetermined pressure which, when said lifting fluid is admitted to the tubing, will be sufficient to lift the column of well fluid (above the point of admission) to the surface. However, the height of the column of well fluid, or the hydrostatic load together with the lifting velocity it is necessary to maintain, must be estimated, so that under normal production flows satisfactory lifting and delivery of the well fluid is obtained.

The column of well fluid may rise above the optimum working level in the tubing from different causes. One instance is where the supply of lifting pressure fluid is shut off either intentionally or unintentionally; another, where the pressure of the lifting fluid stored under a head pressure in the casing or annular space, drops sufficiently to make it inadequate. In either case the column of well fluid will rise in the tubing to the point where it must be "kicked off" from higher elevations or where lifting fluid at additional pressure must be admitted at substantially the same elevation in order to elevate the increased load.

Another instance would be where the normal or predetermined amount of lifting fluid was being admitted to the tubing and the well "headed," thus increasing the hydrostatic load beyond the capacity of the admitted lifting fluid to carry the

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load of well fluid to the top of the well and deliver it; or inadequately elevate such well fluid.

In the devices set forth in my Patent No. 2,204,-817, a mechanically operated valve was located at the point down in the well where the lifting fluid is admitted under predetermined well flowing conditions; and at higher elevations automatic or pressure differential valves were mounted, in upwardly spaced order. The automatic valves would open under pressure differentials, but being at a higher elevation than the mechanically operated valve, they did not co-act therewith. For this reason the well could only be produced at one level with the mechanically operated valve, and due to the many different producing characteristics of all wells, it was difficult to predetermine the most favorable location for the mechanical operated valve.

One object of the invention is to provide an improved system of flowing wells wherein a head of pressure fluid is carried in the casing and valve means are provided, whereby surface-controlled mechanical admission of the pressure fluid to the tubing, may be periodically performed to lift fluid in the tubing, and additional pressure fluid may be automatically admitted to the tubing, to maintain lifting efficiency when the load so requires.

An important object of the invention is to provide an improved flow unit adapted to be connected in the tubing and including both a mechanically operated pressure-fluid inlet valve and an automatic pressure fluid inlet valve, arranged to operate in conjunction or independently; whereby the quantity of pressure fluid admitted to the tubing may be varied in accordance with the load of fluid to be lifted and also, whereby the well may be "kicked off" with a reduced amount of manual manipulation and supervision.

A further object of the invention is to provide a unit of the character described, whereby both a mechanically operated pressure fluid inlet valve and an automatic pressure fluid inlet valve may be mounted in the tubing at substantially the same elevation, and also whereby, the number of connections in the tubing may be reduced, over the use of separate valve housings and the number of "thread hazards" lowered.

Still another object of the invention is to provide a unit of the character described wherein the opening of the mechanically operated valve causes the pressure in the tubing to build up, thereby causing, the automatic valve to open and admit additional pressure fluid when the load to be lifted requires such additional energy.

A further object of the invention is to provide

an automatic valve which may operate independently as a "kick-off" valve and which includes, resilient means, acting once the valve is open, to hold it open; together with means for controlling the inlet velocity of the pressure fluid and means for causing the valve to close with a snap action.

A construction designed to carry out the invention will be hereinafter described together with other features of the invention.

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:

Fig. 1 is a view partly in section and partly in elevation, illustrating generally, a system and apparatus constructed in accordance with the invention,

Fig. 2 is an enlarged transverse, vertical sectional view of one of the units and showing the valve operating bar in engagement with one of the mechanical valves to open the same,

Fig. 3 is an enlarged horizontal cross-sectional view taken on the line 3—3 of Fig. 2,

Fig. 4 is an enlarged horizontal cross-sectional view taken on the line 4—4 of Fig. 2,

Fig. 5 is an enlarged horizontal cross-sectional view taken on the line 5—5 of Fig. 2,

Fig. 6 is an enlarged sectional view of the valve bushing.

In the drawings, the numeral 10 designates the usual well casing having a casing or tubing head 11 at its upper end which supports the tubing 12 in the usual manner. The head is suitably connected to the upper end of the casing to close the same, and is suitably packed off around the tubing so that pressure fluid may be trapped or introduced into the casing, thereby providing a head of pressure fluid in the casing available for immediate admission to the tubing under a predetermined pressure. The casing 10 may have the usual perforated liner or strainer 13, at its lower end and the lower end of the tubing may be equipped with a bull plug strainer 14 and a standing valve (not shown) as is customary in this art. In order to prevent the pressure fluid flowing down to the producing formation and also, to provide a more efficient trapping of the pressure fluid, a suitable packer 15 may be disposed between the casing 10 and the tubing 12 at the proper elevation; however, in some installations the packer could be omitted.

In the string of tubing 12 one or more elongated flow units 16 are connected. The number and spacing of the flow units, at different elevations, depends on the conditions of circumstances surrounding each individual well installation, as well as the use or requirement of any other flow equipment used therewith. Under some conditions it might be preferable to employ only one flow unit 16 located below the standing level of the fluid in the well at the desired distance therefrom.

Each valve unit includes a cylindrical housing 17 having an axial bore 18 connecting internally screw-threaded boxes 19 at each end of the housing. These boxes are of the type in common use in the oil fields and receive the screw-threaded ends (not shown) of the sections of tubing 12. At one side of the bore spaced vertical flow ducts 20 open to the bore 18, extend from one box to the other box. At the central portion of the housing a pair of vertically spaced annular recesses 21 are provided in the outer surface and each recess is provided with an axial screw-threaded bore 22 extending radially of the housing to the vertically bore 18 thereof.

A bushing 23 is screwed into each radial bore 22 so that its inner end is substantially flush with the housing bore 18. Each bushing has an integral collar or head 24, received in the recess, but less in diameter than said recess. The head 24 may be provided with wrench faces (not shown) for receiving a socket wrench whereby the bushing may be radially screwed into the bore 22. The bushings are of particular construction but a description of one bushing with its coacting elements will suffice for both.

As shown in the enlarged view (Fig. 6) the bushing has an axial duct or passage 25 which is provided at its outer end with screw threads 26 for receiving a flanged retaining nut 27, which has a central port 28. The inner end of the duct is reduced to provide an annular seat 29. A valve ball 30 is confined in the duct between the nut 27 and the seat 29. The ball is of such size as to engage the seat and close the duct as well as to move freely from the seat and provide sufficient clearance for a pressure fluid, entering through the port 28, to by-pass said ball and flow into the bore 18 of the housing. When the ball is seated, (by the pressure fluid from the casing) a portion of its surface will protrude into the bore 18, whereby the beveled end 31 of a weight bar 32 may engage said ball and displace it from its seat; the ball being held off its seat by the cylindrical surface of said bar. There may be sufficient clearance between the bar 32 and the wall of the bore 18 to permit fluid to by-pass; however, the vertical flow ducts 20 are provided to permit a free upward flow of fluids and liquids.

The bushing 23 and its ball 30 constitute a mechanically operated valve, which will be referred to generally as A and, as hereinafter described, the valve is opened by the bar 32 and closed by the velocity of the pressure fluid flowing through the duct 25. In order to protect the valves and prevent obstructive matter entering the same, a perforated screen or guard 33 is provided. The guard is curved transversely on an arc conforming to the surface of the housing which is milled out at 34, to receive said guard, so that its outer surface lies flush with the surface of the guard. The housing may be suitably fastened in place, as by machine screws 35 (Fig. 3).

By making a chordal cut across the side of the housing opposite the valves A, a vertical recess 36 is provided for an automatic valve B. The valve B includes a transverse plate 37 having integral with its central portion a vertical valve casing 38. The plate 37 is removably fastened in the recess 36 by machine bolts 39 on each side of the casing and has its vertical edges terminating flush with the surface of the housing 18 and finished to conform to the housing contour. The vertical edges of the guard 33 abut the projecting edge portions of the plate 37, whereby a smooth joint is formed. The outer face of the casing 38 is curved transversely to conform to the contour of the housing. The casing is bored and counterbored axially, to form an upper fluid receiving chamber 40, the top of which is closed by a plug 41 countersunk in the top of the casing.

Below the chamber 40, the casing 38 is counterbored to form a piston cylinder 42, below which the casing is further counterbored to form a sump 43 having a valve seat 44 at its lower end. An axial duct 45 extends from the seat to a point

adjacent the bottom of the casing. A counterbored lateral 46 extends from the inner side of the casing to the bore 45 and communicates with its port 47 extending through the wall of the housing and providing communication with the bore 18 thereof. A flanged bushing 48 is driven in to the lateral 46 and is provided with a central duct 49. This bushing is an important element because the diameter of the duct 49, is one means for controlling the velocity of the flow into the housing bore 18, and by substituting bushings with bores of different sizes the velocity of flow through the bushing may be varied, as will be hereinafter described.

A tubular piston 50 is disposed to reciprocate vertically in the cylinder 42 and sump 43. This piston is provided with a head 51 at its upper end having a close sliding fit in the upper end of the cylinder. A coiled spring 52 surrounds the piston in the cylinder and is confined between the head 51 and a flanged collar 53 resting on the bottom of the cylinder, as is clearly shown in Fig. 2. The lower end of the piston 50 is tapered as shown at 54, to engage the seat 44 and shut off flow of fluid to the duct 45 and also to the bore 18 of the housing 17. A manifold 55 extends from the top of the tubular piston axially down into the head 51, and has a plurality of upwardly inclined spaced ports 56 extending radially therefrom through the head to the outer surface thereof. When the piston 50 is seated these ports are closed by the wall of the cylinder, but when the piston is moved upwardly, these ports are exposed in the chamber 40. For limiting the upward movement of the piston, an adjusting screw 57 mounted in the plug 41, is set to be engaged by a cap screw 58 which is screwed into the upper end of the manifold 55 and closes the upper end of the same. By adjusting the screw and limiting the upward stroke of the piston, the areas of the ports 56 exposed in the chamber 40, may be varied and controlled.

As hereinbefore stated the housing is connected in the tubing 12 and a head of pressure fluid is carried in the casing 10 above the packer 15. Gas which is usually available in oil fields may be employed as the pressure fluid and such gas is forced into the casing so that a working pressure is built up in the casing, suitable to lift a load or column of liquid standing in the tubing above the point of admission. The well conditions, of course, control the degree of pressure, however, working pressures of from 300 to 500 pounds per sq. in. have been found satisfactory. Of course, air or any other kind of pressure fluid may be employed. To properly admit the pressure fluid to the chamber 40, the outer wall thereof is provided with perforations 58 which act as a strainer to keep out foreign matter. When the piston 50 is elevated to expose the ports 56, the pressure fluid which constantly fills the chamber 40, will be admitted to the manifold 55, whereby it may flow through the bore of the piston, downwardly thereof.

Intermediate its ends, the piston is provided with a plurality of small ports 59 which are so located as to always discharge into the cylinder 42. These ports admit pressure fluid to the cylinder so that when the ports 56 are open, pressure is equalized above and below the head 51. At the lower end, the piston is provided with a plurality of ports 60 which discharge into the sump 43, thus permitting flow into the duct 45 when the piston is unseated. The pressure fluid flows from the duct 45 through the duct 49 of



the bushing 46 and thence through the port 47 into the bore 18 of the casing 17. When the piston 50 is in its closed position as shown in Fig. 2, the spring 52 will be under a predetermined compression but will not exert enough expansive force to move the piston upwardly so long as its tapered end 54 is in engagement with the seat 44 and the ports 56 are closed, because the fluid pressure exerted on the upper end of the piston in the chamber 40 will be greater than this expansion force.

It is obvious that when the column of liquid rises in the bore 18 of the housing, that back pressure will be exerted through the port 47, duct 49 and duct 45 against the exposed area of the lower end of the piston. When the back pressure coupled with the expansive force of the spring is sufficient to overcome the pressure fluid acting on the upper end of the piston 50, the piston will be moved upwardly thereby exposing the ports 56 in the chamber 40 and opening the valve B. Pressure fluid will be admitted through the ports 56 and discharged through the ports 60 into the duct 45, from whence it will flow through the duct 49 and port 47 into the bore 18, and provide a lifting fluid for the column of liquid standing thereabove in the bore 18. The spring 52 acts to hold the piston 50 open, once the ports 56 are exposed. When flow conditions reach the point where a predetermined velocity of flow through the duct 49 is attained, the flow of the pressure fluid through the piston will initially move the same downward until the ports 56 are closed, thereafter the pressure fluid will act directly upon the upper end of the piston, thus seating it with a snap action.

It is pointed out that the closing of the automatic valve may be controlled through the ports 56 instead of through the port 49 of the bushing 48. It is obvious that when the head 51 of the piston has moved downwardly into the bore 42 sufficiently to partially close said ports, the flow therethrough will be restricted and the velocity stepped up, whereby the valve will be closed with a snap action.

The weight bar 32 is suspended on a wire line 61 and is operated in a manner, fully described in Nixon Patents 2,204,817 and 2,171,478. When the well is shut down, the weight bar may be in the position shown in Fig. 2, with respect to the lowermost unit, hereinafter referred to as C, or it may be raised to the top of the tubing above the uppermost unit 16, hereinafter referred to as E.

Under normal or regular operation, one unit 16 is connected in the tubing at a depth or elevation, above which elevation, the column of fluid to be lifted, is accumulated; and this unit may be referred to as the regular or normal flowing unit C. If more than one unit 16 is connected in the tubing at higher spaced elevations, the regular unit C is lowermost. Usually several units 16 will be installed, but for the purpose of illustration only three such units C, D and E are shown in Fig. 1. The number of units will depend upon the particular well installation. The reason for this is manifold because it permits the weight bar 32 to be successively lowered through the units and open the valve or valves A in each unit, thus mechanically "kicking off" the well; or it allows the automatic valves B to open and admit lifting fluid when the weight bar is inoperative at the lowermost unit, to kick off the well, when the column of well fluid builds up in the tubing. Also, whenever the valves A are opened at any given

elevation, automatic valves B at substantially the same elevation may open to automatically assist in lifting the column of well fluid or a slug thereof. Also the automatic valve in each unit may open whether the mechanical valve is open or closed.

As before stated, the unit 16 may be operated under various well conditions. When the well fluid is being produced under regular flowing, as hereinbefore set forth, the bar 32 will be moved upwardly in the bore 18 of unit C to unseat the ball 30 and admit a predetermined quantity of lifting fluid. The lifting fluid admitted may or may not be sufficient to raise to the surface and discharge, the column of well fluid, usually accumulated above the valves 30.

The opening of the automatic valves B is controlled entirely by pressure differentials thereacross. When the pressure of the lifting fluid from the casing 10, predominates, the automatic valves will be closed. However, when the pressure of the hydrostatic load of liquid in the tubing 12, plus the expansive force of the spring 52, creates a sufficient pressure differential, the automatic valve will open. Thus, if such hydrostatic pressure differential is sufficient, the automatic valves below the liquid level will be open and the automatic valves above said liquid level will be closed.

When flow from the tubing is cut off, as by a valve 62, the automatic valves cease to function to lift liquid. Also, when the well is shut off and the automatic valves below the liquid level in the tubing are open, liquid will flow therethrough into the casing, thus establishing liquid levels in both the tubing and the casing.

The auxiliary supply of lifting fluid is entirely automatic and being admitted at substantially the same elevation as the mechanically admitted fluid, is of great advantage in maintaining a stabilized lifting of the well fluid. Further, the valves B will automatically close when the proper upward flow or discharge of well fluid is attained. The ball 30 is velocity-seated as described in my Patent No. 2,171,480. As a head of gas is carried in the well casing 21, such stored gas is carried under sufficient pressure to compensate the pressure drop when gas is admitted to the tubing so that the gas admitted to the tubing while the valves are open will be under sufficient working pressure to adequately lift the slug or column of well fluid.

Should for some reason the supply of gas to the well casing be cut off, or drop below the necessary working pressure, the column of well fluid in the tubing would build up. This occurrence would be in the nature of an emergency and would be somewhat controlled by the amount and duration of the gas-pressure failure and the rate at which the well built up its column of fluid. Assuming that the bar 32 was resting adjacent and below the regular flow unit C, at this time, and gas pressure was restored, then when the bar 32 was moved to open the valve A, the valves B would also be automatically opened and supply additional gas to lift the load. If additional units 16 were installed above the regular unit C, the valves B thereof would open according to the pressure differentials at the same, and unload the well.

When a well is intentionally shut down by closing valve 62 and cutting off the supply of pressure fluid, as under proration laws, the column of liquid will build up in the tubing to its highest standing level. When it is desired to start flowing the well by a gas lift, it is necessary to "kick off" the well, whereby the level of the well liquid is lowered to a working level, where the regular column of well liquid usually stands, when operation from the lowermost unit C is performed. Under such "kicking off" or unloading, the weight bar 32 having been raised to the top of the well, is lowered into the first or uppermost unit E to open the valves A thereof to admit lifting fluid, and then down to the next valve unit D, and so on until the lowermost unit is reached. This, however, is a mechanical operation and requires manual manipulation and supervision.

It is one of the features of this invention to provide the valves B for automatically kicking off the well, thus obviating manual manipulation and supervision. When a well is shut down, the supply of pressure fluid to the casing 10 is cut off so that the pressure in the casing declines or it may be suitably vented to the atmosphere. The uppermost unit E is, of course, connected in the tubing, usually a suitable distance below the high level to which the liquid will rise therein when the well is shut for a period of hours or days; however, the liquid may not rise to the uppermost valve E.

When the fluid pressure in the casing 10 reduces and the liquid rises in said casing, as herein before described; the spring 52 of any valve B above the liquid level in the casing, will force the piston 50 upwardly and thus open the valve; while the hydrostatic load in the tubing and the springs 52, will force open all valves B, below the liquid level in the casing. To start the well flowing, that is to kick it off, pressure fluid is again supplied to the casing to build up the pressure therein and the valve 62 is opened. Any valve B located above the liquid levels will be closed by the pressure fluid.

As the pressure fluid builds up in the casing the liquid level therein will be depressed and the liquid from the casing forced back into the tubing through the immersed valves B until the automatic valve of unit D is reached. When this occurs the level in the tubing will have been raised above unit D, and therefore pressure fluid will enter through the automatic valve of unit D and start the liquid thereabove in the tubing, flowing upwardly. This operation will be repeated at each succeeding lower unit until regular flow is established. The well is thus automatically kicked off. Of course, when the velocity flow through any automatic valve reaches the predetermined point, such valve will be automatically closed.

It may occur that it is desired to mechanically kick off the well and in such case, the weight bar 32 would have been raised to the top of the tubing. The weight bar 32 is lowered to unseat the valves 30 of the first immersed unit, merely passing through the units thereabove. When this occurs the automatic valve of such unit will also open, but as the hydrostatic load in the tubing at this first immersed unit, may be relatively low, said automatic valve would probably not remain open for its usual period of time, particularly when both the valves A and B are open.

It is pointed out that after a slug or column of liquid being lifted, passes any automatic valve, the hydrostatic load plus the expansive force of the spring 52, will cause the valve to open and admit additional lifting fluid to the tubing. This arrangement has many advantages because an adequate supply of lifting fluid is assured under

all flowing conditions. Where the force exerted by the lifting fluid falls below the lifting requirements of the load; there is danger of "slippage" of the slug being lifted. This term is applied where the slug of oil tends to slip down the tubing instead of being carried upwardly therein. Oil and gas wells have a habit of unexpectedly flowing abnormally, which in the oil fields is called "heading." Heading of oil brings into the tubing an abnormal amount of oil and causes the oil level therein to rise above its working level. As the automatic admitting of additional lifting fluid to the tubing is controlled almost entirely by the hydrostatic load of liquid in the tubing, it is obvious that when the well is being operated mechanically, any additional liquid load is automatically handled. However, the automatic valve is so collaborated that when the well is being regularly operated, the automatic valve will not open until after the slug or colum of liquid being lifted has passed the port **49** of such valve. This prevents pressure fluid entering intermediate the ends of the slug and channeling therethrough.

It is also to be observed that by providing the mechanically operated valves A in the units and also the automatic valves B, either type of operation is available. Automatic valves are subject to certain imperfections and sometimes fail to work. Sanding up, clogging and spring breakage are some of the causes. If an automatic valve should fail to "kick-off," the operator may raise or lower the weight bar **32** and open the necessary valves A, at the level where the trouble occurs. When the well is automatically kicked-off, the weight bar **32** is usually maintained in its lowered position at the unit C, where it is available for immediate operation.

The general construction of the automatic valve B is important. Owing to the size of the piston **52** and the various passages and ports, this valve is not likely to clog up with sand. Also there are no delicate or finely balanced parts. The automatic valve is rugged as well as simple.

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. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes, means providing a source of pressure fluid outside of the tubing, means operable from the surface at the top of the well for controlling the admission of pressure fluid to the tubing to lift a predetermined column of well fluid from a given elevation, means for automatically admitting additional pressure fluid to the tubing at substantially said given elevation when the hydrostatic head of the well fluid column sets up a predetermined pressure differential to co-act with the first admitted lifting fluid to maintain continuous lifting of said increased column and prevent channeling of said lifting fluid therethrough, and means for automatically shutting off the admission of such additional pressure fluid when a predetermined increased inward flow velocity is reached.

2. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes, means providing a source of pressure fluid outside of the tubing, means operable from the surface at the top of the well for controlling the admission of pressure fluid to the tubing to lift a predetermined column of well fluid from a given elevation, means for automatically admitting additional pressure fluid to the tubing at substantially said given elevation when the hydrostatic load of the well fluid column sets up a predominating pressure differential, but which is less in pressure than the pressure of the lifting fluid to co-act with the first admitted lifting fluid to maintain continuous lifting of said hydrostatic load, and means for automatically shutting off the admission of such additional pressure fluid at said given elevation.

3. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes, means providing a source of pressure fluid outside the tubing, means for mechanically and positively admitting pressure fluid to the tubing to lift a load of liquid in the tubing from a given elevation, means for admitting additional pressure fluid at substantially the same elevation to assist in lifting increased loads, and means for automatically shutting off the admission of such additional pressure fluid when a predetermined velocity flow of such pressure fluid is reached.

4. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes, means providing a source of pressure fluid outside the tubing, means for mechanically and positively admitting pressure fluid to the tubing to lift a slug of liquid in the tubing, means for automatically admitting additional pressure fluid to the tubing substantially opposite the point of mechanical admission when the slug of liquid being lifted has passed the point of admission of said additional lifting fluid, and means for shutting off the admission of all lifting fluid when the slug of liquid reaches a predetermined point at the top of the well.

5. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes, means providing a source of pressure fluid outside the tubing, means for mechanically and positively admitting pressure fluid to the tubing to lift a slug of liquid in the tubing, means for automatically admitting additional pressure fluid to the tubing substantially opposite the point of mechanical admission when the slug of liquid being lifted has passed the point of admission of said additional lifting fluid, and means for automatically shutting off the admission of such additional pressure fluid when a predetermined velocity of such pressure fluid is reached.

6. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes means providing a source of pressure fluid outside the tubing, means for positively admitting pressure fluid to the tubing, means for automatically admitting additional pressure fluid to the tubing while positively admitting such pressure fluid at substantially the same elevation to lift a load of liquid to the top of the tubing, and means for shutting off the dual admission of pressure fluid when the load of liquid is elevated in the tubing.

7. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes means providing a source of pressure fluid outside the tubing, means for positively admitting pressure fluid to the tubing, means for automatically admitting

additional pressure fluid at substantially the same elevation to the tubing while positively admitting such pressure fluid to lift a load of liquid to the top of the tubing, and means for automatically shutting off the dual admission of pressure fluid when the load of liquid is elevated in the tubing.

8. The system of flowing a well having tubing therein receiving well fluid flowing from the producing formation which includes means providing a source of pressure fluid outside the tubing, means for positively admitting pressure fluid to the tubing, means for automatically admitting additional pressure fluid to the tubing while positively admitting such pressure fluid at substantially the same elevation to lift a load of liquid to the top of the tubing, and means for automatically shutting off the admission of the automatically admitted pressure fluid when a predetermined velocity flow thereof is reached.

9. In combination, a well tubing, and spaced units connected in said tubing, each unit having a mechanically operated valve for admitting pressure fluid and an automatically operated valve substantially opposite the mechanically operated valve for automatically admitting pressure fluid.

10. In combination, a well tubing, and spaced units connected in said tubing, each unit having a mechanically operated valve for admitting pressure fluid and an automatically operated valve substantially opposite the mechanically operated valve for automatically admitting pressure fluid, each valve having means for closing it when a predetermined flow of pressure fluid therethrough is reached.

11. In combination, a well casing carrying a head of pressure fluid, a tubing in said casing having liquid standing therein, a plurality of units connected in spaced order in said tubing, each including an enclosure connected at each end to the tubing having a mechanical pressure-fluid inlet valve, means movable through successive units and controllable from the surface of the well for opening the mechanical valves, and an automatic pressure-fluid inlet valve carried in the enclosure of each unit adjacent the mechanical valve.

12. A well-fluid lifting unit including, a housing having a fluid passage therethrough, a mechanical pressure-fluid inlet valve having a portion exposed in said housing passage, means controlled from the surface of the well for engaging the exposed portion of the mechanical valve and opening the same, and an automatic pressure fluid inlet valve carried in said housing and communicating with the fluid passage thereof adjacent the mechanical valve.

13. A well-fluid lifting unit including, a housing having a plurality of pressure fluid inlet openings and a flow passage communicating with said openings, a ball valve closing one of said openings, a spring-impelled valve closing the other



opening, both of said valves being adapted to close under predetermined flow velocities thereacross.

14. A well-fluid lifting unit including, a housing having a flow passage therethrough, a positively operable valve for admitting pressure fluid to said passage, and an automatic valve for admitting pressure fluid to said passage including resilient means for opening it and means for causing the valve to close when a predetermined velocity flow therethrough is attained.

15. A flow unit for a well for controlling the admission of a pressure lifting fluid to a column of well fluid during the varying rates of flow of the column including, a flow conductor adapted to be connected to the well fluid flow line, mechanically operated means for admitting pressure lifting fluid to the flow conductor for lifting a column of well fluid therein, and automatically operated means substantially opposite the mechanically operated means for admitting pressure lifting fluid to the flow conductor when the column of well fluid passes said automatically operated means.

16. An apparatus for flowing oil wells having a casing and tubing therein which includes, means for trapping a volume of pressure fluid in the casing, and means for admitting pressure fluid to the tubing in two stages at substantially opposite points including surface controlled elements for positively admitting pressure fluid to the tubing from the casing to lift a load of well fluid to the top of the well at a single operation and elements for automatically admitting additional pressure fluid to the tubing substantially opposite the point of positive admission when the hydrostatic load of the well fluid reaches a predetermined amount.

17. A single flow unit for a well fluid lifting apparatus including, a unitary enclosure having means at each end for connecting in a well tubing and having a well fluid passage therethrough, a mechanical valve in the enclosure opening to the passage adapted to be mechanically opened to admit a predetermined volume of pressure lifting fluid, and an automatic valve in the enclosure opening to the passage substantially opposite to the mechanical valve adapted to be automatically opened by an excessive load of well fluid after the mechanical valve is opened.

18. A well-fluid lifting unit including, a housing having a plurality of pressure fluid inlet openings and a well fluid flow passage therethrough communicating with said openings, a ball valve closing one of said openings, a spring-impelled valve closing the other opening, the spring-impelled valve responsive to load variations of the well fluid and to open when the load increases beyond a predetermined point and to close when the well fluid load decreases to a predetermined value.

JEDDY D. NIXON.