July 13, 1965 W. C. CARLISLE ETAL 3,194,175

FLUID-OPERATED GAS LIFT APPARATUS

Filed Oct. 30, 1963 2 Sheets-Sheet 1

Fig. 1

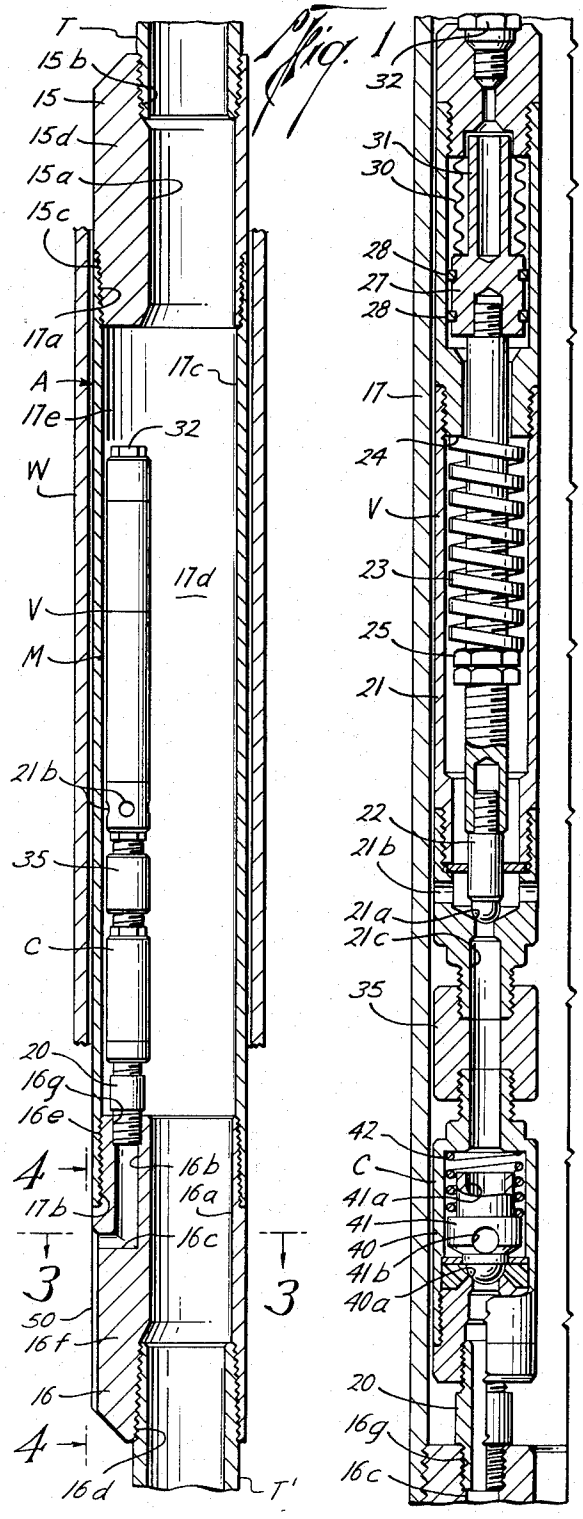


Fig. 2

Fig. 3

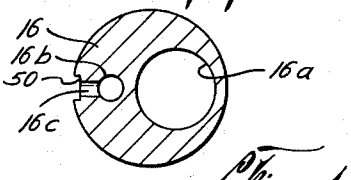


Fig. 4

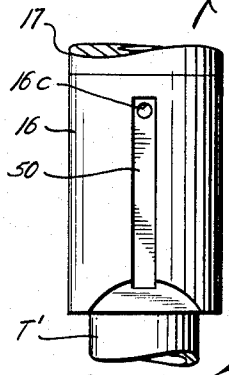


Fig. 5

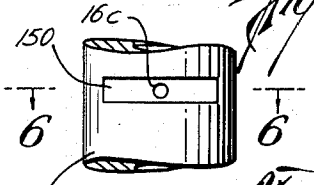
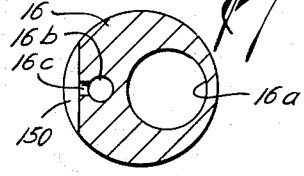


Fig. 6



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Fig. 7

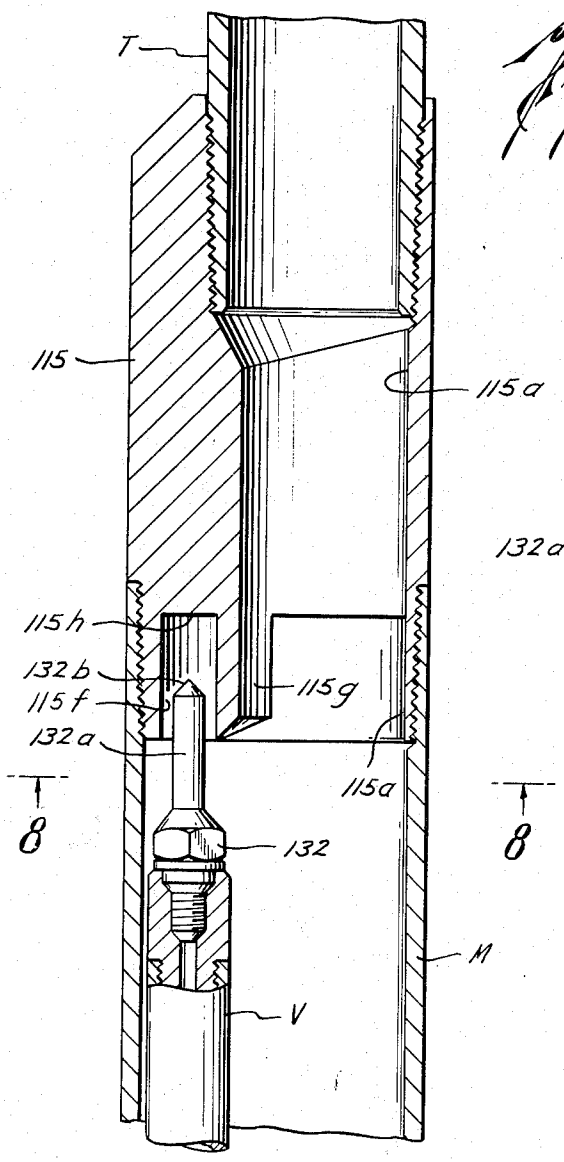
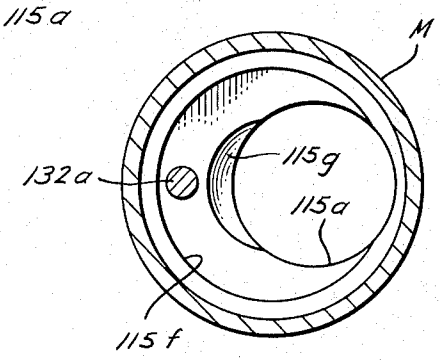


Fig. 8



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FLUID-OPERATED GAS LIFT APPARATUS

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Filed Oct. 30, 1963, Ser. No. 320,953
3 Claims. (Cl. 103—232)

This application is a continuation-in-part of our copending U.S. patent application, Serial No. 211,701, filed July 23, 1962, now abandoned.

This invention relates to new and useful improvements in fluid-operated gas lift apparatus.

In drilling practices today, more and more emphasis is being placed on slim hole oil wells and multiple-completion oil wells having a plurality of tubing strings of small diameter. Slim hole casing may be as small as two and one-half inches nominal pipe drift size (2.347 inches) in diameter. Although it has been desirable to produce oil in such slim lines or multiple-lines by gas lift, many problems have been heretofore encountered due to the extreme space limitations and the high temperatures in the wells. For example, a flexible sleeve valve made of rubber or other elastic material has been used for admitting gas from the casing annulus to the interior of the tubing, but such sleeve valve is subject to hardening and deterioration at well temperatures above about 250 F. Therefore, such sleeve valves, although theoretically workable, are not practical in actual well conditions.

Attempts have also been made to mount other types of gas lift valves in the tubing strings for slim holes and multiple-line production, but such prior constructions have all obstructed the bore of the tubing string so as to prevent well tools from passing below the upper one of such valves.

It is an object of this invention to provide a new and improved gas lift apparatus which is adapted to be mounted in well tubing or pipe for use in slim hole casing while still providing a full open bore so that well tools may pass below such gas lift apparatus for performing various well operations such as taking bottom hole pressure readings, performing fishing jobs and conducting various types of wire line work.

An important object of this invention is to provide a new and improved gas lift apparatus for use in slim holes and multiple-completion wells, wherein such apparatus is substantially unaffected by the temperatures encountered in the wells.

Another object of this invention is to provide a new and improved gas lift valve apparatus wherein a fluid-operated gas lift valve is threaded or otherwise secured at its lower end in an offset of an eccentric mandrel with the upper end projecting into a protective recess or pocket of the mandrel, such valve being secured in the mandrel prior to positioning same in a well.

A further object of this invention is to provide a new and improved gas lift valve apparatus having a gas lift valve mounted in a tubular mandrel with one end thereof in communication with the area externally of said mandrel for introducing gas into the mandrel upon an actuation of the valve by a head of liquid in the mandrel and the tubing string therewith.

Still another object of this invention is to provide a new and improved gas lift apparatus having a gas lift valve mounted in a mandrel with fluid passage means establishing fluid communication from the exterior of the mandrel through the valve to the interior of the mandrel, and wherein the external surface of the mandrel has a groove or grooves merging with said fluid passage means to permit gas flow to said fluid passage means from the exterior of said mandrel even though the external surface of the mandrel is in contact with the inside of a well casing or 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 vertical sectional view, partly in elevation, illustrating the construction of this invention;

FIG. 2 is a partial view, partly in section and partly in elevation, illustrating the details of the preferred form of the fluid-operated gas lift valve and check valve shown in the apparatus of FIG. 1;

FIG. 3 is a cross-sectional view taken on line 3—3 of FIG. 1;

FIG. 4 is a view taken in the direction of lines 4—4 of FIG. 1 showing one form of an external groove on the mandrel of the apparatus of this invention.

FIG. 5 is a partial view illustrating another type of external groove on the mandrel of the apparatus of this invention;

FIG. 6 is a cross-sectional view taken on lines 6—6 of FIG. 5 to further illustrate the construction of the modified form shown in FIG. 5;

FIG. 7 is a fragmentary view, partly in section and partly in elevation, showing a modified form of the invention; and

FIG. 8 is a cross-sectional view taken on line 8—8 of FIG. 7 to further illustrate the modified form of FIG. 7.

In the drawings, the letter A designates generally the apparatus of this invention which is adapted to be connected between sections T and T' of a tubing string or pipe. Such tubing string or pipe with the apparatus A connected therein is normally used in a well casing W, a portion of which is shown in FIG. 1, of the type and size used in slim or small diameter hole production. Briefly, the apparatus A of this invention includes an eccentrically shaped mandrel M which is constructed for receiving a gas lift valve V in an offset portion of the bore of such mandrel M. As will be explained more in detail, the mandrel M is so constructed and the valve V is so located within the bore of the mandrel M as to provide an unobstructed main portion of the bore of the mandrel M which is in alignment with the bore of the tubing string formed by the tubing string sections T and T'. The valve V is adapted to be actuated by a head of liquid in the mandrel M and the tubing string so as to open same for admitting gas from the casing annulus to the interior of the mandrel M for gas lift operations.

Considering the invention more in detail, the mandrel M includes an upper head 15 and a lower head 16 which are interconnected with an intermediate tubular body 17. The upper head 15 has a longitudinal passage 15*a* formed therethrough which is of substantially the same diameter as the internal diameter of the tubing section T thereabove and also the tubing section T' at the lower end of the apparatus A. Such longitudinal opening 15*a* is in alignment with the tubing sections T and T'.

The lower head 16 has a similar longitudinal opening 16*a* therethrough which is also of substantially the same diameter as the sections T and T' of the tubing string and is in alignment therewith and also with the longitudinal opening or passage 15*a*. The cross-sectional appearance of the heads 15 and 16 is identical and is illustrated in connection with the head 16 in FIG. 3, except that the head 16 has a fluid-passage 16*b* extending longitudinally and connecting with another fluid-passage 16*c*, the purpose of which will be explained hereinafter.

The upper head 15 has internal threads 15*b* thereabove to be connected with external threads on the lower end of the tubing string section T. Likewise, the lower head 16

has internal threads 16*d* which are connected with external threads on the upper end of the tubing section T'.

The intermediate tubular body 17 is preferably formed separately from the heads 15 and 16 as shown in FIG. 1, but it will be appreciated that such body 17 may be integral with the heads 15 and 16. As shown, the body 17 has upper internal threads 17*a* which are adapted to engage with lower external threads 15*c* upon the upper head 15. The body 17 also has lower internal threads 17*b* which are adapted to make a threaded connection with external threads 16*e* at the upper end of the lower head 16.

The intermediate tubular body 17 has an internal bore 17*c* which is of a larger diameter than the longitudinal openings or passages 15*a* and 16*a* so as to provide a main portion 17*d* which is in alignment with the passages 15*a* and 16*a* and also an offset portion 17*e* which is out of alignment with such passages 15*a* and 16*a*. The offset portion 17*e* of the bore 17*c* is disposed between the enlarged thickness portions 15*d* of the head 15 and 16*f* of the lower head 16. Thus, the offset portion 17*e* does not obstruct the movement of well tools passing downwardly through the tubing string and the main portion 17*d* of the bore 17*c*.

The gas lift valve V is mounted in the offset portion 17*e*, preferably with a threaded nipple 20 which is in threaded engagement with internal threads 16*g* at the upper end of fluid passage 16*b*.

The gas lift valve V is a fluid-operated valve which is actuated by a head of oil or other liquid within the bore of the mandrel M and the tubing string connected therewith. The amount of the head of liquid required to open the valve V is predetermined as explained hereinafter.

As particularly shown in FIG. 2, the gas lift valve V includes a valve casing 21 having a valve seat 21*a* at the lower end thereof. A plurality of fluid passages 21*b* are provided for communication directly with the bore 17*d* of the mandrel M. The number of the openings 21*b* may of course be varied and in some cases a single opening 21*b* may be used. A valve stem 22 is mounted in the valve casing 21 and is urged towards a seated position by a spring 23. The spring 23 is preferably confined between a shoulder 24 and an adjustable nut 25 so that the compression of the spring 23 may be adjusted to set the amount of liquid head required to open the valve stem 22 from its seat 21*a*. The upper end of the stem 22 has a dampening head 27 connected thereto with split snap rings 28 of metal or other material mounted thereon. The snap rings 28 engage the internal surface of the valve casing 21 and dampen the movements of the stem 22, but the split in the rings 28 permits fluid flow past such rings 28 so as to prevent a fluid lock above the rings 28. A flexible bellows or diaphragm 30 is connected to the upper end of the head 27 and the area internally of the bellows 30 is preferably at atmospheric pressure. A guide sleeve and stop member 31 is connected to the head 27 within the bellows 30. A closure plug 32 is connected in the upper end of the casing 21 to close the area confined by the bellows 30.

It is preferable to include a check valve C below the gas lift valve V so as to prevent a loss of the liquid within the tubing string in the event the gas pressure externally of the tubing string drops below a predetermined pressure while the valve stem 22 is moved upwardly to an open position. The check valve C is connected to the gas lift valve V by any suitable means such as a connecting threaded sleeve 35.

The check valve C includes a housing 40 and a valve seat 40*a* therein which is adapted to be engaged by the lower end of a longitudinally movable valve member 41. The valve member 41 has a central bore 41*a* which is open at its upper end and which is in communication with a lateral port or ports 41*b*. A spring 42 holds the valve member 41 in a seated position on the valve seat 40*a* to prevent the fluid flow from the interior of the mandrel M to the exterior thereof. However, upon an upward movement of the valve member 41 to an open position, the spring 42 is compressed and the fluid such as gas in the casing annulus then may flow through the port 41*b* and the central bore 41*a* to the sleeve 35 and then through the openings 21*b*, providing the valve stem 22 has been moved to the open position by the head of liquid in the mandrel M.

Since the apparatus A of this invention is normally run in well pipe or casing W which is of the slim hole type, or in multiple-string production, the relatively small clearance between the mandrel M and the casing W might result in the contact of the external surface of the mandrel M with the interior surface of the casing W or some other pipe. In order to be certain that the gas in the casing annulus can reach the laterally extending fluid passage 16*c* when the gas lift valve V is open, it is preferable to provide some means such as the longitudinal groove 50 (FIGS. 1, 3 and 4).

Alternatively, such groove 50 may extend transversely as indicated by the groove 150 in FIG. 5 and FIG. 6. It will be understood that the particular shape or direction of the groove 50 or 150 may be varied, so long as the entry of the gas into the fluid passages 16*c* and 16*b* is made possible even though the exterior surface of the lower body 16 in the vicinity of the openings 16*c* and 16*d* is in contact with the interior surface of the well casing W.

In the operation or use of the apparatus of this invention, the apparatus A is connected in a tubing string or well pipe at a desired location for a gas lift operation. Several of the apparatus A may be connected at selected elevations in the tubing string, but only one of such apparatus A has been illustrated. Normally, the apparatus A of this invention is located in a well casing C which is of a slim hole size or diameter so that the relative clearances between the parts is extremely small. This invention provides for an adequate unobstructed tubing opening (approximately 1¼ inches in diameter), even in the area of the apparatus A, while permitting the apparatus A to be lowered into slim hole casing (for example, a drift pipe size of 2.347 inches a diameter).

With the apparatus A connected in the tubing string, the gas lift valve V is normally closed, but it is opened when the head of the oil or other liquid in the tubin string rises to the predetermined level for urging the valve stem 22 upwardly to unseat same from the seat 21*a*. Thus, when the gas lift valve V is opened by the liquid head within the tubing string, the gas which is under pressure in the casing annulus is permitted to enter through the check valve C and the lower inlet passage 21*c* for discharge through the opening or openings 21*b* directly into the main portion 17*d* of the bore 17*c* of the mandrel M. Thus, no external tubes or seals are required around the gas lift V of this invention, thereby preventing any obstruction to the main portion 17*d* of the mandrel M while providing the advantages of the gas lift valve V which is fluid-operated.

The gas which is injected into the liquid functions in the normal manner for gas lifting in that it serves to raise the oil or other liquid to a higher level in the tubing string and ultimately to the surface. When the head of the oil or other liquid in the tubing string falls by reason of the gas lifting, the spring 23 returns the valve stem 22 downwardly to the seated and closed position to prevent further entry of the gas from the area exteriorly of the apparatus A. The liquid level in the tubing string then builds up from the flow from the well below again until it reaches the predetermined height necessary to overcome the force of the spring 23 to open the valve V. Then, the gas is again admitted from the area exteriorly of the apparatus A into the bore 17*c* and gas lifting of the oil or other liquid again occurs.

The foregoing functioning of the apparatus of this invention continues repeatedly so long as the level of the

liquid continues to rise in the tubing string due to the well pressure sufficiently to open the gas lift valve V. The particular level at which the apparatus A is located in the tubing string will of course depend upon the height to which the level of the liquid rises due to such well pressure.

In the modified form of the invention illustrated in FIGS. 7–9, the apparatus is identical with that illustrated in FIGS. 1–6, except for the portions shown in FIGS. 7 and 8, as will be explained. Thus, the upper head **115** corresponds with the upper head **15** of FIG. 1, but it has been modified to provide a recess or pocket **115***f*, and also an arcuate extension or protector tab **115** g.

The upper end of the valve V is identical with that illustrated in FIG. 2, except that the plug **132** of FIG. 7 includes therewith a retaining pin or rod **132***a*. Preferably, the retaining rod **132** is an integral part of the plug **132** and is therefore normally machined from the same piece of metal. However, it will be understood that such pin or rod **132***a* may be formed separately and then secured to the plug **132**. The pin or rod **132***a* is of such a length that it extends approximately half way into the recess **115***f* when the lower end of the valve V is secured or threaded into the internal threads **16***g* (FIG. 1). In any event, the upper end **132***b* of the pin or rod **132***a* must be spaced a sufficient distance from the upper end **115***h* of the recess **115***f* so that when the threaded nipple **20** (FIG. 1) is unthreaded from the threads **16***g*, the rod or pin **132***a* can move upwardly into the recess **115***f* without contacting the upper end **115***h*, at least until the disconnection of the threads **16***g* from the nipple **20** has been made. Also, the width of the recess or pocket **115***f* should be large enough as compared to the diameter of the pin or rod **132***a* to permit a slight angling of the entire valve V when the threads of the nipple **20** have been disconnected from the threads **16***g* and it is desired to remove the valve V from the mandrel M. Since such insertion and removal of the valve V is all accomplished at the surface prior to the insertion of the mandrel M or the tubing string T into the well, such manipulation of the valve V for removal and insertion thereof can be accomplished.

In the use of the form of the invention shown in FIGS. 7 and 8, the operation thereof is identical, except that the protector tab **115***g* prevents any inadvertent contact by well tools with the valve V as such well tools move longitudinally past such gas lift valve V. Also, the projection of the retaining rod or pin **132***a* into the pocket **115***f* prevents any deflection of the valve V from its aligned position offset from the unobstructed longitudinal bore of the mandrel M. Therefore, there is no danger of the valve V inadvertently moving over into an obstructing position with respect to the bore **115***a*. The form of the invention illustrated in FIGS. 7 and 8 therefore has all of the advantages of the form illustrated in FIGS. 1–6, but in addition thereto, the form of FIGS. 7 and 8 is an improvement thereon for the reasons enumerated above.

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. A gas lift apparatus mounted in a tubing string prior to positioning in a well casing, comprising:

(a) a tubing string,

(b) a tubular mandrel having an upper head with an eccentrically positioned longitudinal opening therethrough,

(c) means connecting said upper head to said tubing string,

(d) said tubular mandrel also having a lower head with an eccentrically positioned longitudinal opening therethrough,

(e) means connecting said lower head to said tubing string,

(f) said tubular mandrel including an intermediate tubular body having a longitudinal bore which is larger than said openings in said upper and lower heads,

(g) said longitudinal openings in said upper and lower heads being of substantially the same size as the bore of the tubing string and in longitudinal alignment therewith,

(h) said longitudinal bore of said intermediate tubular body having a portion thereof in alignment with said longitudinal openings in said upper and lower heads but also having an offset portion thereof which is out of alignment with said longitudinal openings,

(i) a fluid-operated gas lift valve in said offset portion of said intermediate tubular body, said gas lift valve being of a length substantially equal to the length of the offset portion,

(j) means securing said gas lift valve to said lower head of said mandrel, and

(k) said lower head having fluid passage means establishing fluid communication from the area exteriorly of said mandrel to said valve so that gas may flow through said valve into said mandrel upon an opening of said valve by said head of liquid.

2. The structure set forth in claim **1**, including:

(a) a check valve connected between said gas lift valve and said mandrel for permitting gas flow from the area exteriorly of the mandrel through the gas lift valve to the interior of the mandrel and for preventing gas flow in the opposite direction.

3. A gas lift apparatus adapted to be mounted in a tubing string for positioning in a well casing, comprising:

(a) a tubing string,

(b) a tubular mandrel having an upper head with an eccentrically positioned longitudinal opening therethrough,

(c) means connecting said upper head to said tubing string,

(d) said tubular mandrel also having a lower head with an eccentrically positioned longitudinal opening therethrough,

(e) means connecting said lower head to said tubing string,

(f) said tubular mandrel including an intermediate tubular body having a longitudinal bore which is larger than said openings in said upper and lower heads,

(g) said longitudinal openings in said upper and lower heads being of substantially the same size as the bore of the tubing string and in longitudinal alignment therewith,

(h) said longitudinal bore of said intermediate tubular body having a portion thereof in alignment with said longitudinal openings in said upper and lower heads but also having an offset portion thereof which is out of alignment with said longitudinal openings, the space between said offset portion and the rest of the bore being free of any obstructions throughout substantially the entire length thereof,

(i) a fluid-operated gas lift valve in said offset portion of said intermediate tubular body, said gas lift valve being of a length substantially equal to the length of the offset portion,

(j) thread means securing said gas lift valve to said lower head of said mandrel,

(k) said gas lift valve having an opening communicating directly with said longitudinal bore of said mandrel, and

(l) said lower head having fluid passage means establishing fluid communication from the area exteriorly of said mandrel to said valve so that gas may flow through said valve into said mandrel upon an opening of said valve by said head of liquid.

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