Dec. 10, 1968 J. K. ELLIOTT ETAL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 1

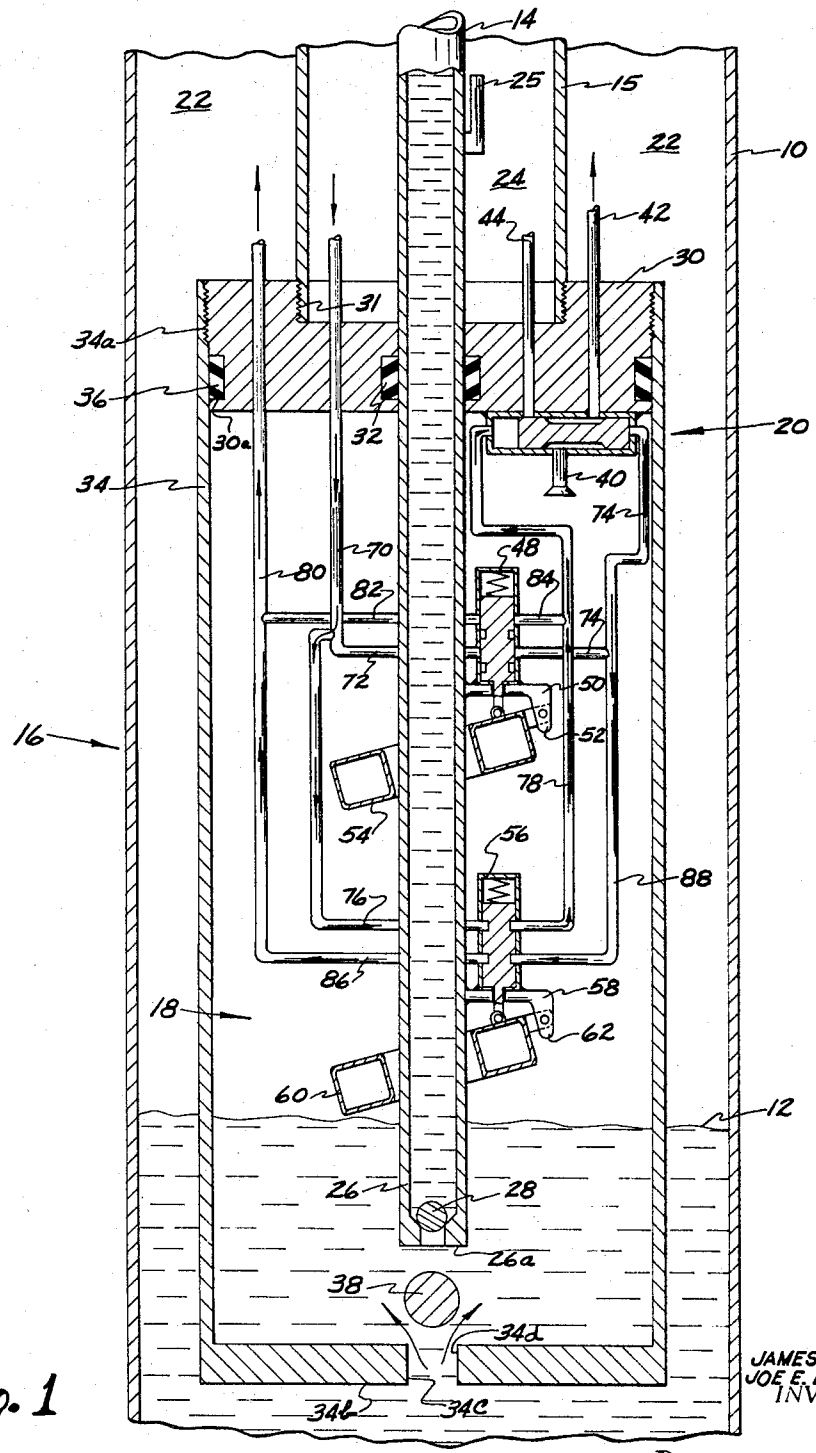


Fig. 1

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Gunn

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ET AL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 2

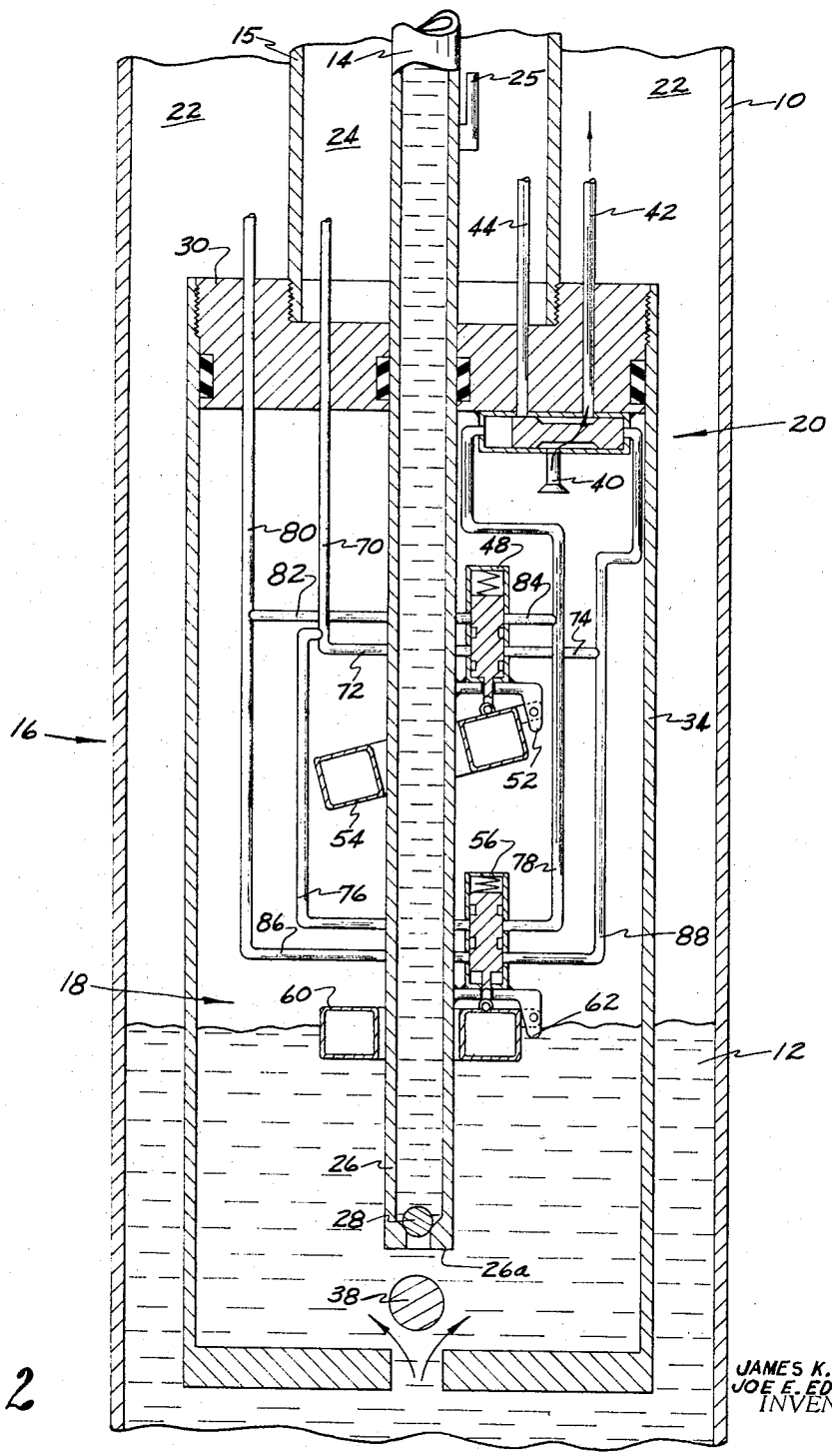


Fig. 2

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Gunn

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ETAL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 3

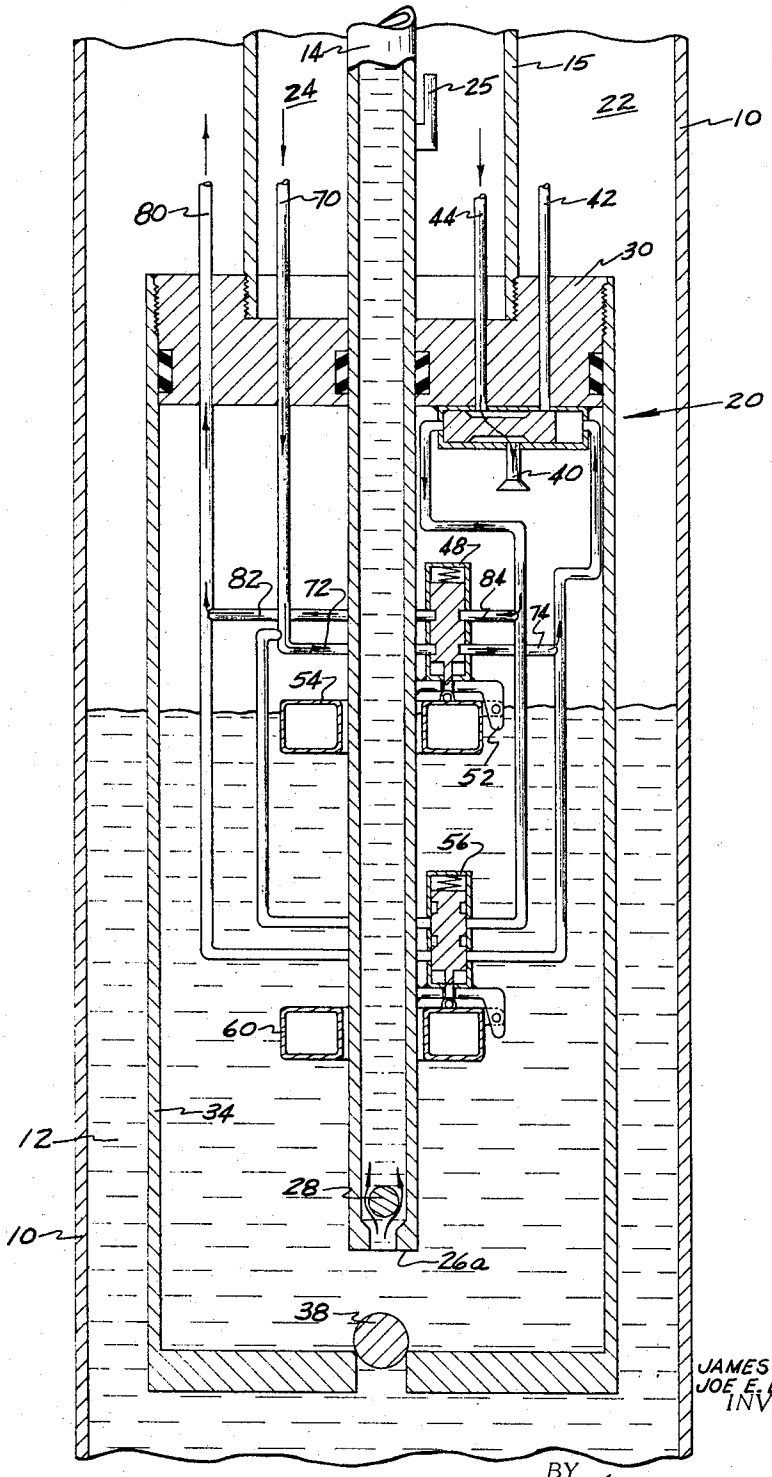


Fig. 3

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Gunn

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ET AL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 4

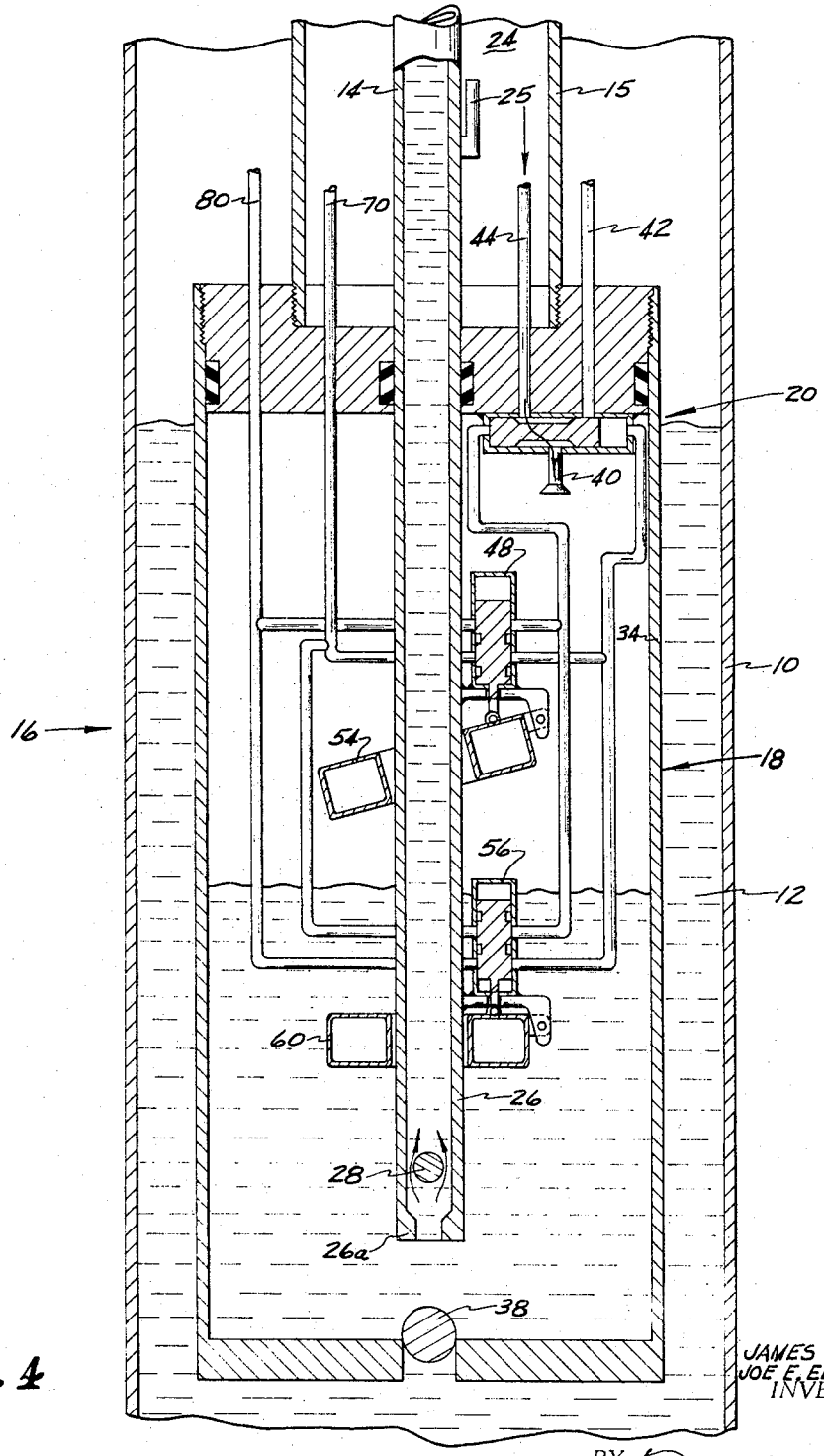


Fig. 4

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald James

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ETAL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 5

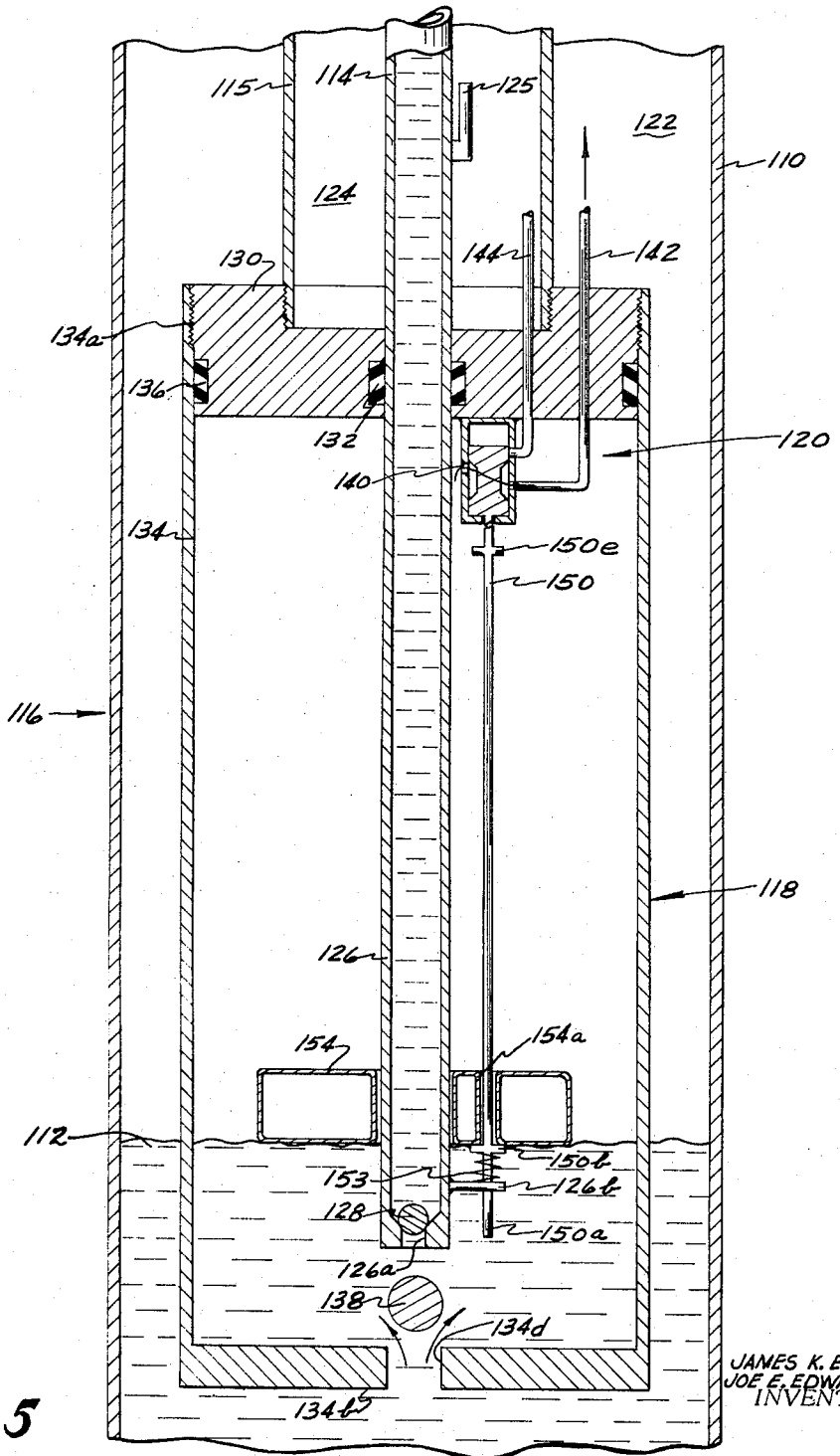


Fig. 5

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Gunn

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ETAL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 6

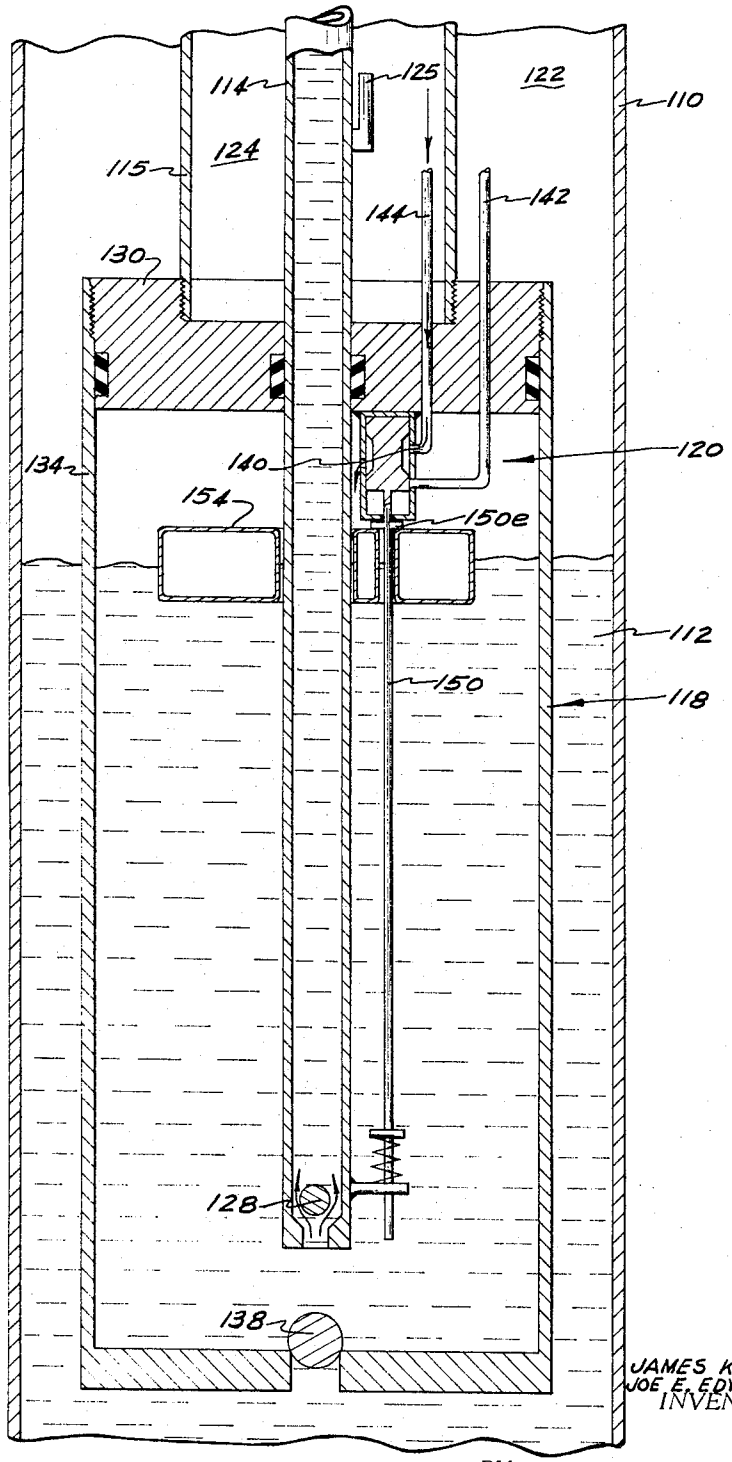


Fig. 6

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Gunn

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ETAL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 7

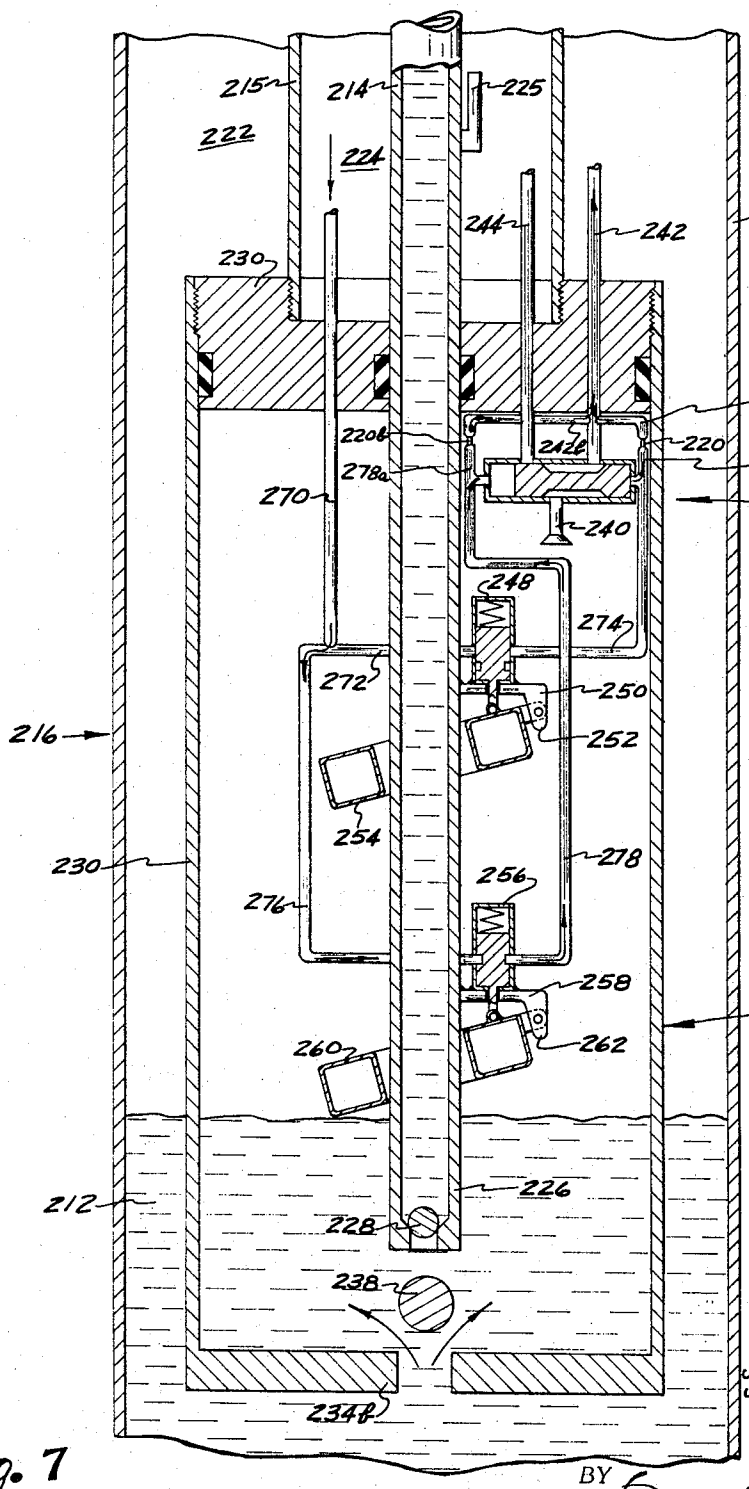


Fig. 7

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Dunn

ATTORNEY

Dec. 10, 1968 J. K. ELLIOTT ETAL 3,415,199

AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

Filed Oct. 13, 1966 8 Sheets-Sheet 8

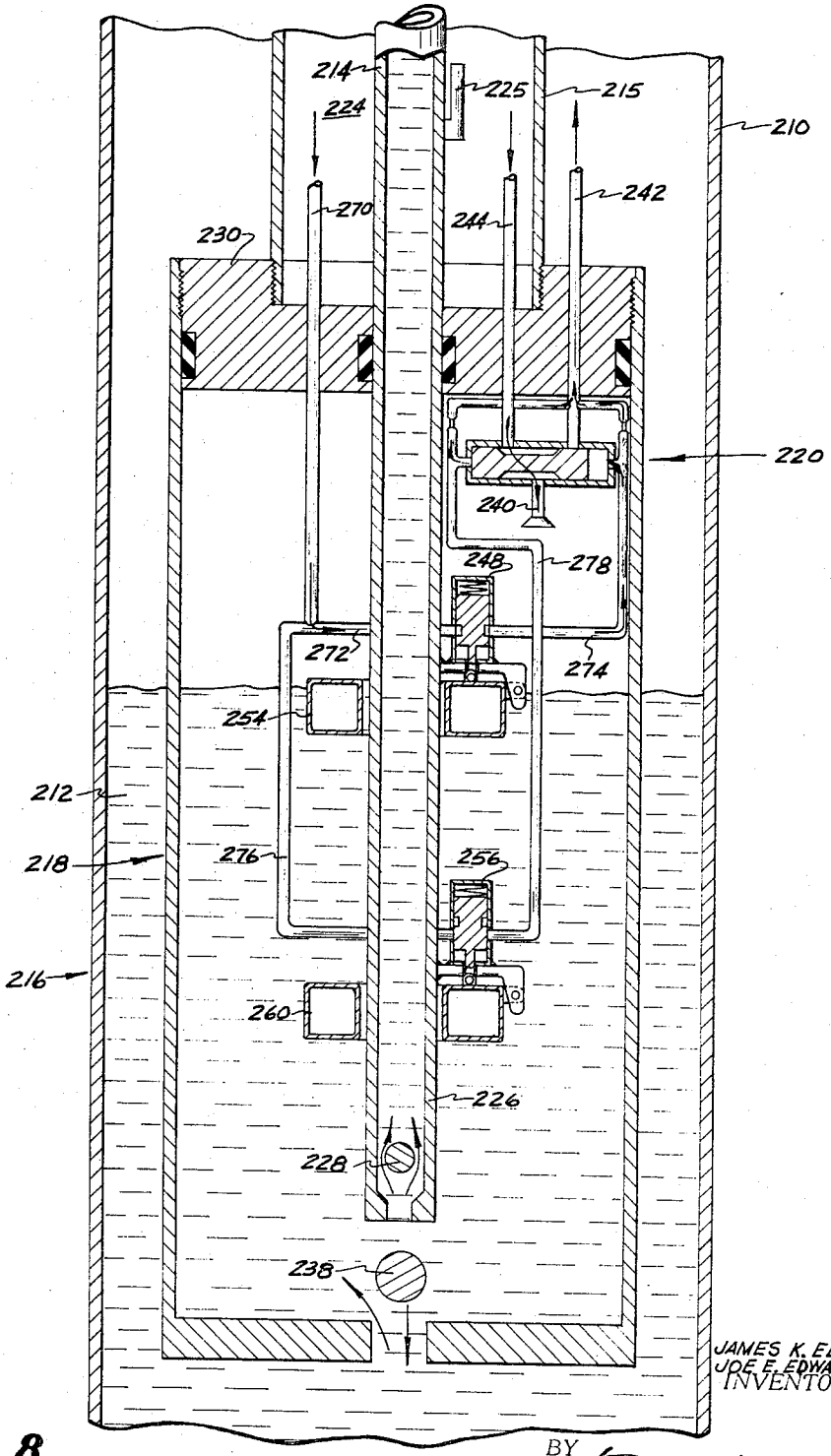


Fig. 8

JAMES K. ELLIOTT
JOE E. EDWARDS JR.
INVENTORS

BY Donald Gunn

ATTORNEY

United States Patent Office 3,415,199 Patented Dec. 10, 1968



3,415,199

# AUTOMATIC DOWNHOLE GAS LIFT APPARATUS

James K. Elliott and Joe E. Edwards, Jr., Houston, Tex., assignors to Macco Oil Tool Company, Inc., a corporation of Texas

Filed Oct. 13, 1966, Ser. No. 586,468
6 Claims. (Cl. 103—248)

## ABSTRACT OF THE DISCLOSURE

For use in oil wells produced by gas lift, apparatus including a chamber for accumulation of fluid from a producing formation, there being upper and lower float means in said chamber which control the admission of gas under pressure to said chamber when a suitable accumulation of liquid is attained therein for lifting same through a suitable tubing string to thereafter remove a predetermined quantity of liquid from said chamber.

The present invention relates to downhole gas lift apparatus, and more particularly relates to gas injection apparatus which accumulates liquids from a producing formation in a chamber with low back-pressure to obtain a predetermined and substantial volume whereupon gas is injected into the chamber to lift the liquid upwardly of the tubing string for recovery at the wellhead, it being noted that the apparatus functions sequentially automatically to deliver substantial volumes of liquid with each sequential operation.

One object of the present invention is to provide a new and improved gas lift valve for producing formations which utilizes a float in a closable chamber to sequentially gather liquid from the formation wherein the liquid accumulation and resultant movement of the float thereon initiates gas injection into the closed chamber wherein the liquid is lifted in the tubing string from the closed chamber, and the injection is automatically terminated on removing a substantial volume from the chamber.

A timely object of the present invention is to provide a new and improved gas lift valve apparatus which is float controlled to accumulate liquid prior to gas injection and subsequent lifting up the tubing string wherein the pressure injection first transfers a substantial portion of the liquid into the tubing string and then terminates operations automatically.

A related object of the present invention is to provide a new and improved gas lift apparatus which seals off the accumulation chamber during admission of high pressure gas to prevent forcing liquid back into the formation during lifting and wherein the chamber is maintained at a low back-pressure during liquid accumulation to permit accumulation of liquids as rapidly as possible from the producing formation.

A related object of the present invention is to provide a new and improved gas lifting apparatus including a closable chamber for delivering liquids into the tubing string wherein a surrounding annulus is provided for accumulating the continual production of the formation during delivery of the liquids trapped in the closable chamber.

Another object of the present invention is to provide a new and improved gas lift valve apparatus which vents gas diffused in the liquids to the casing annulus which is maintained at a low pressure during accumulation to prevent the back-pressure from impeding the flow of liquids from the producing formation.

Yet another object of the present invention is to provide a new and improved gas lift valve apparatus which initiates and terminates the gas lifting cycle of operation on its own command which is preferably related to the



accumulation of a substantial and predetermined volume of liquid.

Yet another object of the present invention is to utilize a three-way valve communicating with a closable chamber for accumulation of liquids from a producing formation wherein the three-way valve either communicates the interior of the closable chamber with the casing annulus which is maintained at a low back-pressure or the three-way valve injects gas under pressure into the closable chamber.

Other objects and advantages of the present invention will become more readily apparent from the consideration of the specifications and drawings wherein:

FIG. 1 is a sectional view of the gas lift valve apparatus of the present invention illustrating the initial condition of the invention;

FIG. 2 is a view similar to FIG. 1 illustrating an increase in liquid accumulation with three-way valve means exhausting or venting gas in the chamber into the casing annulus;

FIG. 3 is a view similar to FIG. 2 with the apparatus admitting gas under pressure into the closed chamber for lifting liquid in the tubing string:

FIG. 4 is a view similar to FIG. 3 partially illustrating completion of the step of lifting the liquid in the tubing string;

FIG. 5 is a sectional view of an additional embodiment of the present invention utilizing a float movable relative to a push rod connected with the valve means of the present invention;

FIG. 6 is similar to FIG. 5 but illustrates accumulation of liquid in the chamber to lift the float for injecting gas through the valve means of the present invention;

FIG. 7 is a sectional view of another alternative embodiment of the present invention similar to the structure shown in FIG. 1 provided with simplified valving; and

FIG. 8 is the embodiment shown in FIG. 7 illustrating accumulation of liquid in the chamber means to initiate gas injection.

Attention is first directed to FIG. 1 of the drawings which illustrates the preferred embodiment of the present invention. In FIG. 1, a well casing **10** is illustrated in sectional view and is intended to depict a casing extending through the earth's surface and into a producing formation. Liquid from the formation is admitted to the interior of the well casing **10** by perforations or other apparatus (not shown) for accumulation of the liquid **12**. A tubing string **14** for retrieving liquid from the means **16** of the present invention is located interiorly of a larger tubing string **15**. The gas lift valve apparatus **16** of the present invention incorporates a closable chamber **18** for receiving the liquid **12** therein prior to injection of high pressure gas. A valve means indicated generally at **20** is provided with three ports, one of the ports communicating with the closable chamber **18**, another port communicating with the casing annulus **22** and a third port communicating with the annulus **24** between the smaller tubing string **14** and the larger tubing **15**. The present invention vents gas from the closable chamber **18** into the casing annulus **22** during accumulation of liquid to maintain minimum back-pressure while the valve **20** is closed to the annulus **24**. Upon accumulation of sufficient liquid, the gas lift means **16** then operates valve **20** to inject gas under pressure from the tubing annulus **24** into the closable chamber **18** to lift the liquid **12** in the tubing string **14**. Lifting of liquid from the closable chamber **18** continues until the liquid falls to a predetermined level in the chamber means **18**, whereupon the valve **20** is closed off to the gas under pressure in the annulus **24**. The pressure interiorly of the closable chamber **18** is vented and reduced to enable recycling of the present invention by additional liquid accumulation so that the

device is self starting and self terminating and is adapted to function for an indefinite number of cycles when installed in a producing well.

Considering the invention more in detail, the sectional view of FIG. 1 illustrates the casing **10** installed in the producing well. In the first instance, it should be noted that the relative width of the apparatus of FIG. 1 has been exaggerated to enable illustration of all details of the apparatus. The tubing strings **14** and **15** are preferably concentric of one another and are preferably concentric of the well casing **10** although the arrangement may be altered within the scope of the present invention. Tubing hangers are known in the art for positioning the tubing strings **14** and **15** in the casing **10**. The tubing string **14** is provided with a conventional gas lift valve **25** which is symbolically represented in the drawings of the present invention and which is intended to provide additional means for lifting the liquid to the wellhead in cooperation with the present invention as needed. Since gas lift valve **25** is only cooperative with the valve of the present invention and since it further does not relate to operations of the gas lift valve **16** of the present invention, it can be represented symbolically as shown in the drawings.

The tubing string **14** is somewhat longer than the tubing string **15**, as shown in FIG. 1. The lower end of the tubing string **14**, denoted as a tailpipe **26**, extends almost to the lower end of the closable chamber **18**, and is provided with an open end for receiving liquid therein. The opening of the tailpipe **26** is shaped at **26***a* to provide a valve seat for a standing valve including the spherical member **28**. The standing valve **28** admits liquid to the tubing string **14** by pressure differential between pressure in the tubing string **14** and the chamber **18**. The check valve **28** closes to reverse flow whereby a standing column of fluid is maintained in the tubing string **14**.

The tubing string **15** suspends the present invention **16** from a threaded adaptor **30**. The adaptor **30** is preferably a relatively large diameter circular member having an internally threaded shoulder for engaging the threads **31** at the lower end of the tubing string **15**. The adaptor **30** extends inwardly of the tubing string **15** to cap off the lower end of the tubing **15** and seal off the tubing string **15**. A seal member **32** of conventional material is located at the central opening of the adaptor **30** as a pressure seal to maintaining a leakproof connection between the adaptor **30** and the tubing string **14**.

The outer edge of the adaptor **30** is threaded for connection to a cylindrical member **34** which defines the chamber means **18** proper. Cylindrical member **34** is threaded at **34***a* for joinder to the adaptor **30**. In addition, a seal member **36** is received in a groove **30***a* facing the internal surface of the means **34** for sealing the threaded connection of the cylindrical member **34** and the adaptor **30**.

The lower end of the closable chamber means **18** is of unitary construction as indicated at **34***b*. The lower closure member **34***b* has a centrally located opening **34***c* which extends upwardly to a valve seat **34***d* receiving a valve member **38** whereby liquid flow from the closable chamber **18** is prevented. As shown in FIG. 1, the inflow of liquid accumulated in the casing **10** opens the standing valve **38** to maintain an equal head of liquid in the chamber means **18**. As will be discussed with reference to FIGS. 2 and 3 and 4, the valve **38** prevents reverse flow from chamber **18** on injection of gas under high pressure which forces the liquid inwardly in the tubing string **14** through the valve **28**.

As previously noted, the large tubing string **15** conveys gas under pressure to the gas lift means **16** of the present invention. By way of example, the pressure in the large tubing **15** can be in the range of 400–1,000 p.s.i. The casing annulus **22** is preferably maintained at a relatively low pressure to provide a minimum back-pressure as will be noted. By way of example, the casing annulus **22** can be essentially open so that the back-pressure acting on the means **16** is not significant.

Three-way valve means **20** are supported from the lower face of the adaptor **30**. The valve means **20** is preferably a spool valve including a central port **40** opening into the chamber means **18**. Additional ports of the valve **20** include a chamber venting port **42**, it being noted that the port extends through the adaptor **30** by means of appropriate tubing or the like. Likewise, the valve port **44** communicates gas under pressure in the annulus **24** with the chamber **18** through a conduit extending through the adaptor **30**. It will be noted that the spool of the valve **20** is arranged to enable fluid flow between either port **42** or **44** with the chamber port **40**.

The tailpipe **26** is utilized in the preferred embodiment to support an upper control valve **48**. Control valve **48**, mounted on an appropriate bracket **50**, is preferably a spring return, push rod operated spool valve with connections to the three-way valve means **20** as will be described.

In addition, the support member **50**, which is joined to the tailpipe **26**, includes a pivot arm **52** which is connected with a ring-shaped float means **54**. The float **54** encircles the tailpipe **26** which is a means of guidance and direction to movements of the float **54**. The float **54** responds to the rising level of liquid **12** in the chamber means **18** whereby the float is moved upwardly from the canted position shown in FIG. 1 to operate the control valve **48**. This will be described in greater detail when discussing the present invention.

The float **54** is joined by way of a tab with the push rod of the spool valve **48** for movement of the spool. As shown in FIG. 1, full extension of the push rod to its limit is associated with the closed condition of the valve **48**.

An additional control valve **56** is also suspended at a predetermined level in the chamber means **18** by an appropriate support member **58** joined to the tailpipe **26** by welding or other appropriate means. The valve **56** is similar to the valve **48** and is a spring return, push rod operated spool valve which is actuated by a float means **60**. Float means **60** is a hollow, ring-shaped member having a protruding tab or ear pivotally joined with a pivot mounting arm **62** carried on the lower side of the support member **58**. In addition, an eyelet connector is provided for connection to the push rod of the spool valve **56**, it being noted that the arrangement of the pivot and the push rod of the spool valve communicate upward movement of the float means **60** to the spool for controlling fluid flow through the valve **56**. It should be noted generally that the spool valve **56** and associated float **69** are similar or even identical to the apparatus **48** and **54** above noted. The float **54** is joined by way of a tab with the push rod of the spool valve **48** for movement of the spool. As shown in FIG. 1, full extension of the push rod to its limit is associated with the closed condition of the valve **48**. As shown in FIG. 1, full extension of the push rod to its limit is associated with the open condition of the valve **56**.

A significant difference in the two control valves and floats is the relative location in the chamber **18**. In this regard, the subsequent discussion of the relationship of the location of the floats **54** and **60** will show the present invention pumps a predetermined volume of liquid up the tubing string **14**. Pressure fluid for valve means **20** regulated by the control valves **48** and **56** is taken from the large tubing annulus **24** by means of a feed-through pipe **70**. The tubing **70** has a branch **72** which communicates with the valve **48** which, when open, continues flow from the conduit **72** into the conduit **74**. In addition, conduit **70** also communicates fluid to a branch **76** extending to control valve **56** which, when open, continues fluid flow to a control conduit **78**. Control tubing **78** continues to the left hand end of the valve means **20** to move

the spool of the valve to a position determined by fluid flow in the control line **78**.

An exhaust system is also provided through the control valves **48** and **56** for pressure from the spool valve **20** when the spool is moved to the opposite end of the valve chamber. Specifically, an exhaust line **80** communicates through the adaptor **30** and into the casing annulus **22** for venting pressure fluid from the low pressure side of the valve means **20**. Exhaust line **80** includes a branch **82** which communicates through the control valve **48**, which, when open, communicates by way of an additional line **84** to the previously noted conduit **78**. In addition, a branch line **86** exhausts pressure fluid through the valve **56** which, when open, communicates the line **86** with an additional conduit **88**. Conduit **88** is connected with the previously noted conduit **74**.

The control valves **48** and **56** both provide control pressure to the valve means **20** and an exhaust route from the opposite end of the valve **20** to permit the valve spool in the valve **20** to move freely against minimum back-pressure. By way of example, the illustrated position of the valves shown in FIG. 1 communicates fluid under pressure through the line **76**, control valve **56**, line **78** and into the left hand end of the valve means **20**. Movement of the spool from the left hand end towards the right hand end expels gas through the conduit **74**, conduit **88**, control valve **56**, branch **86** and exhaust line **80** into the casing annulus **22**. Flow of the pressure through the inlet conduit **70** and the exhausting of pressure fluid through the line **80** is indicated in FIG. 1 by the arrows interposed on the fluid lines.

The sequence of operations in the gas lift valve **16** of the present invention is illustrated in FIGS. 1 through 4, inclusive. The sequential illustrations show the initial filling of the chamber means **18** wherein the liquid **12** flows through the standing valve **38**. The liquid level of FIG. 1 should be contrasted with the level shown in FIG. 2 wherein the float **60** has been lifted by its bouyancy to operate the control valve **56**. Specifically, the spool of the valve **56** terminates flow through the control line **76** to the valve means **20**. It having been previously noted that flow through the lines **76** and **78** moves the spool of the valve means **20** to the right, the interruption of flow through the inlet lines **76** maintains the valve spool in the last position. Also, the exhaust route through conduits **86** and **88** is interrupted whereby the valve means **20** is maintained in the initially provided position.

FIG. 2 illustrates operation of the valve means **20** to vent gas from the chamber means **18**. Liquid accumulation in the chamber means **18** drives gas from the chamber through the port **40** and outwardly through port **42** into the casing annulus **22**. Moreover, the liquid itself is susceptible to surrender of diffused gas which further tends to increase the pressure in the chamber means **18**. Therefore, as a means of venting excessive back-pressure, the vent means is provided communicating the chamber means **18** with the casing annulus **22** whereby rapid liquid accumulation is materially expedited. As represented by the arrow in FIG. 2, gas is vented through the port means **40** and the tubing **42**.

It will be appreciated that the accumulation of liquid indicated in FIG. 2 fully submerges the float **60** and buoys upwardly the float means **54**. This is shown in FIG. 3 wherein the liquid **12** is accumulated to the level of the float **54**. As the float **54** is carried upwardly on the surface of the liquid, it pivots on the pivot arm **52** and moves the push rod connected with the spool of the valve **48** upwardly. Upward movement of the spool opens passages of communications through the valve **48** wherein the pressure in line **72** is communicated to the line **74** and the pressure exhaust line **84** is communicated with the line **82**. The flow arrows of FIG. 3 represent fluid flow from the pressure inlet line **70** through the valve **48** and into the right hand end of the valve **20** resulting in movement of the spool to the left. Leftward movement of the spool expels fluid from the left hand end of the valve **20** through the conduit **84** and outwardly to the vent line **80**. Movement of the spool to the left hand end of the valve **20** communicates the chamber port **40** with the gas injection port **44**. Admission of gas under high pressure to the chamber means **18** on opening the control valve **48** initiates lifting of liquid from the chamber means **18** whereby liquid is forced into the upstanding tubing string **14**.

It will be appreciated that the process of lifting liquid from the chamber means **18** and upwardly of the tubing string **14** is dependent on continued admission of gas under pressure from the tubing annulus **24**. In this regard, attention is referred to FIG. 4 which illustrates partial completion of lifting of liquid from the chamber means **18**. It will be noted that the liquid level illustrated in FIG. 4 is below the level of the float member **54** whereby the float has dropped downwardly to a condition similar to that shown in FIG. 1. Downward movement of the float **54** closes the valve **48**. It will be noted further that both control valves **48** and **56** are closed to prevent any fluid flow in the control lines to sustain the valve means **20** in the illustrated condition. As the liquid level drops below the valve **48** and its associated float **54** and the valve **48** is closed by the float, valve means **20** continues to inject gas into the chamber means **18** without interruption whereby the liquid in the chamber means **18** is expelled upwardly of the tubing string **14**. This is the condition illustrated in FIG. 4 and it will be appreciated that the liquid level drops from that illustrated in FIG. 3 to a point lowering the float **60** in the chamber to reopen control valve **56**. This completes one cycle of operation of the gas lift apparatus of the present invention.

It should be noted that in the transfer of liquid from the chamber means **18** through the standing valve **28** and into the tubing string **14** that the device repetitively delivers approximately the same volume with each operation. Moreover, the flow of liquid in the tubing string **14** to the conventional gas lift valve **25** enables final recovery of the liquid and delivery to the wellhead.

Attention is next directed to FIGS. 5 and 6 which illustrate an alternative embodiment of the present invention indicated by the numeral **116**. The structure shown in FIG. 5 is incorporated with a casing string **110** which surrounds a smaller tubing string **114** placed within a slightly larger tubing string **115**. The casing string **110** encloses a casing annulus **122** while a smaller annulus **124** is provided through which gas under pressure is communicated. Typically, gas in the range of 400 to 1,000 p.s.i. can be provided for operation of the device of the present invention.

The gas lift apparatus **116** of the present invention is somewhat similar to the structure shown in FIG. 1 and to this extent, similar components bear reference numerals increased by 100. Thus, it will be noted that the adaptor plate **130** is joined to the cylindrical member **134** which includes a bottom member **134*b*** for defining the chamber means **118**. In addition, a standing valve **138** is provided in the lower portions of the chamber means **118** for admitting liquid to the chamber from the producing formation. Likewise, a tailpipe **126**, an extension of the small tubing string **114**. includes a standing valve **128** for admitting liquid from the chamber means into the tailpipe **126**. Other similarities will be noted from an examination of FIGS. 5 and 6 and the previously described views.

Of particular interest to the structure shown in FIG. 5 is the valve means **120** which is operated by movements of a connective rod **150** as opposed to the operation of the valve **20** (see FIG. 1) which is opened and closed by control valves **48** and **56**. The float member **154** is provided with a walled opening through the buoyant structure of the float whereby the control rod **150** restricts the motion of the float member **154**. A gusset **126*b*** is welded to the exterior of the tailpipe and has an upwardly facing hole or guide for receiving the lower end **150*a*** of the control

rod. In addition, an enlargement **150***b* is located on the control rod **150** near the lower end and a similar enlargement **150***e* is carried on the control rod immediately below the valve means **120**.

The upward and downward movements of the float **154** borne on the surface of the liquid **112** carry the float to the extremes of movement permitted by the enlargements **150***b* and **150***e*. On the downward movement of the float **154**, the enlargement **150***b* is engaged as shown in FIG. 5 whereby the control rod **150** is moved downwardly against the resilient member **153**. The downward movement of the control rod **150** moves the spool in the valve means **120** to provide a fluid path of communications including the chamber port **140** of the means **120** and the outlet port **142** communicating with the casing annulus **122**. It was previously noted that the casing is maintained at a relatively low pressure whereby gas under pressure is vented from the chamber means **118** into the casing annulus **122** against minimum back-pressure. As previously noted, the port **144** provides an inlet from the annulus **124** through the valve means **120** into the chamber means **118** to inject gas under pressure. As has been previously noted, the liquid **112** accumulated in the chamber means sometimes carries dissolved gas which tends to bubble off at reduced pressures to fill the chamber with gas. Also, the addition of liquid to the chamber means **118** requires the exhaustion of air from the chamber. It should be further noted that the liquid **112** is admitted to the chamber means **118** through the standing valve **138**. The accumulation of liquid lifts the float **154** upwardly along the control rod **150** without changing the position of the valve means **120** since the valve means **120** and the control rod are sufficiently inert to maintain the control rod in the last attained position until the float means **154** engages one of the enlargements.

FIG. 6 illustrates the float means **154** lifted by the liquid **112** to contact the enlargement **150***e* on the control rod **150**. The movement of the control rod upwardly moves the spool in the valve means **120** whereby fluid flow through the valve means is altered. Specifically, the arrows in FIG. 6 indicate the flow of gas under pressure from the tubing annulus **124** through the port **144** and the chamber port **140**. Since the chamber means **118** is a closable chamber by operation of the standing valve **138**, the admission of gas under high pressure lifts the liquid from the chamber means **118** in the tubing string **114**. The standing valve **128** in the tubing string is shown in the open position whereby the liquid flows upwardly into the tubing string **114**. The liquid is evacuated from the chamber means **118** by gas injection until the float member **154** is moved from the position shown in FIG. 6 at an upper, predetermined level in the chamber means to a lower level (see FIG. 5). At this point, the valve member **120** is reoperated to return the valve to the condition previously shown in FIG. 5. Thereupon, the apparatus can recycle to deliver another volume of liquid.

Attention is next directed to FIGS. 7 and 8 which illustrate a third alternative embodiment of the present invention indicated by the numeral **216**. The structures shown in FIGS. 7 and 8 are arranged in similar installations to those previously shown. For instance, the well casing **210** surrounds the chamber means **218** carried below the adaptor **230** which is connected to the tubing strings **214** and **215**. Other portions of the structure are identified by the numerals found in FIG. 1 increased by 200.

The structure **216** uses control valves **248** and **256** which are similar in function and arrangement to the valves **48** and **56** shown in FIGS. 1 through 4 inclusive. The provision of pressure fluid to the valves **248** and **256** for operation of the valve means **220** is distinctive as will be noted hereinbelow. The injection gas provided in the tubing annulus **224** is communicated through the conduit **270** to either of the valves **248** or **256** through branches **272** or **276**. The valves communicate with branches **274** and **278** connected to opposite ends of the valve means **200**. The valve means **220** is similar to the valve means **20** in providing a spool operated, three-way valve which has a chamber port **240**, a vent port **242** and a port **244** communicating with gas under pressure in the tubing annulus **224**. However, the distinctions of the structure shown in FIGS 7 and 8 lie, in part, in the provision of bleed chokes **220***a* and **220***b*. The bleed choke **220***a* is communicated with the right hand end of the spool valve by the conduit **274***a* and the restricted flow of gas then passes through the branch **242***a* to the vent line **242**. Likewise, conduit **278***a* flows pressure fluid through the choke **220***b* which connects with the branch line **242***b* and thence to the vent line **242**.

In operation of the valve **220**, it will be recognized that the illustrated position in FIG. 7 is achieved by admitting gas under pressure through the gas line **278** into the left hand end of the valve means **220**. Gas is expelled from the right hand end by movement of the spool. The fluid line is exhausted through the branch **274***a* to the choke **220***a* and is eventually vented through the line **242**. It will be appreciated that the flow of gas into the left hand end of the valve means **220** is accompanied by a continual leakage through the choke **220***b* and the vent means **242**. However, in view of the large volume of gas provided under pressure in the tubing annulus **224**, the small leakage through the bleed choke is no burden to the gas injection system.

Considering the embodiment **216** as a whole, the structure is similar to the embodiment **16** previously discussed. Specifically, the control valves **248** and **256** are operated by the float members **254** and **260**, respectively. The lower float **260** opens control valve **256** to provide control pressure to the valve means **220** for positioning the spool at the right hand end of the valve as illustrated in FIG. 7. When the liquid rises to the level of the float **260** and closes the valve **256**, the absence of flow through conduit or line **278** leaves the spool of the valve in the condition previously attained. This provides a vent for gas in the chamber means **218** into the casing annulus **222**. This is similar to the process described for the embodiment **16**.

The accumulation of liquid in the chamber means **218** to the level of the float **254** is illustrated in FIG. 8. The buoyant float **254** is lifted to open the valve **248**, and control fluid is admitted through the line **272** into line **274** for moving the spool of the valve means **220** to the left hand end. Movement of the spool admits gas from the tubing annulus **224** through the port **244** and the port **240** into the chamber **218**. Injection of gas under pressure drives the liquid from the chamber means **218** upwardly through the tailpipe **226** whereby the liquid is lifted in the small tubing string **214** towards the wellhead. As the liquid level drops in the chamber means **218**, the valve **248** is eventually closed as the float member **254** drops to its original position but the valve **220** is maintained in the illustrated position of FIG. 8 until the valve **256** is opened. Thereupon, the cycle of operation is repeated wherein the liquid is again accumulated to the level illustrated in FIG. 8. As a consequence of the above sequence, the gas lift valve means **216** of the present invention cycles to repetitively deliver liquid through the tubing string **214**.

It should be noted that the standing valve **238** closes when gas under pressure is admitted to the chamber means **218**. This is particularly advantageous when using the gas lift apparatus **216** with producing formations with low internal pressures or inadequate formation drive against high back-pressure. Moreover, the devices of the present invention are adapted for use with conventional gas lift valves as previously noted where the additional gas lift valves are used to complete lifting of the liquid to the wellhead.

The description of the above noted embodiments is directed to three embodiments of the present invention;

however, the scope of the present invention is to be determined by the appended claims.

What is claimed is:

1. A device for lifting liquid in a well using gas under pressure supplied through a first tubing string comprising:

(a) chamber means adapted to be connected to a second tubing string for accumulating liquid therein from a formation;

(b) three-way valve means communicating said chamber means with the first tubing string for admitting gas under pressure to said chamber means;

(c) said valve means alternately communicating said chamber means with the well string maintained at a relatively low back-pressure for relieving pressure in said chamber means on accumulation of liquid therein;

(d) a first valve means;

(e) a second valve means;

(f) supply line means providing gas under pressure to each of said first and second valve means;

(g) conduit means extending from said first valve means to said three-way valve means to operate same to vent gas in said chamber means into the well string;

(h) additional conduit means extending from said second valve means to said three-way valve means for operating said three-way valve means to admit gas under pressure to said chamber means for lifting liquid in said chamber means in the second tubing string;

(i) float means opening said first valve means to supply gas through said supply line means and said conduit means to operate said three-way valve means to vent gas in said chamber means into the well string;

(j) additional float means opening said second valve means to supply gas through said supply line means and said additional conduit means to operate said three-way valve means to admit gas under pressure to said chamber means for lifting liquid in said chamber means in the second tubing string; and

(k) said additional float means being located in said chamber means above said float means to define the volume of liquid lifted from said chamber means.

2. The apparatus of claim 1 wherein said three-way valve means is a spool valve.

3. The apparatus of claim 2 wherein gas under pressure is applied to one end of said spool valve, and an additional conduit means extends from the opposite end thereof to one of said valve means for exhausting gas from the opposite end of said spool valve.

4. The apparatus of claim 2 wherein bleed port means are communicated with both ends of said spool valve and the well string for exhausting gas from said spool valve.

5. A device for lifting liquid up a tubing string in a well with gas under pressure supplied to the device, comprising:

(a) a chamber means for accumulating liquid in the well from a formation, said means including a connection with a tubing string in the well;

(b) first valve means having two positions, one being an open position for communicating gas under pressure supplied through the well string with said chamber means to lift liquid from said chamber means and up the tubing string;

(c) said first valve means having a closed position preventing admission of gas under pressure to said chamber means to permit accumulation of liquid in said chamber means at reduced pressures therein;

(d) a first float means located at a lower level in said chamber means;

(e) a second valve means operated by said first float means for communicating control pressure fluid to said first valve means for maintaining same in a position closing said chamber means to gas under pressure;

(f) upper float means located at the predetermined level in said chamber means;

(g) third valve means operated by said upper float means for communicating control pressure fluid to said first valve means for maintaining same in a position admitting gas under pressure to said chamber for lifting liquid from said chamber means; and,

(h) said lower and upper float means responding to liquid level in said chamber means and operating said second and third valve means, respectively, to open said first valve means for admitting gas under pressure to said chamber means on accumulation of liquid to said upper float means, and also closing said first valve means after the gas under pressure has lifted liquid from said chamber means to act on said lower float means.

6. A device for lifting liquid up a tubing string in a well with gas under pressure supplied to the device, comprising:

(a) a chamber means for accumulating liquid in the well from a formation, said means including a connection with a tubing string in the well;

(b) first valve means having two positions, one being an open position for communicating gas under pressure supplied through the well string with said chamber means to lift liquid from said chamber means and up the tubing string;

(c) said first valve means having a closed position preventing admission of gas under pressure to said chamber means to permit accumulation of liquid in said chamber means at reduced pressures therein;

(d) a first float means located at a lower level in said chamber means;

(e) a second valve means operated by said first float means for communicating control pressure fluid to said first valve means for maintaining same in a position venting said chamber means into the well string to permit liquid to accumulate therein against reduced back pressure;

(f) second float means located at the predetermined level in said chamber means;

(g) third valve means operated by said second float means for communicating control pressure fluid to said first valve means for maintaining same in a position closing said chamber means to communication with the well string; and,

(h) said lower and upper float means responding to liquid level in said chamber means and operating said second and third valve means, respectively, to open said first valve means for admitting gas under pressure to said chamber means on accumulation of liquid to said upper float means, and also closing said first valve means after the gas under pressure has lifted liquid from said chamber means to act on said lower float means.

**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 122,332 | 1/1872 | Roe | 103—248 |
| 2,177,517 | 10/1939 | Cuthrell | 103—248 X |
| 2,207,318 | 7/1940 | Gollner | 103—234 X |
| 2,223,417 | 12/1940 | Havens | 103—248 |
| 2,730,961 | 1/1956 | Yeomans | 103—248 X |
| 2,764,104 | 9/1956 | Yeomans | 103—248 |
| 3,302,586 | 2/1967 | Brugnoli | 103—232 |

FRED C. MATTERN, JR., *Primary Examiner.*

W. J. KRAUSS, *Assistant Examiner.*

U.S. Cl. X.R.

103—232