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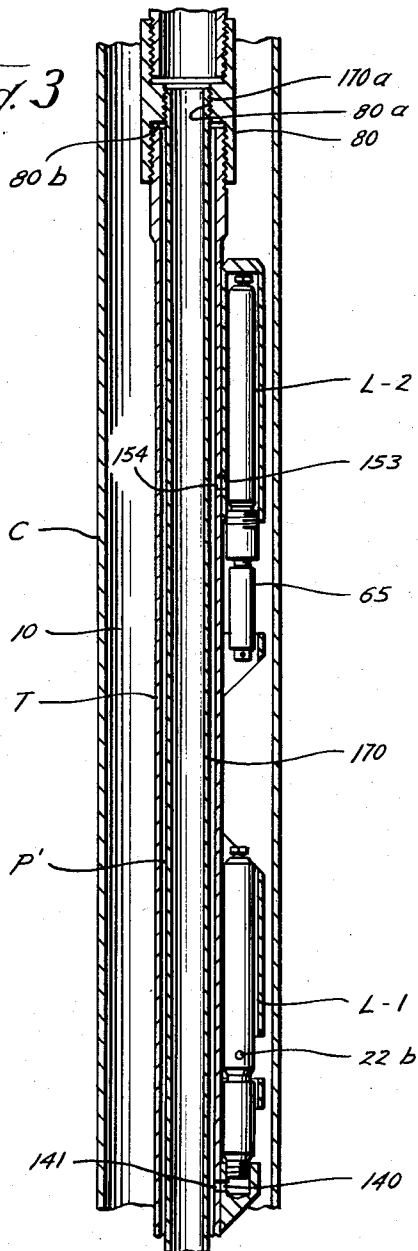
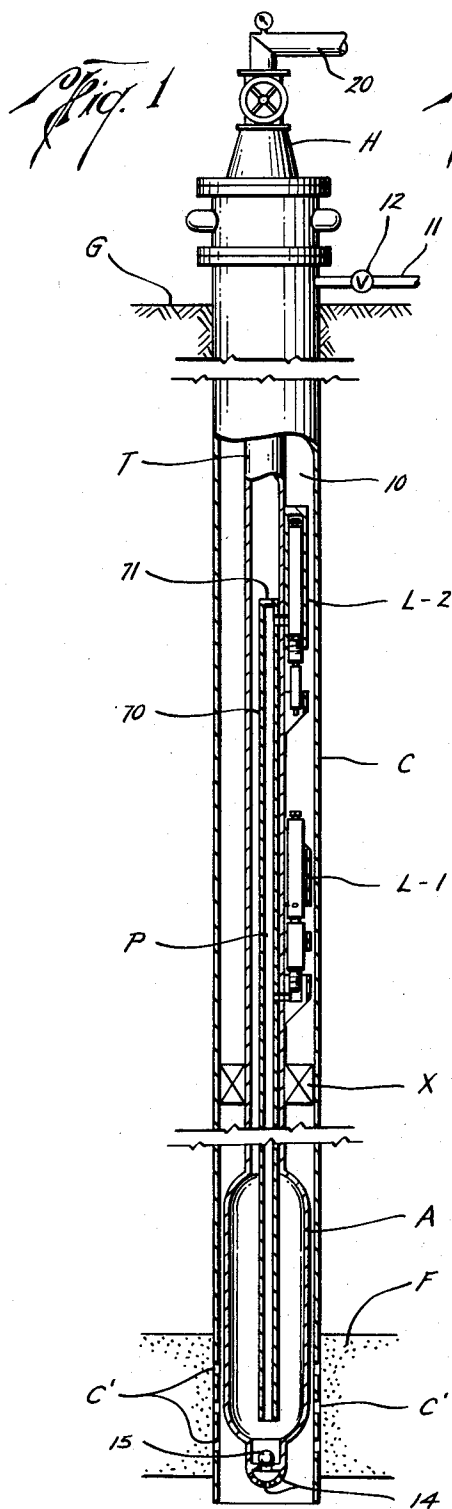
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GAS LIFT METHOD AND APPARATUS

Filed July 18, 1957

2 Sheets-Sheet 1



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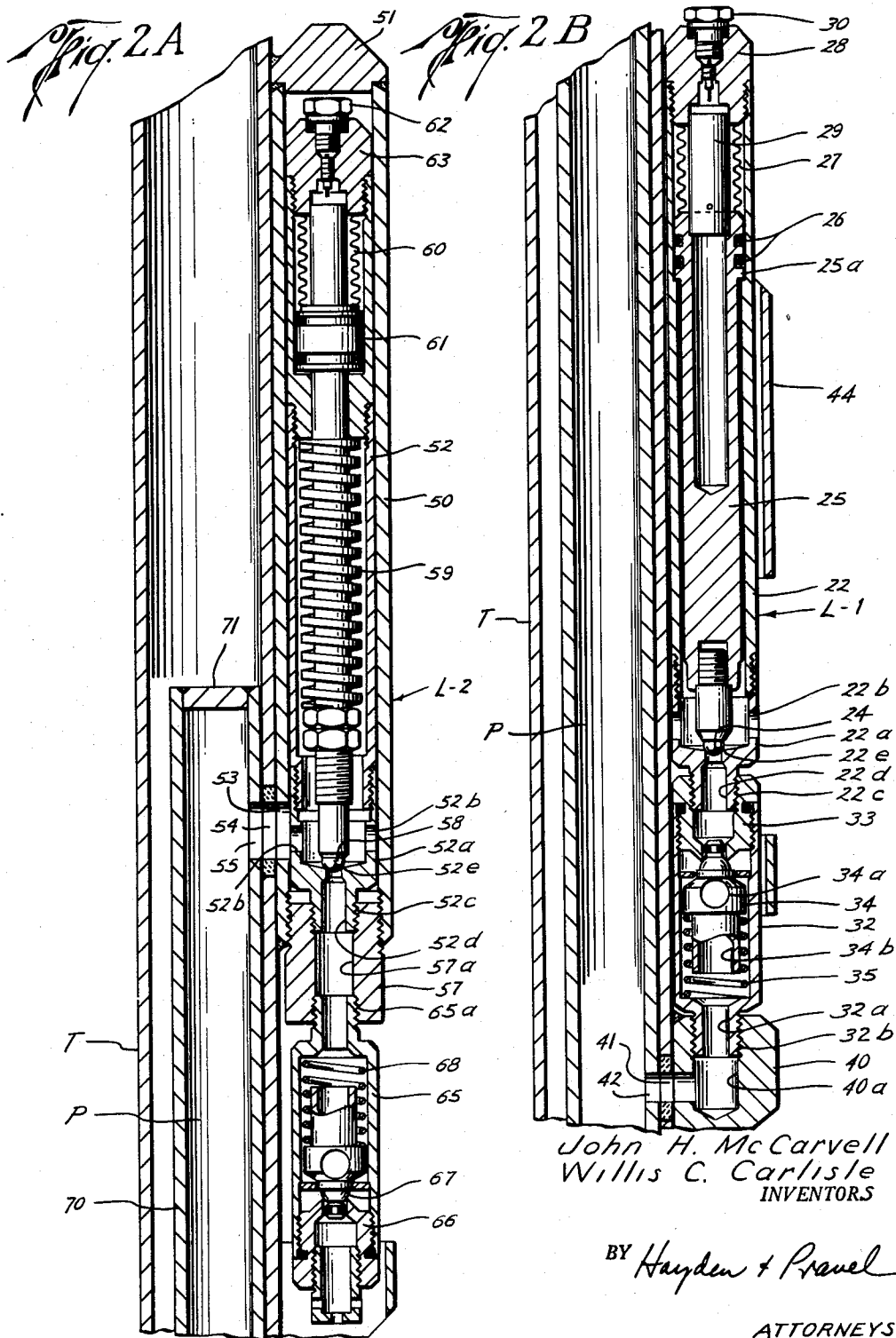
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2,948,232

## GAS LIFT METHOD AND APPARATUS

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This invention relates to new and useful improvements in gas lift methods and apparatus for recovering liquids such as hydrocarbons from wells.

An object of this invention is to provide a new and improved method and apparatus for lifting liquid such as oil in a well with gas under pressure, wherein a compressor of reduced capacity may be utilized at the surface or ground level for providing the gas under pressure which is used in the lifting of the liquid.

An important object of this invention is to provide a new and improved method and apparatus for lifting liquid such as oil in a well with gas under pressure, wherein the liquid is permitted to collect in a chamber which has a reduced area as compared to the pipe in which the chamber is formed, and wherein a surge of the gas under pressure is admitted to the chamber periodically for imparting an increased lifting force to the liquid as compared to the lifting force which would be provided by injecting the gas directly into the pipe.

Another object of this invention is to provide a new and improved method and apparatus for lifting liquid such as oil in a well with gas under pressure, wherein a combination of gas lift valves are utilized for admitting gas under pressure into a well pipe having the liquid therein, one of said valves opening to admit the gas into said pipe when the gas reaches a predetermined pressure externally of the pipe, and the other of said valves opening to admit the gas into said pipe when the pressure in the well pipe reaches a predetermined pressure which is a substantial amount below the predetermined pressure at which said one of the valves opens, whereby the gas is thereafter admitted into said well pipe through said other of the valves until the pressure externally of the pipe reaches the predetermined pressure at which said other of the valves opens to thereby provide a surge of gas under pressure in the well pipe which is sufficient to lift a quantity of the liquid in the pipe to the surface or ground level for discharge therefrom.

A further object of this invention is to provide a new and improved gas lift method and apparatus which is particularly suitable for low pressure oil wells in which the maximum natural height of the oil is reached very slowly after each removal of a quantity of oil therefrom, wherein a well pipe is provided which preferably has an enlarged diameter accumulation chamber for accumulating a relatively large volume of oil therein as the oil seeks its natural maximum level and a dip tube or pressure chamber extending from a point within said accumulation chamber to a point a substantial distance thereabove, such dip tube or pressure chamber having a closed upper end to provide an enclosed area above the level of the oil, and such dip tube or pressure chamber also having valve means therewith for admitting gas under pressure into the enclosed area above the oil level for providing a surge of gas pressure which is sufficient to lift an appreciable quantity of the oil in the dip tube and in the accumulation chamber through the well pipe to the surface or ground level for discharge therefrom.

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Still another object of this invention is to provide a new and improved method and apparatus for lifting a liquid in a pipe with gas pressure, wherein the gas is initially admitted into said pipe when it reaches a predetermined pressure, and wherein a reduced gas pressure is developed in said pipe which is substantially below the pressure at which the gas is initially admitted into said pipe, the admission of the gas into said pipe continuing until the pressure of the gas externally of the pipe reaches the lower pressure created in the well pipe.

The preferred embodiment of this invention will be described hereinafter, together with other features thereof, and additional objects will become evident from such description.

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

Fig. 1 is a view, partly in elevation and partly in section, illustrating one type of apparatus for use in carrying out the method of this invention;

Figs. 2A and 2B are views, partly in elevation and partly in section, illustrating in detail the gas lift valves and other structure which is preferably used in the apparatus illustrated in Fig. 1; and

Fig. 3 is a view, partly in elevation and partly in section, illustrating a second type of apparatus for use in carrying out the method of this invention.

First, considering the invention briefly, the letter C in the drawings designates a well casing or bore in a well which extends from a well formation F to a point above or in the vicinity of the ground level or earth's surface G. A well tubing or pipe T is positioned within the well casing or bore C and it is constructed with an accumulation chamber A and a dip tube or pressure chamber P formed therewith, as will be explained in detail hereinafter. The upper end of the tubing T extends to the ground level G and it is connected with the casing C in the usual manner by means of a well head assembly H of known construction. Gas lift valves L-1 and L-2 are mounted with the tubing T for controlling the admission of gas under pressure from the annulus or passage 10 between the casing C and the tubing T into the pressure chamber or dip tube P in a manner to be hereinafter more fully explained. A well packer X of known construction is positioned in the casing annulus 10 between the well casing C and the well pipe or tubing T below the gas lift valves L-1 and L-2 so as to close the annulus 10 to prevent the flow of well fluid upwardly past the packer X and also to confine the gas under pressure within the annulus 10 above the packer X. The gas under pressure is admitted into the casing annulus 10 at the ground level G through an inlet pipe 11 which preferably has a valve 12 therewith. A gas pump or compressor (not shown) is connected in any desired manner with the inlet pipe 11 so that the desired gas pressure is developed within the longitudinal passage or annulus 10.

Briefly, the method of this invention involves the admission of gas under pressure with a pump or compressor at the earth's surface or ground level G so as to develop a predetermined or desired gas pressure within the passage or annulus 10. During the build-up of the gas pressure in the annulus 10, the valves L-1 and L-2 are closed, and the packer X prevents the escape of the gas downwardly in the annulus 10 past the packer X. During the build-up or development of the pressure of the gas in the annulus 10, oil or other well fluid from the formation F flows through the perforations C' in the casing C. The lower end of the accumulation chamber A is preferably formed with suitable openings 14 and a

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downwardly closing check valve 15 so that the well liquid or oil coming from the well formation F flows upwardly into the accumulation chamber A at the lower end of the well pipe or tubing T. As will be more evident hereinafter, the method of this invention is particularly suitable for use in conjunction with well formations wherein a relatively low well pressure is available so that the well liquid rises in the accumulation chamber A at a relatively slow rate. While the oil or other well liquid rises to its natural level in the well pipe or tubing T, the desired or predetermined casing gas pressure in the passage or annulus 10 may be developed with a relatively small pump or compressor as compared to the sizes of pumps or compressors presently used. For example, under ordinary circumstances, the pump or compressor which is used can be one which has about one-third of the cubic feet per minute capacity that the ordinary pump or compressor for gas lift operations is required to have. Despite the fact that the smaller capacity pump or compressor is used, the present invention accomplishes an extremely great lifting force on successive quantities of the oil or other liquid, as will be explained. When the gas pressure in the passage or annulus 10 reaches the predetermined gas pressure which is sufficient to open the gas lift valve L-1, the gas pressure is admitted from the annulus 10 into the pressure chamber P. The level of the oil or liquid in the pressure chamber P is thus acted upon by the gas under pressure which is admitted into the pressure chamber P so as to force the liquid level in the pressure chamber P downwardly. The amount of pressure in pounds per square inch acting on the column of the liquid in the pressure chamber P is extremely great as compared to the normal gas lift pressure due to the reduced cross-sectional area of the pressure chamber P. As the level of the liquid in the pressure chamber P is thus forced downwardly by the gas pressure admitted from the passage or annulus 10 through the valve L-1, the level of the liquid in the rest of the tubing T is raised accordingly so that a head of liquid is created by reason of the differences in the levels of the liquid within the pressure chamber P and the liquid in the rest of the tubing T. Such head of liquid continues to increase until a predetermined gas pressure is developed in the pressure chamber P above the level of the liquid therein, at which time, the valve L-2 is forced to open by such predetermined back pressure of the gas in the pressure chamber P. The predetermined back pressure in the pressure chamber P is substantially below the gas pressure in the annulus 10 which was utilized for opening the valve L-1. The pressure differential is sufficient, therefore, to cause a surge of gas under pressure into the pressure chamber P through the valve L-2 and such surge of gas pressure applies a surge of lifting force to the liquid or oil in the well tubing T to lift a quantity thereof upwardly to the surface or ground level G for discharge through an outlet pipe 20 at the well head H or other elevated discharge point, so that a quantity of the well liquid or oil is lifted to the surface or ground level G with a gas pressure which could not ordinarily be supplied in sufficient volume by a low capacity pump to effect such lifting of the oil or liquid. When the pressure in the pressure chamber P is equal to, or substantially equal to, the pressure of the gas externally thereof in the annulus 10, then the valve L-2 closes because the gas pressure is insufficient to maintain such valve L-2 open. As will be more fully explained, the valve L-1 had previously closed, so that both of the valves L-1 and L-2 are then closed and a repetition of the above described method steps are then conducted. In that manner, successive quantities of the well liquid or oil from the formation F are lifted to the discharge pipe 20 or other discharge point.

Considering the invention in detail, the detailed construction of the gas lift valves L-1 and L-2 is shown in Figs. 2A and 2B. The valve L-1 may be of any con-

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struction so long as it is opened by a predetermined gas pressure externally of the well pipe or tubing T for admitting gas under pressure into the pressure chamber P. As shown in Fig. 2B, the gas lift valve L-1 includes a tubular housing 22 which is formed with a lower housing adapter 22a having an opening or openings 22b therein which establishes fluid communication between the area externally of the valve L-1 and the area internally of the housing 22. The lower end 22c of the adapter 22a is threaded externally and is provided with a hollow bore 22d, the upper end of which is formed with a valve seat 22e, against which a valve member 24 is adapted to seat to close fluid flow through the bore 22d. The valve member 24 is mounted for longitudinal movement within the housing 22 on an elongated rod 25 which is formed with an enlarged piston head 25a at its upper end. Suitable seal rings 26 are provided for sealing contact with the interior of the housing 22. A diaphragm or bellows 27 is connected to the upper end of the head 25a and also to a removable plug 28, with a pressure chamber being provided internally of the diaphragm or bellows 27. A tube 29 is positioned internally of the bellows 27 to limit the extent of the upward movement of the rod 25 with respect to the upper closure plug 28 so as to prevent damage to the diaphragm or bellows 27. A removable cap 30 is threaded into the plug 28 or it is otherwise suitably connected thereto so that a predetermined amount of gas under pressure can be provided within the diaphragm or bellows 27. Such pressure within the bellows 27 must be overcome by the pressure acting upwardly on the piston head 25a in order to lift the valve member 24 upwardly off of its seat 22e to open the bore 22d and permit the gas flow therethrough.

A check valve is preferably mounted below the housing adapter 22 and such check valve includes a check valve housing 32 which has an upper removable valve seat member 33 threadedly engaged with the external threads 22c on the adapter 22a. The check valve member 34 is slidably positioned within the housing 32 and is urged to a seated position by a spring 35 which is positioned within the housing 32 and is located externally of the valve member 34. The valve member 34 contacts the seat member 33 to close fluid flow through the check valve until the pressure in a downward direction (as viewed in Fig. 2B) is sufficient to overcome the force of the spring 35, at which time the fluid flows downwardly through the valve seat member 33, through the openings 34a and the bore 34b of the check valve member 34 for discharge through the bottom bore or opening 32a of the housing 32.

A support and fluid passage member 40 is welded or is otherwise secured to the external surface of the well tubing or pipe T and it is provided with internal threads which receive external threads 32b on the lower end of the housing 32 so that the entire gas lift valve L-1 is threadedly supported on the support member 40. Such member 40 has a fluid passage 40a formed therein which is in communication with openings or passages 41 and 42 formed in the well tubing T and the pressure chamber P, respectively. Therefore, there is a means for fluid communication between the interior of the pressure chamber P and the area externally of the tubing T through the valve L-1. A substantially U-shaped bracket 44 is welded or otherwise secured to the external surface of the tubing T into which the gas lift valve L-1 is positioned to retain same against damage during use. With the valve L-1 as described in connection with Fig. 2B, the valve member 24 is moved to an open position when the gas pressure externally of the well pipe or tubing T reaches a predetermined amount which is sufficient to overcome the pressure in the area defined by the diaphragm or bellows 27. The valve member 24 remains open until the pressure externally of the tubing T is dropped sufficiently to permit the force of the pressure within the bellows 27 to return the valve member 24

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to a seated position on the valve seat 22e. The pressure which unseats the valve member 24 is of course sufficient to also unseat the check valve member 34 downwardly so that the gas under pressure then flows directly from the area externally of the tubing T into the pressure chamber P. The valve L-1 automatically closes when the pressure externally of the well pipe T falls below the amount necessary to overcome the pressure set in the diaphragm 27.

The valve L-2 which is illustrated in Fig. 2A of the drawings includes a valve support sleeve 50 which is tubular and which is welded to the external surface of the well pipe or tubing T, or is otherwise suitably connected thereto. The upper end of the support sleeve 50 is closed with a cap 51 which is welded or otherwise secured thereto. The actual valve housing 52 fits within the support sleeve and is removable therefrom. The housing 52 has a lower housing adapter 52a which has one or more lateral openings 52b formed therein which are in fluid communication with the interior of the housing 52. Suitable openings 53, 54 and 55 are provided in a sleeve 50, well tubing T, and the wall of the pressure chamber P, respectively, so as to establish fluid communication from the interior of the pressure chamber P to the interior of the housing 52. The adapter 52a has lower external threads 52c for connecting same with an annular nut 57 which is threaded into the lower end of the sleeve 50 for holding the portion of the valve L-2 thereabove in position within the sleeve 50. The interior of the lower end of the adapter 52a is a bore 52d which is formed with an annular valve seat 52e, against which a valve member 58 is adapted to seat for closing fluid flow through the bore 52d. The valve member 58 is urged to a closed position by the combination force applied thereto through a coil spring 59 and through pressure provided within a diaphragm or bellows 60 which is connected at the upper end of a piston 61. The amount of pressure within the diaphragm or bellows 60 is controlled in any suitable manner, but a removable cap 62 is provided on the closure plug 63 at the upper end of the housing 52 so that the amount of pressure within the bellows 60 can be varied. In any event, the valve member 58 is unseated or opened so as to permit fluid flow through the bore 52d when the pressure within the pressure chamber P is sufficient to overcome the downward force of the coil spring 59 and the pressure within the bellows 60. Of course, it will be understood that other types of constructions can be used for maintaining the valve member 58 in a seated position until a predetermined force is applied thereto to unseat same.

The annular nut 57 is provided with an internal bore 57a into which is threaded or otherwise connected a check valve body 65 which has external threads 65a formed thereon. The check valve illustrated in Fig. 2A is identical with that illustrated in Fig. 2B except that it is upside down and it therefore includes the valve seat member 66 and the valve member itself 67 which contacts with the valve seat member 66 to close fluid flow there-through. A coil spring 68 within the housing 65 maintains the check valve member 67 closed with a predetermined spring pressure. When the valve member 58 is opened by the action of the predetermined pressure within the pressure chamber P, then the pressure externally of the tubing T is permitted to flow inwardly through the check valve and then into the pressure chamber P until the pressure in the pressure chamber P falls sufficiently so that it is below the pressure required to maintain the valve member 58 in a raised or open position. It can thus be seen that the valve L-2 is opened by the pressure within the pressure chamber P so as to admit the pressure from externally of the tubing T into the pressure chamber P. On the other hand, as previously explained, the gas lift valve L-1 is opened by the gas pressure externally of the well pipe or tubing T and it likewise serves to admit pressure from the area externally of the pipe T into the pressure chamber P within

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the tubing T. In connection with this invention, the valve L-2 is opened with the gas in the annulus 10 at a substantially lower pressure than the pressure of the gas in the pressure chamber P at which the valve L-1 is opened. It should be noted that the valve L-2 is exposed to the pressure of the gas in the annulus also, but because only a very small area of the valve member 58 is exposed to such gas pressure in the annulus as compared to the other area of the member 58 and connected parts which is exposed to the gas pressure in the chamber P, it requires a far greater fluid pressure force externally of the tubing T to open the valve L-2 than it requires to open such valve with the pressure in the chamber P. Also, the valve L-2 is adjusted and constructed so that the gas pressure in the annulus 10 does not ever have sufficient force to open the valve member 58, and the gas pressure in the annulus 10 which opens the valve L-1 is insufficient to open the valve L-2.

It will be noted that the pressure chamber P is formed with a tubular pipe 70 in the form of the invention shown in Figs. 1, 2A and 2B, and the upper end of such pipe 70 is closed with a cap or plate 71 which is welded or otherwise secured thereto. The tube or pipe 70 is welded or otherwise secured to the interior of the tubing T and has a reduced cross-sectional area as compared to the full opening of the tubing T thereabove. The lower end of the pipe or tube 70 is open and it preferably extends substantially to the lower end of the accumulator chamber A.

The method of this invention employing the form of the invention illustrated in Figs. 1, 2A and 2B is believed evident from the previous description of the method. As previously stated, the gas under pressure is pumped into the casing annulus or passage 10 through the inlet tube or pipe 11 and the inlet valve 12 to develop a desired predetermined gas pressure therein. While such gas pressure is being developed, the oil or well liquid from the well formation F flows upwardly into the accumulator chamber A and into the pressure chamber P. In the ordinary case, the natural pressure of the well formation F is not sufficient to raise the level of the oil or liquid above the point at which the gas pressure is admitted into the pressure chamber P from the lower gas lift valve L-1, but in any event, the gas under pressure which is developed in the casing annulus 10 ultimately reaches a sufficient amount to open the valve L-1 so that the gas under pressure from the annulus 10 then flows through the valve L-1 into the pressure chamber P. The level of the oil in the chamber P is forced downwardly by the gas pressure which is admitted from the annulus 10, and such downward movement of the liquid in the chamber P causes the liquid level in the rest of the pipe T to rise. The difference in the liquid levels between the liquid in the chamber P and the rest of the pipe T creates a hydrostatic head of liquid and causes a back pressure of gas to develop in the chamber P above the level of the liquid therein as the gas from the annulus 10 passes through the valve L-1 to the chamber P. Such a back pressure within the pressure chamber P acts on the valve L-2 and when the pressure becomes sufficient, it lifts the valve member 58 and opens the valve L-2. When that condition occurs, the gas under pressure in the well casing 10 is then admitted through the valve L-2 and substantially simultaneously therewith, the pressure in the annulus 10 drops sufficiently to permit the valve L-1 to close. The valve L-2 preferably opens when the pressure in the pressure chamber P is considerably below the pressure in the annulus 10 at which the valve L-1 was open. For example, assuming that a pressure within the annulus 10 of 300 pounds per square inch is sufficient to open the valve L-1 to admit the gas under pressure into the pressure chamber P, the valve L-2 would ordinarily open at a pressure within the pressure chamber P of about 200 pounds per square inch. In other words, there would be approximately 100

pounds per square inch differential in the opening pressures for the two valves L-1 and L-2. However, it is to be noted that the pressures which open the valves L-1 and L-2 are different pressures from different areas, as previously explained in detail. Thus, continuing with the example, when the pressure in the chamber P reaches the 200 pounds per square inch, that is sufficient to open the valve L-2. Once the valve L-2 is opened by the 200 pounds per square inch pressure within the pressure chamber P, then the pressure of 300 pounds per square inch within the casing annulus 10 flows through the check valve housing 65 and through the valve L-2 into the pressure chamber P. The drop in pressure in the annulus 10 which is caused by the flow of pressure gas from the annulus 10 through the valve L-2 lowers the gas pressure acting on the valve L-1 to such an extent that the valve L-1 closes. A surge or rapid inlet of a large volume of the gas under pressure occurs from the annulus 10 into the pressure chamber P through the valve L-2 due to the great difference in the pressure between the pressure within the pressure chamber P and the area in the annulus 10 externally of the tubing T. Such surge of gas pressure forces the liquid or oil within the pressure chamber P downwardly and forces the oil or liquid within the accumulator chamber A upwardly within the rest of the tubing or pipe T with a terrific lifting force so that as such gas rises, it lifts the quantity of liquid thereabove to a discharge point such as the discharge pipe 20 above the ground level G.

When a sufficient quantity of the gas passes up the pipe T to lift the liquid thereabove, the pressure of the gas within the pressure chamber P falls because the pump or compressor is not large enough to replenish the pressure in the annulus 10 and the chamber P as fast as it is utilized in lifting the oil in the pipe T. Therefore, when the pressure in the chamber P falls below the amount necessary to hold the valve L-2 open, the valve L-2 will also close, so that then both of the valves L-1 and L-2 are closed. Thereafter, the gas pressure is again gradually built up within the casing annulus 10 and at the same time the well fluid is again gradually flowing upwardly into the accumulator chamber A from the well formation F so that the foregoing cycle of method steps can be repeated successively and automatically. With such method, successive quantities of the oil or other well liquid are thus lifted to the surface of the well with an extremely small capacity pump or compressor.

In Fig. 3, a modified structure is illustrated for carrying out the method of this invention. In such modified structure of Fig. 3, the pressure chamber P' is formed between the well tubing T and an inner concentric pipe or tube 170. The section of the well tubing T which surrounds the tube 170 is joined to the well pipe or tubing T thereabove with a coupling sleeve 80 which is specially constructed with a reduced internal threaded bore 80a for receiving the upper threaded end 170a of the tube or pipe 170. The coupling sleeve 80 is provided with an annular shoulder 80b between the section of the tubing T below the sleeve 80 and the tube 170 so as to provide a closed upper end for the pressure chamber P'. It can thus be seen that the pressure chamber P' has a reduced cross-sectional area as compared to the cross-sectional area of the well tubing or pipe T above the coupling sleeve 80, and such reduced cross-sectional area is annular in shape and is formed due to the position of the concentrically disposed tube or pipe 170 within the section of the well tubing T below the sleeve 80. The lower end of the pressure chamber P' is open and an accumulator chamber (not shown) which corresponds to the accumulator chamber A of Fig. 1 is formed with the tubing T below the portion illustrated in Fig. 3. Similarly, the lower end of the dip tube or pipe 170 extends down into the accumulator chamber A in the same manner as the dip tube or pipe 70 extends into

the chamber A in Fig. 1. The gas lift valves L-1 and L-2 may be identical with the valves L-1 and L-2 illustrated in Figs. 1, 2A and 2B. In any event, the valve L-1 is opened at a predetermined gas pressure in the annulus or passage 10 of the well casing C so as to admit such gas under pressure through the openings 22b and then through openings 140 and 141 into the annular pressure chamber P'. Such gas under pressure functions in the same manner as the gas under pressure which was admitted with the valve L-1 in the form of the invention shown in Figs. 1, 2A and 2B in that the gas under pressure forces the level of the liquid in the pressure chamber P' downwardly which causes the liquid level within the tube 170 to rise, whereby a head of liquid is created. Such head of liquid causes a back gas pressure within the pressure chamber P' and when that pressure in the pressure chamber P' reaches a predetermined amount, then it opens the valve L-2. When the valve L-2 opens, the gas under pressure in the casing annulus 10 enters the pressure chamber P' from the annulus 10 through the check valve housing 65 and then through openings 153 and 154. Due to the fact that the valve L-2 opens with a much lower gas pressure within the pressure chamber P' than the pressure of the gas within the casing annulus 10 at the time the valve L-1 opens, there is a surge of the gas under pressure through the valve L-2 into the pressure chamber P' for imparting a surging force of the gas to the liquid for effecting a rapid lifting of a quantity of the gas from the accumulator chamber A upwardly through the interior of the tube 170 and the well tubing T thereabove to an elevated point at the surface of the well.

It is thus believed evident that the structure illustrated in Fig. 3 functions in the same manner and is usable for carrying out the method of this invention as previously described in connection with Figs. 1, 2A and 2B.

The foregoing disclosure and description of the invention is illustrative and 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 is claimed is:

1. An apparatus for lifting liquid in a pipe with gas under pressure, comprising a chamber in said pipe having a closed upper end and an open lower end, the open lower end communicating with the bore of the pipe, a first valve means mounted on said pipe for admitting the gas at a predetermined pressure into said chamber of the pipe to apply a lifting force on a column of liquid in the pipe for creating a back pressure on the gas in the chamber, and a second valve means mounted on said pipe and operable by the gas pressure in said chamber when the gas reaches a predetermined pressure for admitting a large volume of the gas into said pipe rapidly until the pressure of the gas in said chamber of the pipe falls below said predetermined pressure of the gas which is created in the pipe, whereby such surge of gas is provided in the pipe for lifting a quantity of liquid in the pipe.

2. An apparatus for lifting liquid in a pipe with gas under pressure which is supplied from externally of the pipe, comprising means including a chamber in the pipe having a closed upper end and an open lower end in communication with the remainder of the pipe for accumulating liquid in the pipe with a gas space above the level of the liquid in the chamber, means mounted on said pipe for introducing the gas into said chamber from externally of the pipe at a predetermined pressure and for directing the gas into contact with the upper surface of the liquid in the chamber to force the level of the liquid downwardly in the chamber and upwardly in the remainder of the pipe to lift the liquid in the remainder of the pipe which develops a back pressure of the gas in said chamber which is less than said predetermined

pressure of the gas, and additional means associated with said pipe and operable by said back pressure in said chamber for admitting the gas under pressure into the pipe from externally thereof in a surge for applying a sufficient force to the liquid to lift a quantity thereof in the pipe for discharge from the pipe at an elevated point.

3. An apparatus for lifting liquid in a well with a gas under pressure, comprising a well casing, a well tubing disposed in said well casing with a longitudinal passage therebetween, means on said tubing for introducing gas under pressure into said longitudinal passage to develop a predetermined gas pressure in said passage, said well tubing having a pressure chamber with a closed upper end formed therein and an open lower end in communication with the bore of the tubing so as to provide a confined area above the level to which the liquid rises in said chamber, means on said tubing for admitting the gas in said passage at said predetermined pressure into said chamber to force the liquid level downwardly in said chamber and upwardly in the rest of the tubing to create a differential in liquid levels between the liquid in the pressure chamber and the liquid in the tubing externally of the pressure chamber which develops a predetermined back pressure in said pressure chamber, and additional means on said tubing for introducing the gas from said passage into said pressure chamber until the pressure in said pressure chamber falls below said predetermined back pressure for thereby providing a surge of pressure gas in said tubing for forcing a quantity of the liquid in the pipe to discharge therefrom at an elevated point with respect to said pressure chamber.

4. An apparatus for lifting a liquid in a well pipe wherein the lower end of the pipe is open for admitting a fluid flow of well liquid into the pipe, comprising an accumulation chamber in said pipe for accumulating well liquid as it flows upwardly into said pipe, a pressure chamber in said pipe extending downwardly into said accumulation chamber, said pressure chamber having a closed upper end and means establishing communication from said accumulation chamber to said pressure chamber, a pair of gas lift valves mounted on said well pipe, means forming a part of each of said gas lift valves for establishing communication through each of said valves from the pressure chamber to the area externally of the pipe, one of said valves having means therewith for opening same when the gas pressure externally of the pipe reaches a predetermined amount, and means on the other of said valves for opening when the gas pressure in said pressure chamber reaches a predetermined amount.

5. The structure set forth in claim 4, wherein the pressure chamber has a reduced cross-sectional area as compared to the cross-sectional area of the well tubing to increase the lifting force of the gas pressure admitted into said pressure chamber.

6. The structure set forth in claim 4, wherein said accumulation chamber has an enlarged diameter relative to the diameter of the well tubing.

7. An apparatus for lifting liquid in a well with a gas under pressure, comprising a well casing, a well tubing disposed in said well casing with a longitudinal passage therebetween, said tubing having a pressure chamber formed therein with a closed upper end and an open lower end in communication with the bore of the tubing, a pair of gas lift valves on said tubing for controlling the admission of the gas under pressure from said passage to said tubing, the first of said valves being operable by the gas pressure in said passage, the second of said

valves being operable by the gas pressure in said pressure chamber, said first valve being opened at a predetermined gas pressure in said passage to admit such gas pressure into said pressure chamber for forcing the liquid in the tubing upwardly until the head of liquid acted on by the gas pressure creates a predetermined back pressure in said pressure chamber, and the second valve being opened with said predetermined back pressure in said pressure chamber to rapidly admit the gas into said pressure chamber from the passage in a volume which is large as compared with the volume of said pressure chamber until the pressure of the gas in said pressure chamber falls below said predetermined back pressure for lifting a quantity of liquid for discharge from the tubing.

8. The structure set forth in claim 7, including means forming a part of said first valve for closing same after the predetermined back pressure is developed in said pressure chamber, whereby all of the gas is thereafter admitted to the pressure chamber through said second valve.

9. The structure set forth in claim 7, including means forming a part of said second valve for closing said second valve when said pressure in said pressure chamber falls below said predetermined back pressure.

10. The structure set forth in claim 7, including pump means at the surface of the well for pumping the gas into said passage until said gas reaches said predetermined gas pressure.

11. The structure set forth in claim 7, including a downwardly closing check valve in the well tubing below the lower end of said closed chamber to permit liquid to flow upwardly therethrough, but to prevent liquid from flowing downwardly therethrough.

12. The structure set forth in claim 7, wherein said closed chamber in said tubing is formed by an internal tube of reduced size as compared to said tubing, said tube being secured to said tubing.

13. The structure set forth in claim 7, including an inner pipe concentrically disposed within said tubing and circumferentially spaced therefrom for forming said pressure chamber between said tubing and said inner pipe, and means extending from said inner pipe to said tubing above the lower end of the inner pipe to form said closed upper end of said pressure chamber.

14. An apparatus for lifting liquid in a pipe with gas under pressure exteriorly thereof, comprising first and second valves on the exterior of the pipe for admitting said gas into the pipe, means with the first valve for opening same with said gas at a predetermined pressure of said gas for admitting the gas into said pipe from exteriorly thereof, holding means with said second valve for maintaining same closed at the predetermined pressure of the gas exteriorly of the pipe, and means with said second valve for releasing the holding means for thereby opening the second valve by the action of a hydrostatic head of liquid in the pipe created by the admission of the gas through said first valve so as to then admit gas into the pipe from exteriorly thereof through the second valve in a surge.

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