Nov. 29, 1949 C. M. O'LEARY 2,489,665

PNEUMATIC FEED FOR GAS LIFT

Filed March 29, 1945 2 Sheets-Sheet 1

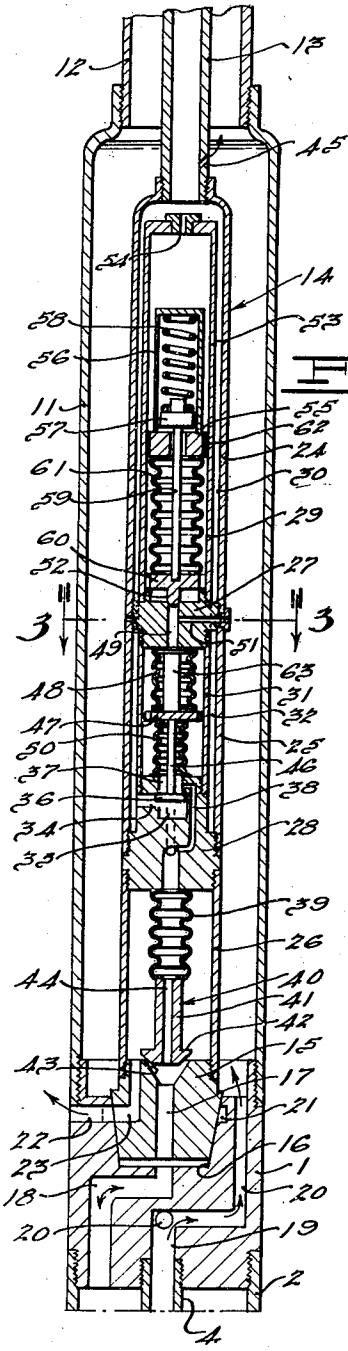

Fig. 1.

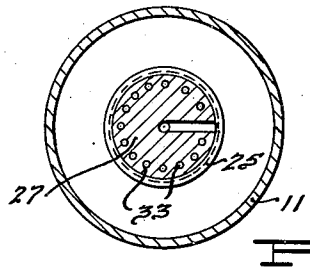

Fig. 3.

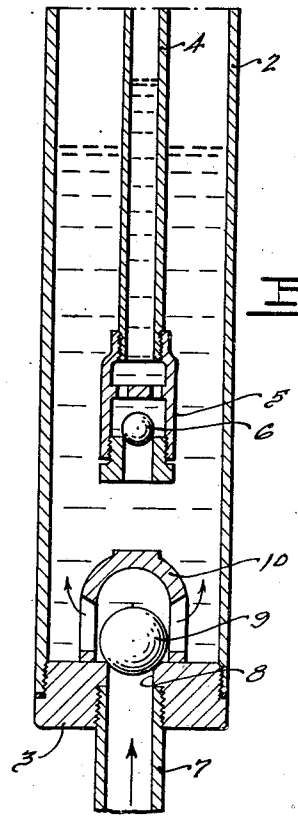

Fig. 2.

INVENTOR.
Charles M. O'Leary.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

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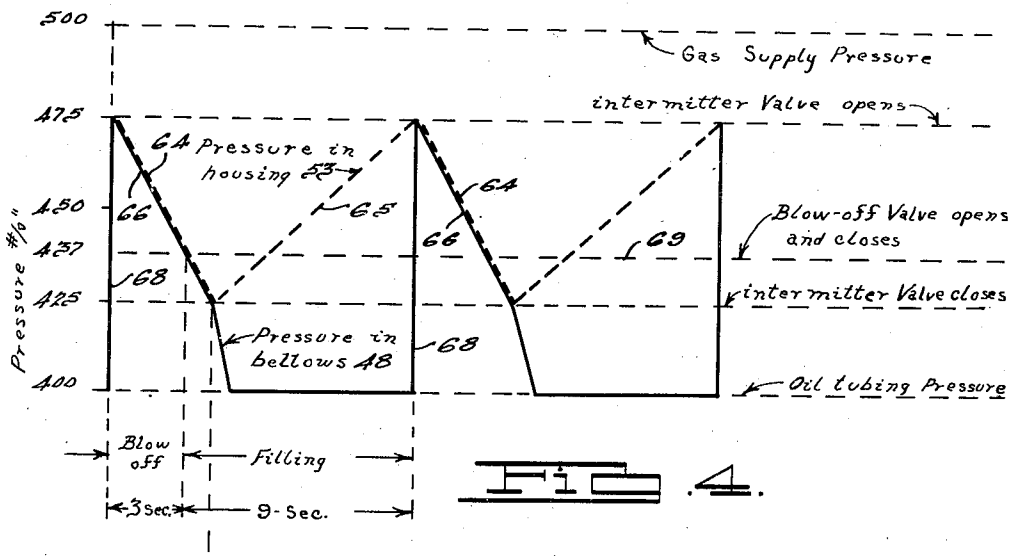

Fig. 4.

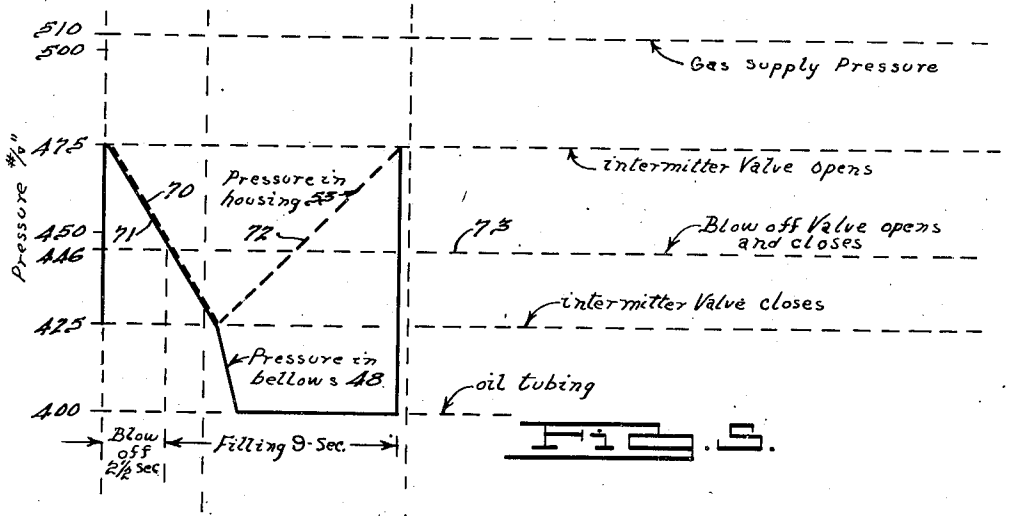

Fig. 5.

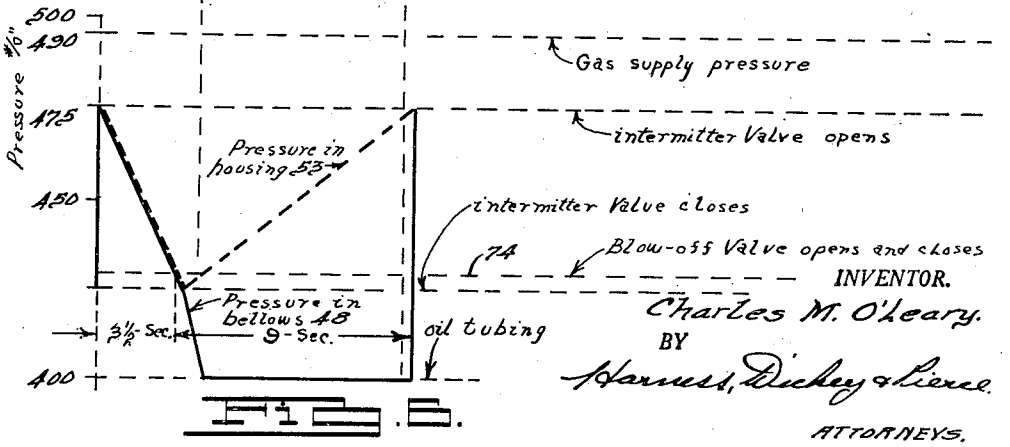

Fig. 3.

INVENTOR.
Charles M. O'Leary.
BY
Harness, Dickey & Pierce
ATTORNEYS.

Patented Nov. 29, 1949 2,489,665

UNITED STATES PATENT OFFICE

2,489,665

PNEUMATIC FEED FOR GAS LIFTS

Charles M. O'Leary, Detroit, Mich.

Application March 29, 1945, Serial No. 585,473

12 Claims. (Cl. 103—232)

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The present invention relates to means for flowing oil wells by gas under pressure and resides in an improved form of bottom hole intermitter particularly adapted for use on large production deep wells.

Ordinary gas lift installations are not particularly effective on large production deep wells, due to the fact that the gas pressure required at the bottom of the well to lift the column of oil materially retards inflow of oil from the formation. In addition, the natural flow rate of wells varies constantly, with the result that it is difficult to determine or maintain the optimum gas-oil ratio for flowing the well. Accordingly, attempts have been made to relieve the bottom of the well from the pressure resulting from the long column of oil and gas in the outflow tubing and to maintain a constant rate of oil flow by installing flow chambers in the bottom of the well which are equipped with check valves past which oil may flow by gravity to fill the chamber. These chambers are then intermittently blown by gas pressure to force the oil up into the oil outflow tubing without applying the pressure in the tubing to the formation. In certain of these constructions control of the blow-off and filling periods has been achieved by periodically varying the gas pressure supplied to the well at the ground surface. This expedient, however, is objectionable because of the long time required to build up the pressure of the large volume of gas in the tubing of a deep well. In addition, these prior expedients have operated to blow each slug of oil entirely from the well, with the result that excessive quantities of gas are required.

Attempts have been made to overcome these difficulties by employing float controlled flow valves which will simply blow the oil from the chamber into the oil tubing in which it may be lifted by an auxiliary supply of gas while the chamber is refilling. However, these float controlled valve mechanisms have proved unsatisfactory for several reasons. In the first place, the floats are subject to forces resulting from the flow or surging of gas and oil independent of the oil level. Secondly, the float mechanism is quickly clogged by wax and foreign matter in the oil; and, finally, if the float and float mechanism are made sufficiently large and heavy to

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minimize the first two difficulties, they require too much space at the bottom of the well and, therefore, cannot be installed or removed without removing all of the oil outflow tubing.

Accordingly, it is the general object of the present invention to provide a bottom hole intermitter which will periodically blow the oil from the filling chamber into the oil tubing, in which it may be lifted by an auxiliary gas supply during the refilling period, and in which the cycle of operation is controlled by the gas supplied under relatively constant pressure to the bottom of the well through a macaroni or gas tubing.

Another object of the invention is to provide a mechanism of the type mentioned, in which the relative duration of the filling and blowoff periods may be readily adjusted to accommodate the natural flow conditions of the well by adjusting the pressure of the gas supplied.

Another object of the invention is to provide a mechanism of the type mentioned which incorporates no mechanism or moving parts in contact with the oil except the conventional ball check valves associated with the flow chamber and which, therefore, cannot get out of order by reason of accumulations of wax or foreign materials such as are present in the flowing oil.

Another object of the present invention is to provide a mechanism of the type mentioned in which all of the operating and control valves are of the poppet or ball check type in which a positive gas pressure operates to hold them in their closed positions and in which all of the valve operations are controlled by gas pressure.

Another object of the invention is to provide a mechanism in which all relatively sliding parts are sealed against contact with gas supplied to the unit and the oil in the well and tubing.

Another object of the invention is to provide a mechanism of the type mentioned, in which the frequency of the cycle of operation may be adjusted to a limited extent by changing the gas supply pressure, and in which the frequency may be adjusted over a wide range to suit conditions existing in any given well by very simple adjustments.

Another object of the invention is to provide a mechanism of the type mentioned, all portions of which, except the flow chamber itself, may

be fixed to the lower end of the macaroni or gas supply tubing and inserted into or withdrawn from the oil outflow tubing without disturbing the latter.

Another object of the present invention is to provide an improved form of valve mechanism for producing a fluctuating gas pressure from a constant pressure source for use in operating a pressure responsive device.

Other objects, which include the provision of an intermitter of the type mentioned which is extremely rugged, compact, and simple in construction, will become apparent from the following specification, the accompanying drawings, and the appended claims.

In the drawings,

Figures 1 and 2 are, respectively, sectional views taken through the upper and lower portions of the preferred embodiment of the invention;

Figure 3 is a sectional view taken on the line 3—3 of Figure 1; and

Figures 4, 5, and 6 are pressure diagrams illustrating the principle of operation of the mechanism.

Referring to the drawings, and particularly Figures 1, 2, and 3 thereof, the improved intermitter mechanism comprises a generally cylindrical valve block 1, to the lower end of which is fixed an elongated cylindrical shell 2 forming the walls of a flow chamber which may be of any desired length and which is closed at its lower end by means of a plug 3. Valve block 2 also carries a centrally located oil flow tube 4 which projects downwardly into the flow chamber and carries at its lower end a housing 5 and a ball check valve 6 which operates to permit free flow of oil upwardly through the tube, but prevents reverse flow. The plug 3 is likewise provided with a downwardly projecting inflow oil tubing 7 which communicates with a port 8 in the plug 3. The port 8 is controlled by means of a ball check valve 9 positioned with reference to the port 8 by means of a cage 10. This ball check valve permits free inflow of oil through tubing 7 to the interior of the chamber 2 but prevents reverse flow. The inflow tubing 7 may be of any desired length, but it will be appreciated that the entire chamber 2 must be located below the natural oil level in the well in order to permit the gravity flow of oil into the chamber past the check valve 9.

To the upper end of the valve block 1 is secured a similar cylindrical casing 11, the upper end of which is threaded, or otherwise suitably secured, to the lower end of the oil outflow tubing 12.

The remainder of the mechanism, which includes the control valves for intermittently blowing the chamber 2, is fixed to the macaroni or gas supply tubing 13 and may be inserted or removed without disturbing the oil tubing 12 and the portions of the mechanism carried thereby. This control valve mechanism is mounted in an elongated cylindrical chamber 14 which is threaded or otherwise fixed at its upper end to the lower end of the gas tubing 13, and which is closed at its lower end by means of a conically tapered block 15 that is adapted to seat within, and make sealing engagement with, a correspondingly conically tapered recess 16 formed in the upper end of the valve block 1. The block 15 is provided with a central bore 17 which is adapted to communicate with a passageway 18 in the valve block 1, and the latter passageway communicates with the interior of the chamber 2. The valve block 1 is provided with an opening 19 in its lower face in communication with the interior of the tube 4,

which in turn communicates at its upper end with a plurality of passageways 20 which connect to the space between the housings 11 and 14. The conical recess 16 in the valve block 1 is provided with an annular groove 21 which communicates with a port 22 in the valve block which opens to the well space outside the oil outflow tubing, the housing 11, and the chamber 2 at a point above the chamber 2. The channel 21 likewise communicates with passageway 23 in the block 15 which leads to the space within the housing 14.

The housing 14 is made in three sections, 24, 25, and 26. Sections 24 and 25 are connected by means of a block 27, and sections 25 and 26 are connected by means of a block 28. Block 27 is fixed to an upwardly projecting cylindrical housing 29 within the housing section 24, leaving a space 30 between the walls of the housings 24 and 29. A cylindrical housing 31 is fixed in sealing relation to and between the blocks 27 and 28, within the housing section 25, and the walls of the housings 31 and 25 are spaced apart to provide a passageway 32. The passageways or spaces 30 and 32 are connected through a plurality of openings 33 in the block 27, as best shown in Figure 3, and the space 30 is in unrestricted communication at its upper end with the interior of the gas supply tubing 13. Block 28 is provided with a side port 34 connecting the space 32 to a valve chamber 35 having a gas blowoff valve 36 controlling a port 37, which is connected by a plurality of passageways 38, through the block 28, to the space within a flexible bellows 39, the upper end of which is fixed to the lower face of the block 28. The bellows 39 carries at its lower end a plunger in the form of a valve element indicated generally at 40, which is made up of a hollow stem 41 and a poppet type head 42, adapted to co-operate with a valve seat 43 at the upper end of the passageway 17 in block 15. The cross-sectional area of the valve seat 43 is greater than the cross-sectional area of the bellows 39, and the opening 44 in the tubular valve stem 41 is more restricted to the passageways 38 and 23, with the result that any flow of gas through the passageway 44 tends to elongate the bellows 39 and seat the valve 40. The normal length of the bellows 39 is such as to hold the valve 40 in spaced relation to the seat 43 when no gas is flowing through passageway 44, and the effective area of valve 42 is greater than that of bellows 39.

As a result of the mechanism so far described, it will be apparent that normally the blowoff valve 36 closes the port 37 in block 27 in response to the pressure of the supply gas, thus shutting off flow of gas through the tubular valve 40 and causing that valve to unseat, as illustrated in the drawings. Under these conditions, the upper end of the chamber 2 is connected to the low pressure space within the well by means of passageways 18, 23, and 22, and no gas under pressure is supplied to the chamber.

When the check valve 36 is forced off its seat against the gas supply pressure which normally maintains it in a seated condition, gas under pressure will flow from the gas supply tubing through space 30, passageway 33, space 32, passageway 34, port 37, passageway 38, bellows 39, valve 40, and passageways 17 and 18 to the upper end of the flow chamber 2, and thereby seat the ball check valve 9 and forcing any oil within the chamber upwardly past the check valve 6 through the tubing 4, passageways 19 and 20 to the space between the housings 11 and 14, and thence to the oil outflow space between the oil tubing 12 and the gas

tubing 13. Since, during these conditions, the space within the housing section 26 is at a lower pressure than the pressure in passageway 17 and bellows 39, and the area of valve head 42 is slightly greater than that of the bellows 39, the pressure within the passageway 17 tends to unseat the valve 40. However, a small pressure drop of the gas passing through the restricted passageway 44 in the valve overcomes that tendency and maintains the valve in a seated condition so long as the check valve 36 is unseated. As soon as the check valve 36 is seated, flow through valve 40 stops, and the pressure within passageway 17, which is the pressure within the upper end of the chamber 2, unseats the valve 40. In this connection it will be noted that the pressure within the upper end of the chamber 2, when valve 42 is closed, may never be less than the pressure at the bottom of the column of oil in the outflow tubing. It will be observed that valves 36 and 42, in combination, operate as a three-way valve to connect the chamber 2 either to exhaust or to the full supply gas pressure. The particular construction and form of valve disclosed is peculiarly suited to an oil well insert mechanism because of its in-line arrangement, and has no relatively moving parts, except the poppet type valves and seats exposed to the gas or oil.

The oil which flows upwardly through the outflow tubing may be lifted by gas supplied thereto in any desired manner, such as by the small opening 45 in the lower end of the gas tubing 13. It will be understood that any other means for supplying gas to the oil column, including gas supply valves responsive to the pressure in the oil tubing, may be employed in accordance with conventional practice.

The flow chamber 2 is entirely immersed in the oil normally standing in the well to any desired depth except that the external pressure on inlet 8 should not exceed the gas supply pressure in tubing 13, since otherwise the oil would simply flow continuously through chamber 2. This is undesirable because there would then be no way of maintaining the oil flow rate constant, with the result that it would be difficult to maintain the optimum gas-oil ratio to flow the well by the lift gas. The exhaust outlet 22 likewise should not be immersed in the oil standing in the well so deeply that the pressure head on outlet 22 exceeds the pressure of the gas lifted column of oil in tubing 12 at the bottom of that column. Preferably, the pressure at outlet 22 should be a low pressure. The rate of inflow of oil to the chamber 2 during the filling period will remain constant regardless of the depth of immersion of the chamber in the oil since it is a function of the size of the oil inlet port 8 and the distance (and therefore the pressure difference) between the port 8 and port 22.

Valve 36 is unseated by means of a stem 46 fixed to a plunger member 47, which is secured to and seals the lower end of an expansible bellows 48. The upper end of the bellows 48 is fixed and sealed with respect to the lower surface of block 27 in communication with a passageway 49 through the block. A second expansible bellows 50 surrounds the stem 46 and is secured in sealing relation at its ends to the plunger 47 and the upper surface of block 28. The effective cross-sectional area of the bellows 50 is approximately equal to the effective cross-sectional area of the port 37, and the effective cross-sectional area of the bellows 48 is slightly greater than that of the bellows 50. As a result of this arrangement, application of pressure to the interior of bellows 48 in an amount less than that of the gas supply pressure acting on the bottom of the blowoff valve 36 will open that valve, and the blowoff valve is balanced against the influence of pressure within the bellows 50 and port 37. The amount of pressure in belows 48 required to open valve 36 depends upon the ratio of the area of the bellows 48 to the port 37, as hereinafter pointed out in greater detail. In the absence of the bellows 50 the pressure in port 37 would rise on opening of the blowoff valve 36, and the resulting increase would tend to move the plunger 47 upwardly and thereby tend to close blowoff valve 36. This would throttle down the pressure in port 37. The bellows 50 prevents this throttling action and, therefore, insures application of the full gas supply pressure for blowoff purposes.

Means are provided for periodically increasing and decreasing the pressure within the bellows 48 at a predetermined frequency in order to alternately fill the chamber 2 and effect a blowoff of the oil in the filled chamber. This means comprises the aforementioned passageway 49 in block 27, a lateral bleed passageway 51 connecting passageway 49 to the oil space between housings 11 and 14 and an intermitter valve 52 for controlling the admission of gas under pressure to the passageway 49. The intermitter valve 52 is operated by an intermitter mechanism, the major portion of which is located within a cylindrical housing 53 fixed in sealed relation to the upper end of block 27 and provided at its upper end with a small inlet bleed port 54 communicating with the supply gas under pressure in the gas tubing 13. The cross-sectional area of the bleed port 54 must be smaller than the cross-sectional area of the previously mentioned bleed port 51, as pointed out hereinafter in greater detail.

Housing 53 is provided intermediate its ends with a block 55, to the upper surface of which is fixed a cylindrical housing 56 containing a plunger 57, which is normally urged downwardly by means of a spring 58. A stem 59 connects the plunger 57 to a plunger 60, which is fixed to the intermitter valve 52, with the result that the spring 58 normally acts to hold the intermitter valve in closed position. A flexible bellows 61 is fixed in sealed relation at its ends to the underside of block 55 and to the plunger 60, with the result that the spring 58, plunger 57, and stem 59 are entirely sealed against contact with the gas in the housing 53. The block 55 is provided with a plurality of openings 62 providing an unrestricted communication within the housing 53, between the space above the block 55 on the outside of housing 56 and the space below the block 55 on the outside of the bellows 61.

The operation of the intermitter valve mechanism is as follows: Gas at supply pressure in tubing 13 enters the bleed port 54 and gradually builds up the pressure within housing 53. This pressure, acting on the underside of plunger 60, tends to lift intermitter valve 52 off its seat, and that tendency is resisted by means of spring 58. The strength of the spring is so chosen with respect to the effective cross-sectional area of the plunger 60 and bellows 61 that the intermitter valve 52 is not opened until the pressure within the housing 53 reaches a pressure slightly below that of the gas supplied in tubing 13. When that pressure is reached valve 52 opens, thus permitting a flow of the gas within the housing 53 through the passageway 49 of the interior bellows 48. It is desirable, although not necessary, to

reduce the pressure drop incident to the filling of bellows 48 to a minimum and, accordingly, there is illustrated a cylindrical plug 63 fixed to the plunger 47 substantially filling the bellows 48 to reduce its volumetric capacity. Once the valve 52 is opened the effective area of the plunger 60 is increased by the area of the valve 52 and, consequently, the valve 52 will remain open until the pressure within the housing 53 drops to a value below the pressure at which valve 52 was opened. It is desirable to keep the difference between the pressures at which valve 52 opens and closes to a small value, in the order of 25 to 50 pounds per square inch.

As soon as the valve 52 is opened the pressure within housing 53, passageway 49, and bellows 48 will begin to drop, by reason of the outflow of gas through the bleed port 51. Since this bleed port has a larger effective area than the bleed port 54, the gas will flow outwardly through port 51 faster than it enters port 54, and result in a gradual reduction in the pressure within the housing 53 and the bellows 48. After the pressure drops to the point at which valve 52 closes, the pressure in bellows 48 drops rapidly to the pressure existing in the space between the housings 11 and 14 (the pressure head at the bottom of the oil outflow tubing), and at the same time the pressure within the housing 53 begins to build up by reason of the flow through port 54. It will be apparent that by adjusting the sizes of the ports 54 and 51 relative to the volume of the gas space within the housing 53 and the bellows 48, the frequency with which the valve 52 opens and closes may be readily adjusted.

Thus, if the size of opening 54 is increased while all remaining features of the design remain unchanged, the period of time required to build up pressure in housing 53 will be reduced, and consequently the period of time during which the valve 52 is closed will be correspondingly reduced; and vice versa. By the same token any increase in the size of passageway 51, all other features of the design remaining the same, will shorten the period during which valve 52 is open; and vice versa.

The frequency of each complete cycle of operation of the valve 52 for any given pressure in the gas supply tubing 13 is fixed by the strength of spring 58, the relative effective areas of the plunger 60 and the valve 52, the sizes of bleed ports 54 and 51, and the volumetric capacity of the housing 53 and the bellows 48. However, for any given frequency for the complete cycle of operation the relative proportions of the filling and blowoff portions of the complete cycle may be varied by varying the relative cross-sectional areas of the bellows 48 and 50. In addition, the relative proportions of the complete cycle devoted to the filling and blowoff periods may also be materially varied for any given construction by slight variations in the pressure supplied to tubing 13. This will be apparent from the pressure diagrams in Figures 4, 5, and 6 which represent diagrammatically the character of the variations in pressure, which result in housing 53 and bellows 48 for one embodiment of the invention.

The pressure diagram of Figure 4 is based upon the assumptions that the gas pressure in tubing 13 is 500 pounds per square inch, the pressure at the bottom of the oil outflow tubing is 400 pounds per square inch, and the intermitter valve 52 and its operating mechanism are so constructed that the valve opens when the pressure in housing 53 is 475 pounds per square inch and closes when the pressure is 425 pounds per square inch. These operating conditions are selected more or less arbitrarily and may be varied as desired, except that the pressure at which the intermitter valve opens must be something less than the full gas supply pressure, and the pressure at which the intermitter valve closes must be more than the pressure in the oil tubing.

If, with an intermitter valve constructed as above described, the outlet bleed port 51 has an effective cross-sectional area approximately three times that of the inlet 54, the pressure in the housing 53, upon closure of the valve 52, will drop along the dotted line 64 until the pressure in the housing 53, of 425 pounds per square inch, is reached. Thereupon valve 52 will close and the pressure in the housing 53 will gradually rise, as indicated by the rising dotted line portion 65, until the pressure again reaches 475 pounds per square inch, whereupon the cycle will repeat itself. The time elapse for a complete cycle of operation of valve 52, which is represented by the horizontal distance on the diagram Figure 4, determines the frequency of the complete filling and blowoff cycle of the chamber 2. While the pressure in the chamber 53 is fluctuating in general accordance with the dotted lines 64 and 65, the pressure in the bellows 48 varies in accordance with the solid line in the same figure. Thus, when valve 52 opens, the pressure in bellows 48 will rise abruptly along the vertical line 68 until it equals the pressure in housing 53. The pressures in housing 53 and the bellows 48 remain equal throughout the period that valve 52 is open. Therefore, the pressure in the bellows 48, indicated by the solid line portion 66, is identical to the pressure indicated by the dotted line 64 until the pressure reaches 425 pounds per square inch, at which the valve 52 closes. From that point on the two curves depart from each other, since the pressure in housing 53 then rises, while the pressure in the bellows 48 continues to drop even more rapidly than before, due to the outflow of gas through the opening 51, until the pressure in the bellows 48 equals the pressure in the outflow tubing, i. e., the space between housings 11 and 14. This more rapid portion of the pressure drop in bellows 42 is indicated by the solid line portion 67. As soon as the pressure in bellows 48 equals the pressure in the outflow tubing it remains constant at that pressure until valve 52 again opens and then immediately rises, as indicated by the solid straight line 68, to approximately the pressure in housing 53 at the time valve 52 opens. This completes the pressure cycle in the bellows 48, and that cycle repeats itself in the same manner.

Given the pressure curve indicated in solid lines in Figure 4 for bellows 48, it is apparent that the duration of the blowoff period may be varied with reference to the duration of the complete cycle by varying the pressure in bellows 48 at which the blowoff valve 36 is opened. Thus, as indicated in the drawing, if the cross-sectional area of the bellows 48 is of such size with respect to the area of port 37 that a pressure in bellows 48 of 437 pounds per square inch will open the valve 36, the duration of the blowoff period will be represented by the length of the dotted line 69 between its points of intersection with the solid lines 68 and 64, and the duration of the filling period will be the remainder of the cycle. Thus, if the duration of the complete cycle, as illustrated in Figure 4, is twelve seconds the blowoff period will be three seconds, and the filling period nine seconds. If, on the other hand the blowoff valve was con-

structed to open at a lower pressure, the blowoff period would be lengthened at the expense of the filling period. Accordingly, for any given pressure curve for bellows 48, the pressure in bellows 48 at which the valve 36 opens must be so chosen for any given installation as to provide the requisite filling and blowoff periods. In the example given, therefore, the size of the inlet opening of the chamber 2, the capacity of the chamber, and the distance between the inlet opening 8 and the outlet opening 22 must be such that the chamber will completely fill in nine seconds. Since the rate of filling is determined entirely by the distance between the openings 8 and 22, the size of the opening 8 and the capacity of the chamber, the rate of filling of any given unit will remain constant regardless of the depth to which it is immersed in the oil standing in the well.

Likewise, in the example given, the rate of blowoff of the oil from the chamber must be completed in three seconds. This is controlled by the difference in pressure between the gas supply and the pressure in the oil tubing, the size of the oil outlet passages 19 and 20 and the volume of oil in the chamber. These factors may be so correlated as to provide a complete blowoff in the blowoff period available. If, for any reason, a greater proportion of each cycle is required for blowoff and less for filling it is only necessary to reduce the pressure at which the blowoff valve opens to achieve that result.

It will be observed that the mechanism so far described provides a means for maintaining a uniform feed of oil to the oil tubing regardless of variations in the natural level of the oil in the well. Consequently, it is possible to maintain, by means of a constant flow of lift gas through the bleed opening 45, or otherwise, the ideal gas-oil ratio to produce the most efficient gas lift conditions in the oil outflow tubing, and there is no possibility of this ratio being upset by surges of variations in the oil flow. In addition, the mechanism entirely relieves the oil formation of the pressure necessary to lift the gas through the oil outflow tubing and, consequently, materially increases the production of the well over conventional gas lift arrangements.

An important feature of the invention resides in the fact that the relative portion of each complete cycle which is devoted to blowoff and/or the filling period may be materially adjusted by small changes in the pressure of the gas supplied through tubing 13. The effect of such changes upon the performance of the apparatus depends upon the relative sizes of the openings 51 and 54. If the size of those openings is such that the pressure cycles approximate those illustrated in Figure 4, it is possible, by small adjustments in the gas supply pressure to vary the blowoff period without any appreciable change in the filling period. This arrangement is advantageous, since the filling rate may be more easily controlled by the design and construction of the chamber and, being usually a longer period than the blowoff period, is less sensitive to small variations. Moreover, the efficiency of the unit is less seriously affected by a filling period which is slightly too long or too short than by a blowoff period which is too long.

The manner in which the above mentioned adjustment in the blowoff cycle is achieved is illustrated diagrammatically in Figures 5 and 6, in which Figure 5 shows the effect of an increase in the gas supply pressure to 510 pounds per square inch, and Figure 6 shows the effect of a decrease in the gas supply pressure to 490 pounds per square inch for the unit, the performance characteristics of which are illustrated in Figure 4.

Referring to Figure 5, it will be seen that the dotted line 70 and the solid line 71, which represent, respectively, the pressure dropping curves for the housing 53 and the bellows 48 after the intermitter valve 52 opens, have a slightly more gradual slope than do the corresponding lines 64 and 66 in Figure 4, due to the fact that the slight increase in gas supply pressure increases the quantity of gas which enters port 54 during the period that valve 52 is open. Likewise the dotted line 72, which represents the ascending pressure curve for housing 53 when the valve 52 is closed, is steeper than the corresponding line 65 for the same reason. One result of the pressure change in the illustrated diagram is a slight reduction in the period required for the complete cycle. In addition, the increase in gas supply pressure, which is effective on the underside of valve 36, results in an increase in the pressure in bellows 48 necessary to open the valve 36. This increase is represented by the higher position of the horizontal line 73 which represents the pressure in bellows 48 at which the blowoff valve 36 opens and closes. As a result of the increase in the height of line 63, as compared with the height of the corresponding line 69 in Figure 4, the blowoff period is reduced from three seconds to two and one-half seconds. However, since the complete cycle was slightly shortened the filling period remains approximately the same, or about nine seconds. The slight decrease in the period for the complete cycle, which results in an increase in the frequency of the cycle, slightly increases the rate of flow of oil to the outflow tubing, thus compensating for the additional supply of lift gas which will be supplied through port 45 as a result of the increase in gas supply pressure.

The blowoff period may be similarly increased, as compared with that represented in Figure 4, by reducing the gas supply pressure to 490 pounds. Thus, as shown in Figure 6, the reduction in gas supply pressure reduces the pressure in bellows 48 required to open the blowoff valve 36, as indicated by the lower position of the horizontal line 74 as compared with the corresponding line 69 in Figure 4. This increases the blowoff period to three and one-half seconds. In this case the reduction in gas supply pressure slightly increases the period for the complete cycle and consequently the filling period remains substantially the same, or about nine seconds. The slight reduction in the frequency of the cycle resulting from the reduction in gas supply pressure reduces the rate of flow of oil to the oil outflow tubing to compensate for the reduction in lift gas, which will result from the lower gas supply pressure.

It is apparent from the above that a final adjustment of the blowoff period may be readily made after the mechanism is positioned within the well, by making a small adjustment in the gas supply pressure. Consequently, it is possible to so control the operation of the mechanism by the gas supply pressure as to insure optimum blowoff conditions.

While, as indicated above and illustrated diagrammatically in Figures 4, 5, and 6, it is possible to so construct the mechanism as to permit a variation in the blowoff period without any appreciable change in the filling period by suit-

ably proportioning the openings 51 and 54, it is likewise possible, by changing the relative sizes of the openings 51 and 54, to provide a unit in which a reduction in blowoff period incident to changes in the gas supply pressure will result in a more or less corresponding increase in the filling period, and vice versa. This can be accomplished, for example, by decreasing the size of the opening 51 so that the opening of the intermitter valve is delayed to a greater extent than that illustrated in Figure 4. It will be understood, however, that in all cases the opening 51 must be larger than the opening 54.

It will also be appreciated that the frequency of the cycle may be changed by changing the sizes of the openings 51 and 54. Thus, a reduction in the size of both openings will reduce the frequency of the cycle, and an increase in the size of the openings will increase the frequency.

It should be noted that the pressure diagrams in Figures 4, 5, and 6 are only approximately correct and are intended only to represent the general character of the cycle of pressures in bellows 48 and housing 53. Actually, the pressures will not rise and fall in straight lines, as indicated on the drawings, and as a practical matter the proper sizes for the bleed openings 51 and 54, as best determined by trial for any given installation. Since the openings are formed in removable plugs, it is a simple matter to substitute plugs having openings of different sizes. In this manner any desired frequency and the character of pressure cycles may be established in the field before the unit is installed in the well.

An important feature of the invention resides in the fact that all portions of the mechanism, except the filling chamber itself and the two check valves associated therewith, is fixed to and removable as a unit with the macaroni or gas tubing 13, and consequently, may be removed from the well without disturbing the oil tubing. It is thus a relatively simple matter to remove the mechanism for repair or adjustment.

Another important feature of the invention resides in the fact that all of the relatively sliding parts are entirely sealed against contact with either oil or gas. It is for this reason that bellows are employed in connection with the three valves 52, 36, and 42. It will be appreciated that from a functional standpoint ordinary piston operated plungers would serve the same purpose as the bellows but would, of course, involve relative sliding members which are in contact with the gas and hence may become contaminated or clogged by wax and other accumulations.

It will be understood that the proportions of the mechanism, as shown in the drawings, are distorted to facilitate illustration. Actually the mechanism should be much longer, as compared with its diameter, than appears from the drawing. Thus the filling chamber may be any desired length up to several hundred feet, depending upon the height of the natural oil level in the well and the rate of production. All of the expansible bellows employed in the valve mechanism should be materially elongated to reduce the stresses thereon due to the small movement required to operate the valves, and the gas exhaust outlet 22 is preferably located at a substantial distance above the top of the filling chamber in order to reduce the exhaust pressure and thereby increase the filling rate of the chamber.

What is claimed is:

1. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising an oil chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, a gas pressure operated valve mechanism for controlling the gas pressure in the oil chamber, said mechanism including a gas chamber and being effective when the gas pressure in said gas chamber is at one value to admit gas under pressure to said oil chamber to discharge oil therein and being effective when the gas pressure in said gas chamber is at a lower value to disconnect the oil chamber from the gas tubing to permit gravity filling of said oil chamber, and pneumatic means adapted to be connected to the lower end of the gas tubing to effect a periodic fluctuation in the gas pressure in said gas chamber from a relatively constant pressure gas supply in the gas tubing from one of said two pressures to the other, said pneumatic means including means providing a bleed passage from the lower end of the gas tubing into the gas chamber and means providing a restricted passage of larger size than said bleed passage and connecting the gas chamber to the lower end of the oil tubing and a valve operable to open said restricted passage only when the pressure in the gas chamber reaches said one value.

2. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a member having a gas supply passage adapted to receive gas from the lower end of the gas tubing, a flow responsive valve member adapted to engage said valve seat, said valve member having an opening therethrough communicating with said gas supply passage whereby said valve is seated by flow from said gas supply passage through said valve, and when so seated connects said gas supply passage to said first chamber, said valve when seated being effective to block flow from said first chamber to said low pressure space, and means for periodically supplying gas under pressure to said gas supply passage from said gas tubing to cause said valve to periodically engage said seat.

3. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a valve adapted to engage said seat and thereby block flow through said passageway between the chamber and said low pressure space, an expansible bellows having one end fixed to said valve in axial alignment therewith, a support for the opposite end of the bellows, said valve and sup-

port having openings communicating with the interior of said bellows, and means for periodically supplying gas under pressure to said opening in said support from said gas tubing to cause said valve to periodically engage said seat, said valve and seat being so arranged that when the valve is seated the gas supplied to said support opening flows through said bellows and said valve into said chamber and such flow holds said valve seated.

4. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a valve adapted to engage said seat and thereby block flow through said passageway between the chamber and said low pressure space, an expansible bellows having one end fixed to said valve in axial alignment therewith, a support for the opposite end of the bellows, said valve and support having openings communicating with the interior of said bellows, said valve and bellows assembly including resilient means normally tending to disengage said valve from its seat, and means for periodically supplying gas under pressure to said opening in said support from said gas tubing to cause said valve to periodically engage and disengage said seat, said valve and seat being so arranged that when the valve is seated the gas supplied to said support opening flows through said bellows and said valve into said chamber and such flow holds said valve seated.

5. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a gas supply passage, a flow responsive valve member adapted to engage said seat, said valve member having an opening therethrough communicating with said gas supply passage whereby said valve is seated by flow from said gas supply passage through said valve and when so seated connects said gas supply passage to said first chamber, said valve when seated being effective to block flow from said first chamber to said low pressure space, and means for periodically supplying gas under pressure to said gas supply passage from said gas tubing to cause said valve to periodically engage said seat, a second valve for controlling said gas supply passage, and pressure operated means for periodically opening and closing said second valve including a second chamber communicating with said means, said second chamber having a restricted inlet communicating with said gas tubing and an outlet having less restrictive effect than said inlet, a third valve for controlling communication between said inlet and outlet of the second chamber, and means

operable in response to a predetermined pressure in said second chamber for opening said valve and effective when the pressure drops to a lower value to close said valve.

6. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a valve adapted to engage said seat and thereby block flow through said passageway between the chamber and said low pressure space, an expansible bellows having one end fixed to said valve in axial alignment therewith, a support for the opposite end of the bellows, said valve and support having openings communicating with the interior of said bellows, said valve and bellows assembly including resilient means normally acting to disengage said valve from its seat, a fourth passageway connecting said opening in the support with the gas tubing, a second valve for controlling the fourth passageway, and pressure operated means for periodically opening and closing said second valve including a second chamber communicating with said means, said second chamber having a restricted inlet communicating with said gas tubing and an outlet having less restrictive effect than said inlet, a third valve for controlling communication between said inlet and outlet of the second chamber, and means operable in response to a predetermined pressure in said second chamber for opening said valve and effective when the pressure drops to a lower value to close said valve.

7. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a valve adapted to engage said seat and thereby block flow through said passageway between the chamber and said low pressure space, an expansible bellows having one end fixed to said valve in axial alignment therewith, a support for the opposite end of the bellows, said valve and support having openings communicating with the interior of said bellows, said valve and bellows assembly including resilient means normally acting to disengage said valve from its seat, a fourth passageway connecting said opening in the support with the gas tubing, a second valve for controlling the fourth passageway, and pressure operated means for periodically opening and closing said valve including a second chamber communicating with said means, said second chamber having a restricted inlet communicating with said gas tubing and an outlet having less restrictive effect than said inlet, a third valve for controlling communication between said inlet and outlet of the second chamber, means operable in response to a predetermined pressure in said second chamber for opening said valve and effective when the pressure drops to a lower value

to close said valve, said last means including a flexible bellows in said second chamber having one end connected to the third valve, a support for the other end of said bellows, the cross-sectional area of said bellows being greater than the effective area of said valve, the space within said bellows being completely sealed from the space within said chamber, and means resiliently urging said valve toward closed position.

8. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a valve adapted to engage said seat and thereby block flow through said passageway between the chamber and said low pressure space, an expansible bellows having one end fixed to said valve in axial alignment therewith, a support for the opposite end of the bellows, said valve and support having openings communicating with the interior of said bellows, said valve and bellows assembly including resilient means normally acting to disengage said valve from its seat, a fourth passageway connecting said opening in the support with the gas tubing, a second valve for controlling the fourth passageway, and pressure operated means for periodically opening and closing said valve including a second chamber communicating with said means, a third chamber having a restricted inlet communicating with said gas tubing, a port connecting the second and third chambers, a third valve for controlling said port, said port when open offering less restriction to gas flow than said inlet opening for the third chamber, an outlet for the second chamber communicating with a low pressure region in said well and having a restrictive effect intermediate that of said third chamber inlet and said port, and means operable in response to a predetermined pressure in said second chamber for opening said third valve and effective when the pressure drops to a lower value to close said valve.

9. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber having inlet and outlet oil passages adapted to communicate respectively with the oil standing in the well and the interior of the oil tubing, check valves in said passageways, means forming a third passageway connecting the chamber at a point above said inlet with the low pressure space outside said oil and gas tubings, said third passageway including a valve seat, a valve adapted to engage said seat and thereby block flow through said passageway between the chamber and said low pressure space, an expansible bellows having one end fixed to said valve in axial alignment therewith, a support for the opposite end of the bellows, said valve and support having openings communicating with the interior of said bellows, said valve and bellows assembly including resilient means normally acting to disengage said valve from its seat, a fourth passageway connecting said opening in the support with the gas tubing, a second valve for controlling the fourth passageway, and pressure operated means for periodically opening and closing said valve including a second chamber communicating with said means, a third chamber having a restricted inlet communicating with said gas tubing, a port connecting the second and third chambers, a third valve for controlling said port, said port when open offering less restriction to gas flow than said inlet opening for the third chamber, an outlet for the second chamber communicating with a low pressure region in said well and having a restrictive effect intermediate that of said third chamber inlet and said port, means operable in response to a predetermined pressure in said second chamber for opening said third valve and effective when the pressure drops to a lower value to close said valve, said last means including a flexible bellows in said third chamber having one end connected to the third valve, a support for the other end of said bellows, the cross-sectional area of said bellows being greater than the effective area of said third valve, the space within said bellows being completely sealed from the space within said third chamber, and means resiliently urging said valve toward closed position.

10. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber fixed to the oil tubing and having an inlet communicating with the oil standing in the well, said chamber having a top closure wall provided with a passage therethrough for the flow of oil into said oil tubing, an outflow tube in said chamber connecting said oil passage to the lower portion of the chamber, a gas flow passage through said wall, a third passage connecting the space above said wall with the space outside said oil tubing, and a gas supply valve mechanism fixed to the gas tubing and removable therewith independently of the oil tubing, said mechanism including means to alternatively supply gas under pressure to said gas flow passage and then connect said gas flow passage to said third passage.

11. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber fixed to the oil tubing and having an inlet communicating with the oil standing in the well, said chamber having a top closure wall provided with a passage therethrough for the flow of oil into said oil tubing, an outflow tube in said chamber connecting said oil passage to the lower portion of the chamber, a gas flow passage through said wall, a third passage connecting the space above said wall with the space outside said oil tubing, and a gas supply valve mechanism fixed to the gas tubing and removable therewith independently of the oil tubing, said mechanism including means to alternatively supply gas under pressure to said gas flow passage, then connect said gas flow passage to said third passage, and check valves in said oil inlet and said oil outflow passages.

12. A gas operated bottom hole intermitter for the uplift of oil through an oil tubing by gas under pressure in a gas tubing associated with said oil tubing, comprising a chamber fixed to the oil tubing and having an inlet communicating with the oil standing in the well, said chamber having a top closure wall provided with a passage therethrough for the flow of oil into said oil tubing, an outflow tube in said chamber connecting said oil passage to the lower portion of the chamber, a gas flow passage through said wall, a third passage connecting the space above said wall

with the space outside said oil tubing, and a gas supply valve mechanism fixed to the gas tubing and removable therewith independently of the oil tubing, said mechanism including means operable in response to a relatively constant gas pressure supply in said gas tubing to alternatively supply gas under pressure to said gas flow passage and then connect said gas flow passage to said third passage.

CHARLES M. O'LEARY.

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