

Sept. 11, 1962

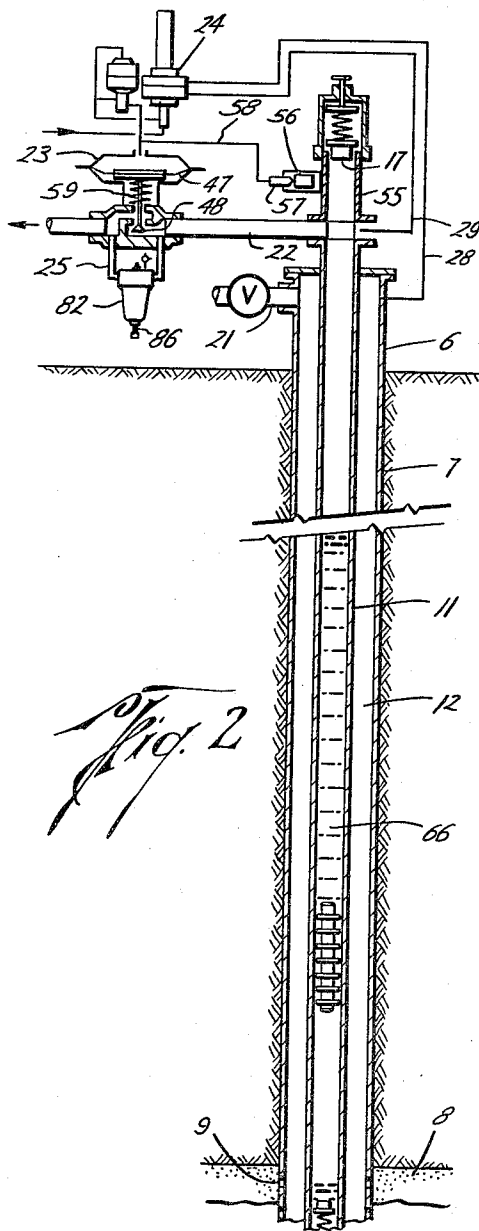
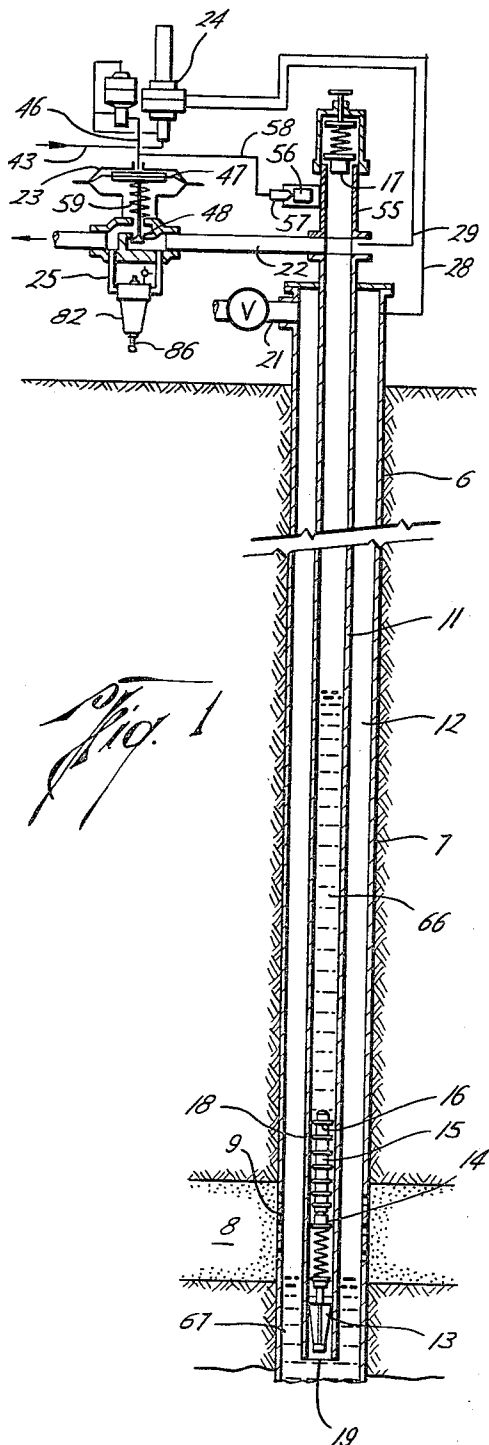
R. W. DINNING ET AL

3,053,188

DIFFERENTIAL CONTROLLER SYSTEM

Filed Dec. 7, 1960

4 Sheets-Sheet 1



Robert W. Dinning
Vernon B. Scott
INVENTORS

BY *Dinning, Simms,
Hyer & Eisenhardt*
ATTORNEYS

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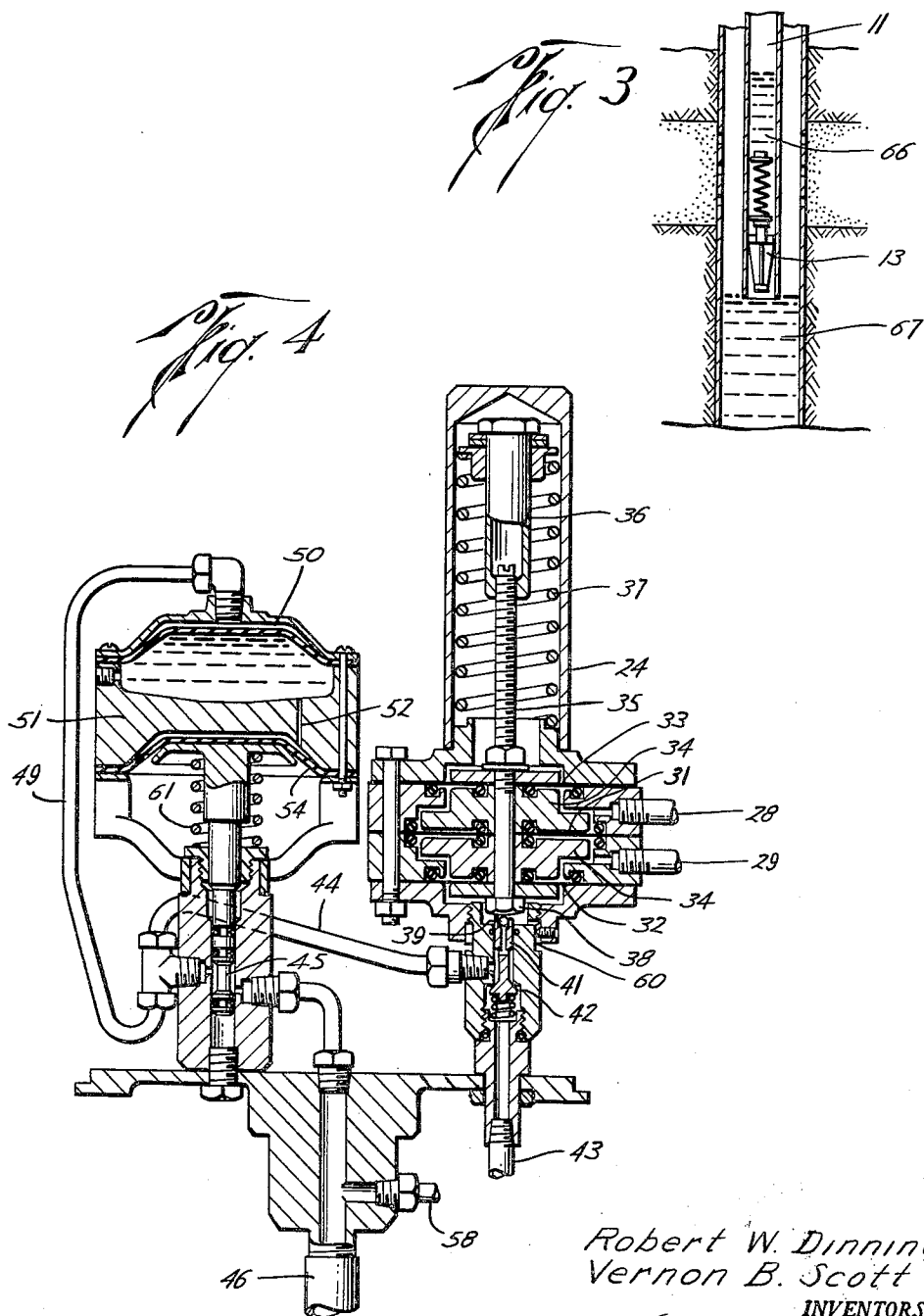
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DIFFERENTIAL CONTROLLER SYSTEM

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4 Sheets-Sheet 2



Robert W. Dinning
Vernon B. Scott
INVENTORS

BY *Dinning, Simms*
Byers & Eisenrodt
ATTORNEYS

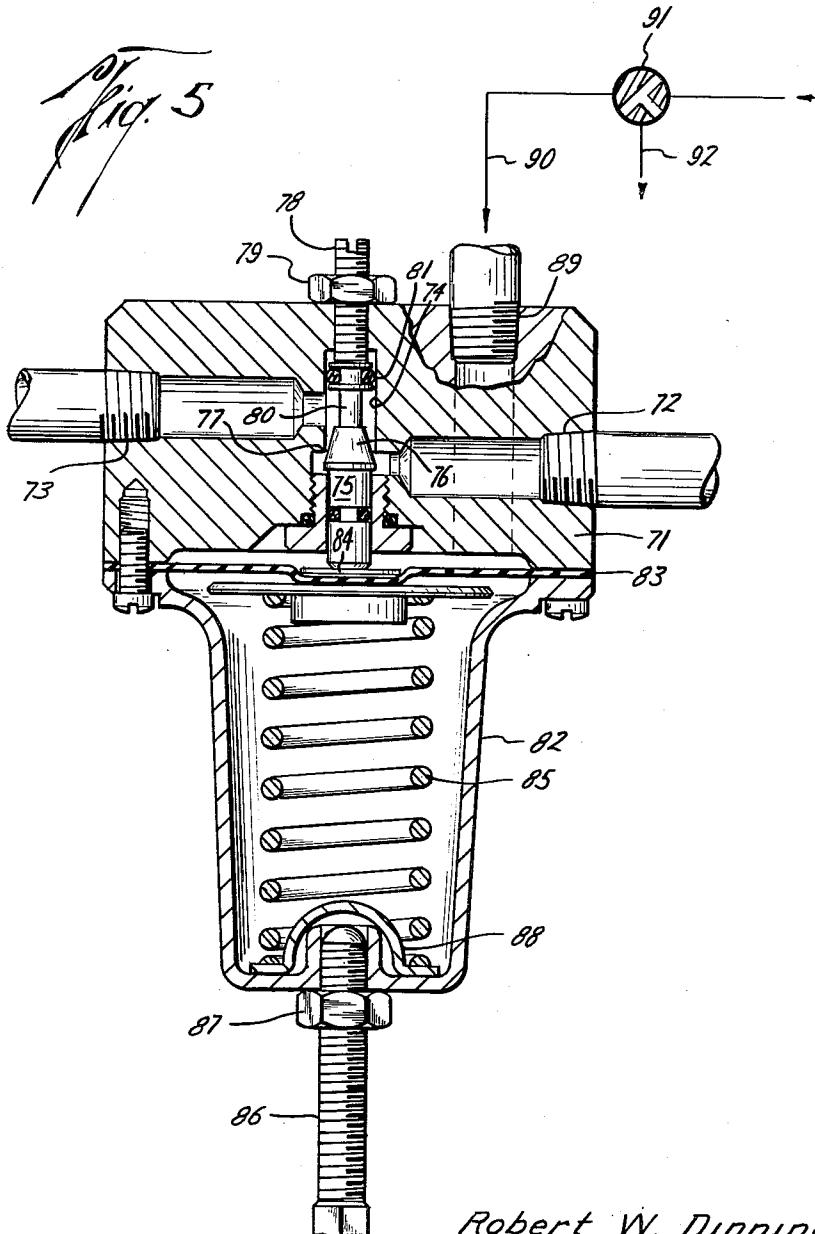
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DIFFERENTIAL CONTROLLER SYSTEM

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4 Sheets-Sheet 3



Robert W. Dinning
Vernon B. Scott
INVENTORS

BY *Browning, Sumner*
Hyer & Eisenhardt
ATTORNEYS

Sept. 11, 1962

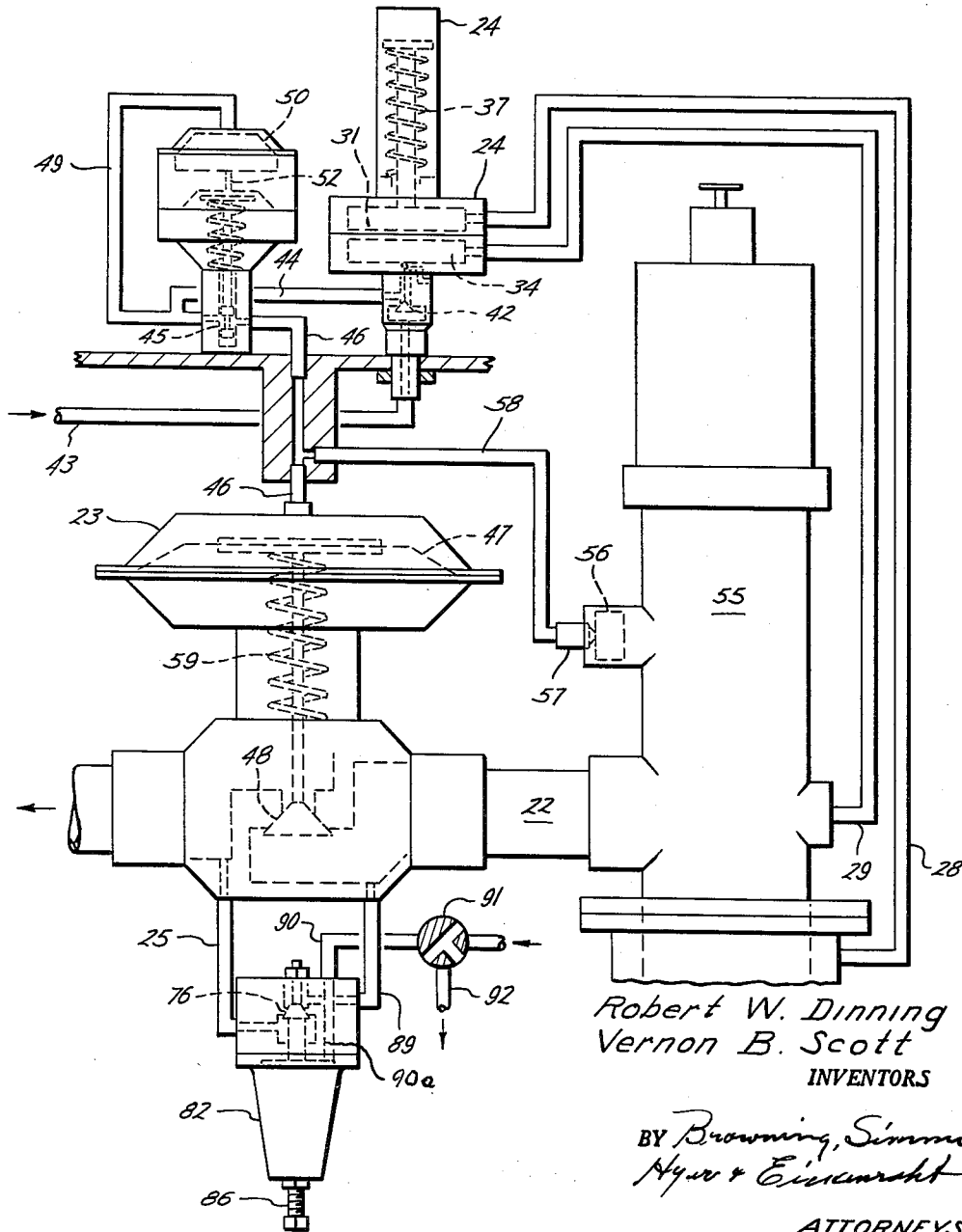
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4 Sheets-Sheet 4

Fig. 6



Robert W. Dinning
Vernon B. Scott
INVENTORS

BY *Browning, Simms,
Hyer & Eisenhardt*
ATTORNEYS

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3,053,188

DIFFERENTIAL CONTROLLER SYSTEM

Robert W. Dinning and Vernon B. Scott, Longview, Tex.,
assignors to U.S. Industries, Inc., New York, N.Y.

Filed Dec. 7, 1960, Ser. No. 74,266

12 Claims. (Cl. 103-52)

This invention is an improved pumping system for removing liquids from wells producing both gas and liquid.

Many gas wells produce both gas and a liquid such as water, oil or condensate but water is the most troublesome of these materials. Water accumulates in the bottom of the well, and as the well fills up with water a considerable back pressure is exerted on the face of the producing formation. This back pressure, due to head of water in the well, may be large enough to substantially stop production of gas or at least to cut down the rate of production to a fraction of what it otherwise would be. Accumulation of oil and condensate has a similar effect, but usually to a lesser degree.

Numerous devices have been developed for removing liquid from gas wells to prevent accumulation of a head which would lower the production of gas. Gas lifts and free piston systems have been suggested for this use, but have required either a constant pressure in the production tubing or in the annulus of the well, or the development of a definite pressure for initiation of operation. Such controls are frequently undesirable as gas pressure in the well often will vary considerably from time to time due to fluctuation in demand for gas passed to a gas sales line.

It is an object of this invention to provide a free piston pumping system for gas wells in which variations in gas pressure within the well do not interfere with pumping operations.

Another object is to provide a system of this class in which a major part of liquid entering the well is accumulated in a liquid production tubing and not in an annulus of the well.

Another object is to provide a system of this class in which the accumulation of liquid in a liquid production tubing may be substantially matched with the rate of production of liquid from a formation by easy manipulation of a control at the surface of the earth.

Another object is to provide improved control mechanism for a free piston pumping system which is responsive to accumulation of liquid in the production tubing.

Another object is to provide a system of this type which is simple in construction, cheap and easy to install and which is rugged and dependable in service.

Other objects, advantages and features of this invention will be apparent to one skilled in the art upon a consideration of the specification, the claims and the drawings.

In the system of this invention, a production tubing is provided extending down in the well into operative contact with liquid filling the bottom of the well. A free piston is disposed in the production tubing for reciprocating travel between a location adjacent to the bottom of the tubing and an upper location adjacent to the surface of the earth. The upper location is preferably in a conventional lubricator extending above the well head. Top and bottom bumpers, preferably of spring type, are installed in the tubing and provide upper and lower limits of travel for the free piston.

The production tubing has an opening at a level below the lower limit of travel of the piston exposing a lower surface of the piston to pressure from fluid in an annulus of the well outside the tubing.

The bottom of the tubing preferably is open and the lower bumper assembly is of a type having openings of

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relatively large area therethrough providing free flow of fluid from the annulus of the well into the interior of the production tubing and exposing the lower surface of the piston to full pressure from fluid in the annulus of the well at all times.

Any type of free piston may be used in this system, but we prefer a simple loose fitting type which has no passageway for liquid through the piston and has no valves. Pistons of this simple type are readily available on the market and ordinarily comprise merely a hollow, substantially cylindrical body surrounded by a number of annular flanges extending outward into loose fitting relationship with the inner wall of the production tubing.

A restricted passageway for liquid connects the interior of the tubing at a point above the piston, when the piston is at its lower limit of travel, with the annulus of the well at a point below a normal liquid level in the annulus. Preferably, this passageway for liquid is merely a narrow annulus within the tubing between the outward projecting flanges of the preferred type of piston and the wall of the production tubing, but many types of passageways may be used such as a bypass mandrel having a bypass extending around the piston when the piston is of the type that makes sealing contact with the inner wall of the production tubing, or may be merely a small opening through the side of the production tubing at a point above the piston at its lower limit of travel when the tubing extends deeply into liquid in the well.

A means for bleeding gas from an upper part of the tubing is provided. This bleeding means preferably is an adjustable self-cleaning choke and may be installed at any location adjacent to the surface of the earth where it is effective to bleed gas from the upper part of the tubing. It is much preferred that this means be adjustable so that an operator at the surface of the earth may select a rate at which gas is bled from the tubing to correspond with a rate of accumulation of liquid in the well.

Bleeding gas from an upper part of the production tubing causes an increasing pressure differential between gas in the annulus of the well and gas in the upper part of the production tubing. The pressure differential causes liquid to be forced from the bottom of the well into the production tubing above the piston, through the restricted passageway. Increase of this gas pressure differential at a rate substantially corresponding to a rate of increase in liquid head in the lower part of the production tubing equivalent to an increase in head that would result from introduction of all liquid produced from the formation into the production tubing results in accumulation of liquid in the interior of the production tubing rather than in the annulus of the well. The principle employed is that of a U-tube. Gas pressure in the annulus above the liquid plus the head of liquid in the annulus above the lowest part of the passageway connecting the well annulus with the interior of the production tubing is equal to gas pressure in the upper part of the production tubing plus the head of liquid within the tubing.

A means for releasing gas pressure in the upper part of the tubing in response to a selected pressure differential between gas in an upper part of the tubing and gas in the annulus of the well outside the tubing is provided. This means for releasing pressure preferably includes a motor valve installed in an outlet line from the production tubing and a controller responsive to a selected pressure differential between gas in the upper part of the production tubing and gas in the annulus of the well arranged to open the motor valve widely when a predetermined selected pressure differential is reached. Wide opening of the motor valve results in venting the upper part of the production tubing to a greatly reduced pressure, which may be substantially atmospheric pressure,

and thus causes a very large pressure differential between the upper part of the tubing and bottom hole pressure exerted on the lower part of the free piston. As a result of this large pressure differential, the free piston is driven upward pushing a slug of liquid ahead of it and discharges the liquid through the outlet line.

A means for closing the motor valve in the outlet line when the piston has reached its upper limit of travel is provided. While a mechanically operated means such as a trigger actuated by contact with the piston may be used, it is preferred to use a short section of non-magnetic stainless steel in a lubricator at the point where the piston reaches its upper limit of travel and to have the piston made of magnetic material, thus permitting a use of a magnetic valve responsive to presence of the piston at its upper limit of travel for closing the motor valve in the outlet line. When the outlet line is closed, gas pressure in the production tubing immediately builds up and becomes substantially equal to that in the annulus of the well outside of the tubing. The piston then drops to its lower limit of travel and remains there until another slug of liquid accumulates in the interior of the production tubing, and gas pressure in the upper part of the tubing falls until the selected pressure differential required to operate the motor valve is reached.

It will thus be seen that this system is responsive only to a differential in pressure between gas in the upper part of the production tube and gas in the casing annulus outside the tubing and that this differential in pressure will be proportional to the differential in liquid head within the tubing and in the well annulus when the bleeding device is set at a rate substantially corresponding to the rate of accumulation of water or other liquid in the well. Variations in pressure in the annulus do not affect the rate of pumping unless these variations are very sharp and short in duration, in which case they may cause some backflow of liquid into the annulus when the pressure in the annulus drops more rapidly than the drop in pressure in the upper part of the tubing.

In the attached drawings, FIG. 1 illustrates diagrammatically a gas well equipped with one type of pumping system of this invention showing the piston at its lower limit of travel and accumulation of liquid in the tubing in response to a bleed of gas from an upper part of the tubing.

FIG. 2 shows the same well installation at a different part of the cycle of operations with the piston on its way to the top of the well pushing a slug of liquid ahead of it and the valve in the outlet line from the production tubing wide open.

FIG. 3 is a schematic drawing illustrating the U-tube principle by which liquid entering the well is accumulated in the production tubing.

FIG. 4 illustrates one preferred type of differential controller in vertical section and illustrates schematically the cooperative association of the controller with other elements of the system.

FIG. 5 is a vertical section through a preferred self-cleaning choke particularly effective in the system described.

FIG. 6 is a more detailed diagrammatic view showing valves and passages in the controller and choke.

In the drawings the reference numeral 6 designates generally a well producing both gas and a liquid such as oil, condensate or water. The well has a casing 7 penetrating a producing formation 8 and perforated at the formation to permit fluids to flow from the formation into the interior of the well.

A liquid production tube 11 is disposed, preferably centrally, in the casing and with the casing 7 delimits an annulus in the well. Liquid entering the well from formation 8 through perforations 9 accumulates in the bottom of the well.

A suitable stop 13 is disposed near the bottom of production tubing 11 and carries a bumper 14, preferably

of spring type, which serves to limit downward travel of a piston 15 disposed for reciprocating movement in the interior of the liquid production tubing 11 and to absorb the impact of the piston. A similar bumper 17 is disposed to limit upward movement of piston 15, preferably in a lubricator above the well head as shown.

Piston 15 may be any type desired. In the preferred form illustrated it is a simple hollow cylinder having a plurality of outward projecting flanges 16 loosely fitting in the interior of tubing 11. The loose fit of the flanges 16 leaves a restricted passageway 18 for liquid which permits liquid to flow from the bottom of the well through the open bottom 19 of tubing 11 past the stop 13 and bumper 14 and around flanges 16 to the interior of the tubing above the body of the piston 15 under the influence of a small differential in pressure between the interior of tubing 11 and the annulus of the well.

Gas produced from formation 8 passes upward through the annulus of the well to a valved line 21 through which it is withdrawn to sales or utilization as desired. Withdrawal of gas through line 21 is controlled according to practices well known in the gas well art to prevent the well from running wild and destroying its productivity. Withdrawal normally will be at such rate that at least 100 p.s.i.g., and usually at least 300 to 400 p.s.i.g., is maintained in annulus 12 at all times. A liquid outlet line 22 communicates with the interior of the production tubing 11 at a point above the well head and a motor valve, designated generally as 23, is disposed in this line to open the line widely in response to pressure of actuating gas applied by operation of a controller designated generally as 24. Motor valve 23 preferably is closed by spring pressure which becomes effective when pressure of actuating gas is vented from a diaphragm in the motor valve.

A means for bleeding gas from an upper part of the liquid production tubing and that part of line 22 between the valve and production tubing is illustrated as a bypass line 25 connected around motor valve 23 and containing a bleed means which preferably is an adjustable self-cleaning choke 82 installed to bleed gas from line 25. A preferred type of choke is illustrated in detail in FIG. 5.

Therein the reference numeral 71 designates a body member having inlet and outlet ports 73 and 72, respectively, located in offset relationship to each other. The inlet and outlet ports communicate with each other through a central choke bore 74. A choke member comprising a stem 75 and a head 76 are disposed in bore 74 for reciprocating movement between a position in which the head 76 is in contact with an annular shoulder 77 on the body surrounding the bore 74 and a fully opened position. An annular sealing member is disposed to surround the stem 75 to prevent leakage around the stem.

An adjustment screw 78 having means for locking it in position illustrated as a nut 79 is threaded into the bore 74. Adjustment screw 78 carries a central pin 80 in opposed relationship to head 76. The minimum spacing between the shoulder 77 and head 76 is limited by the position of pin 80. An annular seal illustrated as an O-ring is disposed around adjusting screw 78 to prevent leakage around the screw.

A spring housing 82 preferably of belled shape is attached to the side of body 71 opposite adjusting screw 78. Diaphragm 83 is disposed across housing 82 and carries a stem contact member 84 in position to bear upon the end of stem 75 of the choke member. A spring 85 is disposed to apply pressure upon diaphragm 83 and stem contact member 84 and means for adjusting the spring pressure also is provided. This means is illustrated as a screw 86 disposed to apply pressure upon a spring retaining member 88 and equipped with means for locking the screw in place, illustrated as a lock nut 87.

A port 89 and passageway 90a are also provided in the body member 71 leading to a space between dia-

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phragm 83 and a surface of body member 71 opposed thereto. A line 90 is connected to port 89 and to a source of actuating fluid under pressure (not shown). Line 90 preferably has valve means suitable for applying pressure to diaphragm 83 and releasing pressure from the diaphragm, illustrated as a three-way valve 91 but which may be of any desired form.

In operation sufficient pressure is applied to spring 85 by adjustment of screw 86 so that stem 75 is forced upward to bring head 76 into contact with pin 80. The desired distance between shoulder 77 and head 76 is obtained by setting of screw 78. The choke is thus held in static position without regard to the pressure that may exist in line 22, and gas will be bled from the upper part of the liquid production tubing 11 at a substantially uniform rate.

The choke can be set at any desired position by manipulation of adjusting screw 78 which can then be locked in place by tightening lock nut 79 and need not be adjusted further until there is some major change in well conditions.

Port 89 and diaphragm 83 provide a self-cleaning feature for the choke. Accumulation of petroleum waxes and other materials that would tend to clog the choke is easily prevented by occasionally admitting pressure through line 90 and port 89 to the upper side of diaphragm 83. This pressure and the size of diaphragm 83 are chosen so that the total force exerted on the upper side of the diaphragm is sufficient to overcome the force exerted by a spring 85 and compress the spring. Compression of the spring relieves pressure on stem 75, and pressure in the central bore 74 on head 76 moves the entire choke to its limit of travel, thus allowing increased flow of fluid through inlet 73 and outlet 72 to perform a flushing action on the entire interior of the choke. When the choke has been flushed, pressure is vented from the upper side of diaphragm 83 as, for example, by the three-way valve 91 and vent 92 illustrated.

The spring 85 then forces the choke downward into contact with pin 80 and the choke again functions to bleed gas from the upper part of liquid production line 11 at constant rate.

The adjustable feature of this choke permits an operator to bleed gas from the interior of liquid production tube 11 at a selected rate easily matched with a rate of production of liquid from the formation.

A preferred type of controller which operates in response to a selected pressure differential between the upper part of the production tubing and the annulus of the well to supply actuating gas to the motor valve is illustrated in FIG. 4. Lines 28 and 29 communicating with gas under pressure in the well annulus and in the upper part of the liquid production tubing, respectively, are connected to the body of the controller.

The body of the controller contains three parallel diaphragms 31, 32 and 33, respectively, which are separated by block members 34. A suitable bolt 35 extends centrally through block members 34 and carries an adjustable member 36 adapted to apply a selected pressure to spring 37. Bolt 35 is thus maintained in tension by pressure of spring 37 tending to force the diaphragms upward. The effective diameter of diaphragm 31 is much greater than that of diaphragms 32 and 33, and as a result the pressure of spring 37 will be overcome and the diaphragms and supporting block members will be moved downward when a pressure differential between lines 28 and 29 applied to the effective area of diaphragm 31 becomes large enough to overcome spring pressure. Downward movement results first in contact of a head 38 of bolt 35 with a ball 39 of a ball check valve having a movable valve seat 41. Pressure exerted on the ball 39 moves valve seat 41 downward into contact with a valve closure member 42 disposed to control flow through an inlet line 43 connected to a supply of actuating gas (not shown). The actuating gas then flows through line 43 around the valve closure member 42 through line 44, a

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shuttle valve 45, and line 46 into an upper part of the housing of motor valve 23 where gas pressure is applied to diaphragm 47 to open valve closure member 48 widely.

Wide opening of valve closure member 48 vents gas pressure from the upper part of production tube 11 very quickly and causes a large differential in pressure between the upper part of tubing 11 and bottom hole pressure exerted on a lower surface of piston 15. The free piston is driven to the well head by this large differential in pressure and pushes a slug of liquid ahead of it to be discharged through the liquid outlet line 22.

Line 44 carrying actuating gas also communicates with line 49 disposed to apply pressure on the upper side of the diaphragm 50 in an actuator for the shuttle valve 45. This actuator has a transverse plate 51 having small opening 52 therethrough and is filled with liquid between diaphragms 50 and 54. The opening 52 is small in size and serves as a timing device which initially insures that shuttle valve 45 shall remain open long enough to permit the housing of motor valve 23 to be pressurized fully before inflow of actuating gas is cut off by operation of shuttle valve 45.

A means for repressurizing the interior of liquid production tubing 11 is illustrated as a magnetic valve disposed adjacent to a non-magnetic section 55 of a lubricator at the well head. Section 55 is preferably made of one of the non-magnetic stainless steels but any non-magnetic material which is strong enough for the service may be used. The magnetic valve comprises a movable magnet adapted to be moved toward the lubricator by attraction to piston 15 when piston 15 is at its upper limit of travel. This magnet is designated by the reference numeral 56 and is normally retracted in position to close a bleed valve 57 connected in line 58 to vent pressure from the upper side of diaphragm 47 when the piston is at the well head.

Removal of pressure from diaphragm 47 permits spring 59 to move valve closure member 48 upward into closed position. Pressure of gas issuing from the formation and entering the liquid production tubing at its open bottom quickly establishes equilibrium between the pressure in the annulus of the well and inside the production tubing. When the pressure is equalized the pressure applied on opposite sides of diaphragm 31 also is equalized through lines 28 and 29 and spring 37 moves the diaphragm assembly upward releasing pressure on ball 39 and venting pressure from diaphragm 50 through lines 49 and 44 and in an axial opening through the movable valve seat 41 and a vent 60. With the removal of pressure from the upper side of diaphragm 50 spring 61 moves diaphragm 54 upward, forcing liquid through the small opening 52 into a space beneath diaphragm 50. The ensuing time lag insures that valve member 42 in the actuating fluid inlet line 43 will be seated before shuttle valve 45 comes into position to connect lines 44 and 46 thus preventing premature application of gas pressure to the upper side of diaphragm 47 in motor valve 23.

One complete cycle of pumping operations will now be described, assuming that the free piston 15 has just dropped to the bottom of the well, valve closure member 48 has seated to close outlet line 22, pressures in annulus 12 and production line 11 are substantially equal, gas is being withdrawn via line 21 at a rate to maintain a high pressure in annulus 12, and choke 82 is bleeding off pressure in production line 11 and that part of line 22 between the production line and valve 23 at a selected rate.

Gas and liquid are driven by formation pressure from the formation 8, through openings 9 in casing 7, into the well annulus 12. Since gas pressure in the production tube is constantly being reduced by action of the choke 82, pressure in the production tube soon becomes appreciably less than pressure in the well annulus 12. Under these conditions, pressure of gas in the well annulus is exerted upon the surface of liquid in the bottom of the well, forcing the liquid through open bottom

19 of tube 11, past bumper stop 13 and bumper 14, through the restricted passageway 18 around flanges 16 of the free piston into the production tube above the piston. So long as choke 82 is set to reduce gas pressure in the upper part of production tube 11 at substantially the same rate that liquid produced by the well can increase liquid head in the production tube, there is substantially no accumulation of liquid in the well annulus where it is in contact with the face 9 of the producing formation. The liquid accumulates in the production tube above the free piston.

When gas pressure in the upper part of the production tube, above liquid therein, decreases sufficiently to produce a predetermined pressure differential between that gas and gas in the well annulus, the controller operates to unseat closure member 48 opening valve 23 widely.

The controller operates in the following manner to open the valve. Lines 28 and 29 communicate with the well annulus 12 and the production tube 11, respectively, and with the interior of the controller housing on opposite sides of diaphragm 31, as is best shown in FIG. 4. A spring 37 is suitably attached so that it exerts a selected force on diaphragm 31 which is additive to the force exerted thereon by gas admitted through line 29 from the upper part of the production tube. The force exerted by spring 37 is, of course, much less than that exerted by gas from the annulus of the well admitted by line 28 tending to move diaphragm 31 in the opposite direction.

It will be seen that, as pressure in the upper part of the production tube is bled off, a point will be reached where the pressure of gas from the production tube plus the force from spring 37 will be overcome by pressure of gas from the well annulus and the diaphragm 31 will be moved in a direction illustrated as downward in FIG. 4.

Movement of diaphragm 31 downward first seats a valve closure member illustrated as a ball 39 upon a movable valve seat 41, thus cutting off communication of a passageway within valve seat 41 with a vent 60. Continued downward movement of the diaphragm results in the movable valve seat 41 being forced against and unseating valve closure member 42, disposed to control supply of actuating gas to motor valve 23. When the valve closure member 42 is unseated, activating gas under pressure flows from a source (not shown) through line 43, line 44, shuttle valve 45, and line 46 into the upper part of the housing of valve 23 where it is effective to depress diaphragm 47 to open the valve widely.

At the same time actuating pressure is applied to valve 23, it is also applied through line 49 to the upper side of an actuator disposed to move shuttle valve 45 longitudinally. Diaphragms 50 and 54 of the actuator move downward slowly as liquid between plate 51 and diaphragm 50 flows through the small opening 52 to the underside of plate 51 where it is held by diaphragm 54. Movement of the diaphragms and plate downward results in moving shuttle valve 45 longitudinally to a position cutting off communication between lines 46 and 43; but since the upper part of the housing of valve 23 and line 46 contain gas under pressure, valve 23 remains wide open.

Opening of valve 23 results in immediate lowering of pressure in the upper part of production tube 11 to a very low value, usually to substantially atmospheric pressure. The differential in pressure between gas in the annulus of the well and in the upper part of the production tube is then so great that pressure from the annulus forces the free piston to the top of the well pushing liquid which has accumulated in the production tube to the well head and out through line 22.

On arrival of the piston in the stainless steel section 55 of the well head, a normally closed bleed valve 57 is opened by movement of magnet 56 toward the piston.

Opening this bleed valve releases pressure in line 58; and since line 58 is in permanent communication with line 46, it also releases pressure on diaphragm 47 and permits the return spring 59 to close valve 23.

Under these conditions, pressure of gas in the well annulus and in the production tube is quickly equalized with the result that pressure of gas upon opposite sides of diaphragm 31 also is equalized and this diaphragm snaps back to its upper position. Pressure on ball 39 is released, thus permitting pressure on the top of diaphragm 50 to be vented through lines 49, 44, the opening through movable valve seat 41 and vent 60. Spring 61 then returns diaphragms 50 and 54 and plate 51 to their upper positions very slowly due to flow of fluid from below plate 51 through opening 52 into the space between plate 51 and diaphragm 50, thus slowly moving shuttle valve 45 upward into position to establish communication between lines 44 and 46. The slow upward movement of shuttle valve 45 insures that valve closure member 42 will be seated before the shuttle valve places lines 44 and 46 in communication with each other and so prevents premature application of gas pressure to the upper side of diaphragm 47 in motor valve 23.

Equalization of pressure between gas in the upper part of production tube 11 and the well annulus also removes pressure holding the free piston in the well head section 55. On equalization of the pressure, the piston immediately drops to the bottom of the well and the cycle of operation is repeated.

It will thus be seen that in the system of the present invention no specific pressure in either annulus or tubing is necessary to initiate operation of the free piston. The pressure in the well annulus may vary widely as demand on the gas sales line varies without affecting the pumping operation of the piston. Only the differential between the pressure in the annulus and gas pressure in the upper part of the tubing is significant in initiating the pumping operation.

This system further causes liquid accumulating in the well to accumulate within the liquid production tubing and not in the annulus of the well where it would exert back pressure upon a producing formation. FIG. 3 illustrates the principle of such accumulation. Water, oil, distillate or other liquid entering the well fills the well at least to the bottom of the tubing. The tubing of course might have a closed bottom with a number of side openings for admission of liquid but the open bottom is preferred as being cheaper and simpler in construction.

Gas pressure in the annulus of the well exerted upon the surface of liquid in the bottom of the well forces liquid up into the liquid production line. Since the accumulation of liquid in the well ordinarily is rather slow the upward flow also is slow and liquid flows through the narrow clearance 18 around the flanges 16 of the piston and accumulates above the piston in the well in the liquid production tubing until a selected gas pressure differential is set up between the liquid production tubing and the annulus of the well. This pressure differential applied to diaphragm 31 results in opening valve 48. The piston then rises. After discharging its slug of liquid through line 22 the piston begins to drop. As pressure in the upper part of the liquid production tubing is bled off at a rate which corresponds approximately to that at which liquid flows into the well from the producing formation, the head of water accumulating in a water production tubing above a piston of the type described may be determined by assuming the specific gravity of the water to be 1.0, and dividing the volume of water produced by the capacity of the production tubing per foot.

It will be seen that the system can be set to initiate a pumping operation at a differential pressure corresponding to any desired head of liquid in the production tubing; and when the volume of the production tubing and average rate of production of liquid are known, the pumping operations are easily initiated at intervals, controlled by

the bleeding device, so that substantially all liquid entering from the formation is accumulated in the production tubing.

From the foregoing, it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. A system for pumping liquid from a well producing gas and liquid which comprises in combination a liquid production tubing extending down in the well into operative contact with liquid in the well; a free piston disposed for reciprocating travel in the tubing between locations adjacent to the surface of the earth and to the bottom of the tubing; an opening in the tubing at a point below the lower limit of travel of the piston exposing a lower surface of the piston to pressure from fluid in an annulus of the well outside the tubing; a passageway for a liquid within at least one of said piston and production tubing, having restricted cross section in at least a part thereof, connecting the interior of the tubing at the level of the piston when the piston is at its lower limit of travel with the annulus of the well at a level below a normal level of liquid in the well; means for bleeding gas from an upper part of the tubing at a selected rate; and means, responsive to a selected differential in pressure between gas in an upper part of the tubing and the well annulus, for releasing pressure in the upper part of the tubing.

2. A system for pumping liquid from a well producing gas and liquid which comprises in combination a liquid production tubing extending down in the well into operative contact with the liquid in the well; a loosely fitting free piston disposed for reciprocating travel in the tubing between locations adjacent to the surface of the earth and to the bottom of the tubing; an opening in the tubing at a point below the lower limit of travel of the piston exposing a lower surface of the piston to pressure from fluid in an annulus of the well outside the tubing; a passageway for liquid, including a narrow annulus in the production tubing around said loosely fitting piston, connecting the interior of the tubing above the piston with the annulus of the well at a level below a normal level of liquid in the well; means for bleeding gas from an upper part of the tubing at a selected rate; and means responsive to a selected differential in pressure between gas in an upper part of the tubing and in the well annulus, for releasing pressure in the upper part of the tubing.

3. A system for pumping liquid from a well producing gas and liquid which comprises in combination a liquid production tubing extending down in the well into operative contact with liquid in the well; a free piston disposed for reciprocating travel in the tubing between locations adjacent to the surface of the earth and to the bottom of the tubing; an opening in the tubing at a point below the lower limit of travel of the piston exposing a lower surface of the piston to pressure from fluid in an annulus of the well outside the tubing; a passageway for liquid within at least one of said piston and production tubing, having a restricted cross section in at least a part of its length, connecting the interior of the tubing at a level above the piston when the piston is at its lower limit of travel with the annulus of the well at a level below a normal level of liquid in the well; means for bleeding gas from an upper part of the tubing at a selected rate; and

means responsive to a selected differential in pressure in an upper part of the tubing and in the well annulus, for releasing pressure in the upper part of the tubing, including an outlet line from the tubing, a normally closed motor valve in the outlet line, and a controller responsive to a selected pressure differential to supply an opening signal to the motor valve.

4. The system of claim 3 wherein the opening signal is a change in pneumatic pressure transmitted through piping connecting the controller and a motor of the motor valve.

5. A system for pumping liquid from a well producing gas and liquid which comprises in combination a liquid production tubing extending down in the well into operative contact to the liquid in the well; a free piston disposed for reciprocating travel in the tubing between locations adjacent to the surface of the earth and to the bottom of the tubing; an opening in the tubing at a point below the lower level of the travel of the piston exposing a lower surface of the piston to pressure from fluid in an annulus of the well outside the tubing; a passageway for liquid within at least one of said piston and production tubing having restricted cross section in at least a part of its length, connecting the interior of the tubing at a level above the piston when the piston is at its lower limit of travel with the annulus of the well at a level below a normal level of liquid in the well; means for bleeding gas from an upper part of the tubing at a selected rate; means, responsive to a selected differential in pressure between gas in an upper part of the tubing and in the well annulus, for releasing pressure in the upper part of the tubing; and means responsive to the presence of the piston at its upper limit of travel, for restoring pressure in the production tubing.

6. A system for pumping liquid from a well producing gas and liquid which comprises in combination a liquid production tubing extending down in the well into operative contact with the liquid in the well; a free piston disposed for reciprocating travel in the tubing between locations adjacent to the surface of the earth and to the bottom of the tubing; an opening in the tubing at a point below the lower limit of travel of the piston exposing a lower surface of the piston to pressure from fluid in an annulus of the well outside the tubing; a passageway for liquid in at least one of said piston and production tubing having restricted cross section in at least a part of its length, connecting the interior of the tubing at a level above the piston when the piston is at its lower limit of travel with the annulus of the well at a level below a normal level of liquid in the well; means for bleeding gas from an upper part of the tubing at a selected rate; means, responsive to a selected differential in pressure between gas in an upper part of the tubing and in the well annulus for releasing pressure in the upper part of the tubing, including an outlet line from the tubing, a normally closed motor valve in the outlet line, and a controller responsive to a selected pressure differential to supply actuating fluid under pressure to a fluid motor disposed to open said motor valve and means, responsive to presence of the piston at its upper limit of travel for restoring pressure in the production tubing, including a line having a vent therein disposed to vent actuating pressure from said fluid valve motor and a normally seated closure member closing said vent disposed to be moved from said vent when the free piston is at its upper limit of travel.

7. A system for pumping liquid from a well producing gas and liquid which comprises in combination a liquid production tubing extending down in the well into operative contact with liquid in the well, including a lubricator having a section of non-magnetic material extending above the surface of the earth; a free piston disposed for reciprocating travel in the tubing between locations adjacent to the bottom of the tubing and said non-magnetic section of the lubricator; an opening in the tubing at a point below the lower limit of travel of the piston exposing a lower surface of the piston to pressure from fluid in an

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annulus of the well outside the tubing; a passageway for liquid in at least one of said piston and production tubing, having restricted cross section in at least a part of its length, connecting the interior of the tubing at a level above the piston when the piston is at its lower limit of travel with the annulus of the well at a level below a normal level of liquid in the well; means for bleeding gas from an upper part of the tubing at a selected rate, including an adjustable choke; means, responsive to a selected differential in pressure between gas in an upper part of the production tubing and in the well annulus, for releasing pressure in the upper part of the tubing, including an outlet line from the tubing, a normally closed valve in the outlet line, a fluid motor disposed to operate said valve, a controller responsive to a selected pressure differential to supply actuating fluid to said fluid motor to open said valve; and means responsive to the presence of the piston at its upper limit of travel for restoring pressure in the production tubing including a line connected to said fluid motor having a vent therein, a closure member normally closing the vent, and a movable magnet connected to said closure member disposed adjacent to the non-magnetic section of the lubricator to be moved toward the piston when the piston is in said non-magnetic section to open said vent.

8. The system of claim 7 wherein the controller includes a housing, a spring loaded diaphragm in the housing exposed on opposite sides to gas pressure from the tubing and well annulus, means for adjusting spring loading on the diaphragm, a connection to a source of actuating fluid under pressure, a passageway for fluid from said connection to said fluid operated valve motor, and a valve in said passageway disposed to be operated by movement of said diaphragm.

9. The system of claim 8 wherein a second motor valve is disposed to control flow through said passageway to said fluid operated motor valve, and a timing means is

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disposed to close said second motor valve at a predetermined time after the valve operated by movement of the diaphragm opens and to open said second motor valve at a predetermined time after the vent is opened.

10. The system of claim 1 wherein the means for bleeding gas from an upper part of the tubing at selected rate comprises an adjustable choke disposed to bleed pressure from an outlet line connected to an upper part of the tubing.

11. The system of claim 3 wherein the means for bleeding gas from an upper part of the tubing at a selected rate comprises a self-cleaning adjustable choke disposed in a by-pass line connected to said outlet line from the tubing on opposite sides of said normally closed motor valve.

12. The system of claim 1 wherein the means for bleeding pressure from an upper part of the tubing at selected rate includes conduit means connected to said tubing and to an adjustable choke, said choke comprising a body member having inlet and outlet ports therein, said inlet and outlet ports communicating with each other through a choke bore, a shoulder on the body surrounding said choke bore; a choke member movable in said choke bore toward and away from said shoulder; an adjustable limiting pin disposed to limit movement of said choke member toward said shoulder; means for pressing said choke member into contact with said limiting pin; and means for moving said choke member back from the limiting pin and flushing the choke.

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