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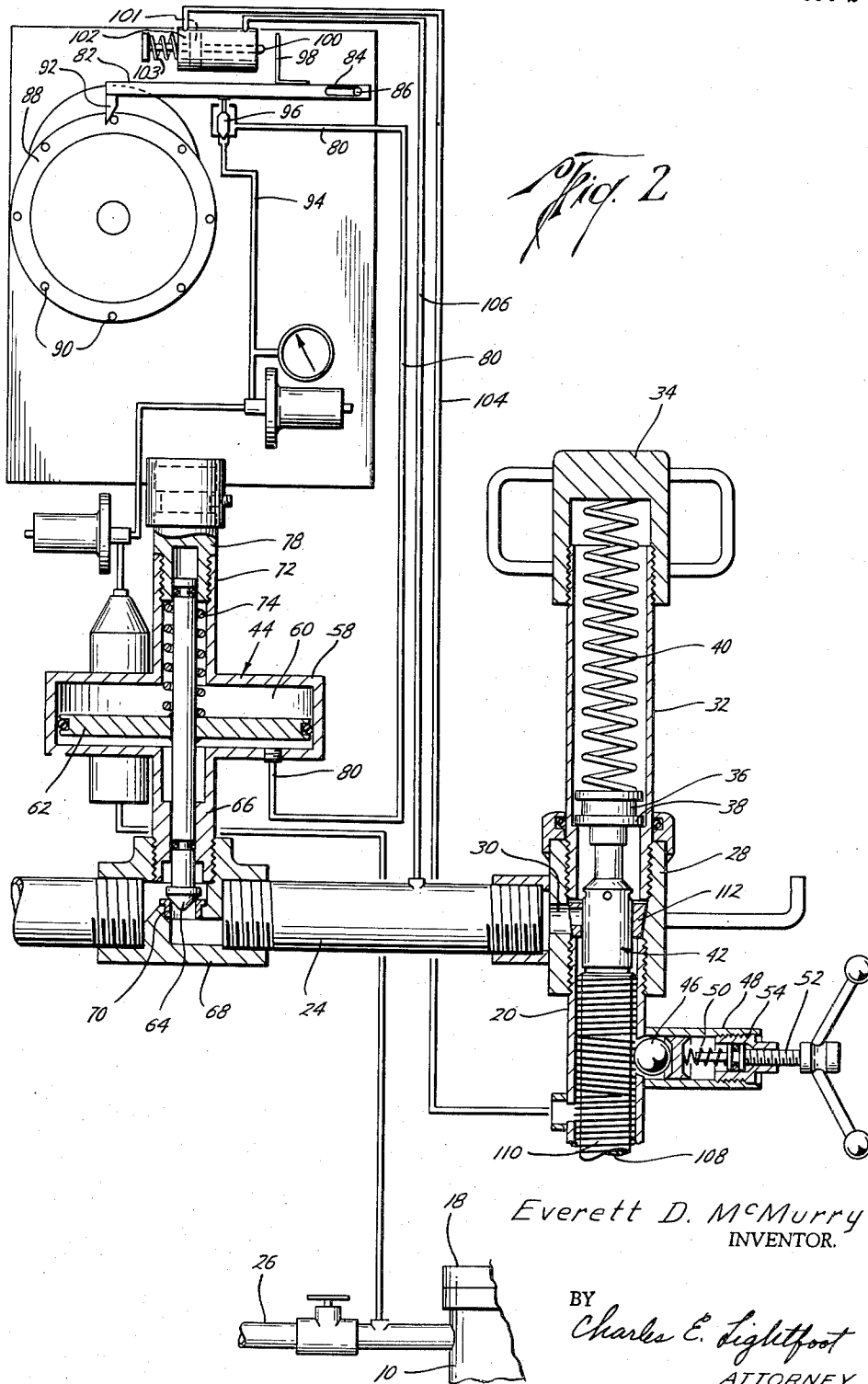
E. D. McMURRY

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WELL PUMPING APPARATUS OF THE FREE PISTON TYPE

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WELL PUMPING APPARATUS OF THE FREE PISTON TYPE

Everett D. McMurry, 600 Hedwig Road, Houston, Tex.

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This invention relates to well pumping apparatus of the free piston type, and more particularly to mechanism for controlling the movements of the free piston in such pumping apparatus.

In the production of oil wells the well fluid is often recovered from such wells by the use of plunger lift equipment employing a free piston which is operated by the pressure of the gas from the formation either alone or supplemented by the pressure of fluid introduced into the well from above. This method of producing wells possesses the advantages over conventional well pumping methods that the equipment is easily applied and operated, the cost of maintenance is greatly reduced, and the equipment may be successfully employed throughout a wide range of well conditions such as variations in well pressure and depth.

As heretofore commonly employed, well pumping apparatus of this type make use of a plunger, which is freely movable in a string of tubing in the well, the plunger travelling the full distance from top to bottom of the tubing. The plunger is frequently provided with a passageway for the flow of fluid from beneath the plunger to above the same and has a valve which is open during the downward movement of the plunger to allow the plunger to pass downwardly freely through the well fluid and which is closed when the plunger reaches bottom to permit the building up of pressure beneath the plunger to force the plunger upwardly together with the column or slug of well fluid in the tubing above the plunger.

Various means have been employed heretofore for regulating the operation of the plunger, such as means for opening the valve of the plunger when the plunger reaches the limit of its upward movement in the tubing or other means for causing the pressure above and beneath the plunger to be balanced or equalized to permit free downward movement of the plunger in the tubing.

In the operation of well pumping equipment of this type, fluid under pressure is often introduced into the well casing surrounding the tubing to augment or regulate the pressure in the well which is effective to move the plunger upwardly.

The cycling of the plunger is frequently controlled by the opening and closing of a motor valve located in the eduction pipe through which well fluid is conducted from the well, this motor valve being opened after the plunger has reached bottom to cause a reduction in the pressure in the tubing above the plunger to permit the plunger to be moved upwardly by the pressure in the well beneath the plunger and being closed when the plunger reaches the limit of its upward movement to permit the pressure above and beneath the plunger to become equalized to allow the plunger to return to the bottom. The opening and closing of the motor valve in equipment of this kind is usually controlled by suitable timing mechanism, the motor valve being opened after the plunger has reached bottom and being closed after a predetermined time interval.

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One disadvantage possessed by well pumping apparatus of the plunger type wherein the opening and closing of the motor valve is controlled by timing mechanism is that the time required for the plunger to move from the bottom to its uppermost position in the tubing may vary substantially from time to time during the operation of the well, depending upon the pressure of fluid in the well and the amount of fluid in the column above the plunger when the plunger begins its upward movement. At times variations in the well pressure and in the amount of fluid which is moved upwardly by the plunger during each cycle of its operation are sufficient to cause the plunger to reach the top substantially before the timing mechanism causes the motor valve to close, so that the outflow of well fluid lifted by the plunger is followed by an outflow of gas under pressure flowing through or past the plunger until the motor valve closes, resulting in a substantial loss of gas when the plunger reaches the limit of its upward movement before the time mechanism functions to close the motor valve.

The present invention has for an important object the provision of control mechanism for well pumping apparatus of the free piston type embodying means operable immediately upon the arrival of the well plunger at the limit of its upward movement in the well tubing to cause equalization of the pressure in the tubing above and beneath the plunger to permit the plunger to return to the bottom.

Another object of the invention is the provision of well pumping apparatus of the free piston type having a well plunger positioned in a well tubing for upward and downward movement throughout the length of the tubing, and whose movements are controlled by a motor valve in the outflow line from the tubing in response to timing mechanism for opening and closing the motor valve, and including means for causing the motor valve to close independently of the timing mechanism when the plunger reaches the limit of its upward movement in the tubing.

A further object of the invention is to provide well pumping apparatus of the free piston type having a well plunger positioned in a well tubing for upward and downward movement throughout the length of the tubing and whose movements are controlled by a motor valve in the outflow line from the tubing in response to timing mechanism, and wherein means is provided for effectively shutting in the well in the event of failure of the motor valve to close.

Another object of the invention is the provision of well pumping apparatus of the free piston type having a well plunger which is movable upwardly and downwardly within a well tubing throughout the length of the tubing, a motor valve in the outflow line from the tubing, timing mechanism for opening the motor valve when the plunger is at the bottom of the tubing and means operable independently of the timing mechanism for causing the motor valve to close when the plunger reaches the limit of its upward movement in the tubing.

A further object of the invention is to provide well pumping apparatus of the kind referred to having timing mechanism for opening and closing the motor valve in the outflow line from the tubing at predetermined intervals and also having means for closing the motor valve independently of the timing mechanism when the plunger reaches the limit of its upward movement in the tubing.

Another object of the invention is the provision of well pumping apparatus of the type mentioned having plunger actuated means for closing the motor valve in the outflow line from the tubing when the plunger reaches the limit of its upward movement in the tubing, and having timing mechanism for opening and closing the motor valve and by which the motor valve is closed to

permit equalization of the pressure in the tubing above and beneath the plunger to allow the plunger to return to the bottom in the event of failure of the plunger actuated means.

A still further object of the invention is to provide well pumping apparatus of the free piston type, which is of simple design and rugged construction and which is economical in operation.

The above and other important objects and advantages of the invention may best be understood from the following detailed description constituting a specification of the invention when considered in conjunction with the annexed drawings, wherein—

Figure 1 is a fragmentary side elevational view, on a reduced scale partly in cross-section and partly diagrammatic, illustrating a preferred embodiment of the invention and showing the same applied to a well;

Figure 2 is a side elevational view, partly in cross-section and on a somewhat enlarged scale illustrating the plunger controlling mechanism of the invention and showing the condition of the mechanism when the plunger has reached the limit of its upward movement in the well tubing; and

Figure 3 is a side elevational view, partly in cross-section, and on an enlarged scale illustrating a preferred form of the well plunger employed in the invention.

Referring now to the drawings in greater detail the invention is illustrated herein in connection with its use on a well, such as an oil well having a well casing 10 positioned in a well bore 12 and extending into an oil bearing formation 14 from which oil and gas or other well fluid may enter the casing through the usual perforations 16 or other suitable means. The casing 10 is provided at its upper end with a closure 18 through which a tubing string 20 is in communication at its lower end with the interior of the casing 10 and may be provided with a tubing stop or retainer 22 or other suitable device within the lower end of the tubing.

Above the upper end of the casing the tubing has an outflow pipe 24, through which well fluid may flow from the tubing. A pipe 26 is also provided which opens into the interior of the casing and which leads to any suitable source of fluid under pressure from which such fluid may be supplied to the casing to pressurize the casing should this be desired.

The tubing 20 has at its upper end a tubular assembly commonly called a lubricator which includes a tubular coupling element 28 provided with a port 30 with which the outflow pipe 24 is connected, and a tubular extension 32 connected at its lower end to the upper end of the coupling 28 and closed at its upper end by a cap 34. Within the extension 32 a follower 36 is movably positioned and the extension is provided with an internal shoulder 38 with which the follower is engageable to limit downward movement of the follower in the extension. Above the follower a coil spring 40 is disposed in the extension which spring is seated at its lower end on the follower 38 and at its upper end on the cap 34.

A plunger, generally designated 42, is movably disposed in the tubing 20 for vertical movement therein, which plunger has a fit in the tubing to permit the plunger to travel freely between the top and bottom of the tubing. The plunger may be of conventional construction, either solid or having a passageway longitudinally there-through within which a by-pass valve may be located having valve stems extending upwardly and downwardly beyond the ends of the plunger so that the valve will be closed by contact of the lower valve stem with the retainer when the plunger reaches bottom and opened by contact of the upper valve stem with the follower 36 when the plunger reaches the limit of its upward movement.

A motor valve, generally designated 44, is provided for the outflow line 24, which is operable to close the

outflow line when the plunger has reached the limit of its upward movement and which opens when the plunger is at the bottom. Suitable timing mechanism described in detail hereinafter, is provided by which the motor valve is opened and closed at predetermined time intervals.

The arrangement of the equipment is such that the plunger 42 may move downwardly in the tubing when the motor valve 44 is closed, the plunger passing downwardly through the column of well fluid in the tubing above the lower end of the tubing, until the plunger reaches bottom. Upon opening of the motor valve after the plunger reaches bottom, the pressure in the well entering the lower end of the tubing builds up beneath the plunger to lift the plunger with the column or slug of fluid above the plunger to the top of the tubing.

As the plunger approaches the upper limit of its movement the fluid above the plunger in the tubing passes out through the outflow line 24, the motor valve being open. When the plunger reaches the limit of its upward movement the motor valve will be made to close, so that the pressure in the tubing above and beneath the plunger may become equalized by passage of fluid about or through the plunger, whereupon the plunger may again return to the bottom.

Suitable means is provided for releasably holding the plunger 42 in its uppermost position in the tubing, such as the ball 46, shown in Figure 2, located in a tubular side arm 48, attached to the tubing near its upper end, which ball is urged inwardly by a coil spring 50, whose inward force may be adjusted, as by means of a screw 52 threadably carried in a cap 54 on the outer end of the side arm. By adjusting the screw 52 inwardly the ball 46 may be engaged with the plunger to hold the plunger against downward movement in the tubing.

The motor valve 44, in the present illustration, has a body housing 58 provided with a pressure chamber 60 within which a piston 62 is movably positioned and to which a valve 64 is attached. Beneath the chamber 60 the body housing has a lower extension 66 which is threadably connected at its lower end to a coupling element 68 forming a part of the body housing and within which a valve seat 70 is located through which fluid may flow through the outflow line. The housing also has an upper, tubular extension 72 in communication with the chamber 60 and within which a coil spring 74 surrounds an upper stem 76 on the piston. The spring 74 bears at its lower end on the piston 62 and at its upper end on a cap 78 to yieldingly urge the piston and valve downwardly to close the motor valve.

Fluid under pressure from a suitable source, such as the pipe 26 is supplied to the chamber 60 beneath the piston 62 through a pilot system including a pilot valve 96 and pipe 80, under the control of time controlled pilot mechanism described in detail hereinafter, to open the valve 44. The pressure in the chamber 60, beneath the piston 62 is also relieved through the pipe 80 under the control of timing mechanism to allow the spring 74 to move the piston downwardly to close the motor valve.

The timing mechanism for the motor valve includes a weight arm 82, shown in Figure 2, which is provided with an elongated slot 84 at one end through which a pin 86 is extended to support the arm for vertical swinging movement and for limited horizontal sliding movement. A rotatable timing member 88 is provided, which is rotatable by means of suitable mechanism, such as clockwork, not shown, and which has a number of laterally projecting removable pins or lugs 90 located at suitably spaced intervals peripherally about the member in position to engage a downwardly projecting tapered extension 92 on the arm 82 to move the arm first horizontally and then upwardly about the pin at predetermined time intervals. Pins 90 may be of a structure to hold the weight arm 82 up for a predetermined time, after which the arm 82 falls to close valve 96 which in

turn causes the motor valve 44 to close. By this arrangement the motor valve 44 remains open for a predetermined time, during which the plunger 42 moves upwardly. If the plunger arrives at the upper limit of its movement before motor valve 44 is closed by the timing mechanism the motor valve is made to close by reduction in pressure in the outflow line 24 caused by the arrival of the plunger.

The pipe 80 is connected in communication with a pipe 94 which leads to the pipe 26 and through which fluid under pressure is supplied to the chamber 60 beneath the piston 62 under the control of a pilot valve 96, positioned to be closed when the arm 82 is in its downmost position. The pilot valve 96 is of a conventional type adapted to close off communication between the pipe 94 and pipe 80, and to open the pipe 80 to atmosphere to permit the outflow of fluid from the chamber 60 beneath piston 62 to allow the motor valve to close, when the arm 82 is in the down position, and to establish communication between pipe 80 and pipe 94 to admit fluid under pressure into the chamber 60 beneath piston 62, to open the motor valve when the arm 82 is in the up position.

The arm 82 also has an upwardly extending abutment 98 positioned to be engaged by the outer end of a piston rod 100 of a piston 101 movably positioned in a cylinder 102 to move the weight arm 82 horizontally when the piston rod is extended, to cause the weight arm to move to its down position to close the pilot valve 96, when the plunger 42 arrives at the limit of its upward movement, to permit the motor valve to close. A coil spring 103 is located to coact with the cylinder and piston 101 to urge the piston in a direction to retract the piston rod 100. The interior of the cylinder 102 is connected at one end in communication with the interior of the tubing 20 through a pipe 104, and at the other end in communication with the interior of the outflow line 24 through a pipe 106. By this arrangement, when the plunger 42 arrives at the limit of its upward movement, the plunger will cause a reduction of pressure in the outflow line 24 below the pressure in the tubing 20, so that fluid under pressure from the tubing beneath the plunger will flow through pipe 104 into the cylinder 102 to cause the piston therein to move the piston rod 100 outwardly to engage the abutment 98 to move the weight arm 82 horizontally to move extension 92 past the timing segment or pin 90 allowing the weight arm to move downwardly to close pilot valve 96, whereupon the fluid in chamber 60 beneath piston 62 may flow out through pipe 80 to allow the motor valve 44 to close.

The plunger 42 may be of the solid type having an elongated solid cylindrical body portion 108 of somewhat smaller diameter than the internal diameter of the well tubing 20 and which is provided with an external spiral groove or thread 110 to provide a partial seal between the plunger and the internal wall of the tubing. At its upper end the plunger has an unthreaded cylindrical portion 112 which fits into the coupling element 28 when the plunger is at the limit of its upward movement to cut off the outflow line 24 which results in a reduction in the pressure in the outflow line to cause the motor valve to close. By this arrangement the pressure of well fluid beneath the plunger is prevented from escaping during the upward movement of the plunger, but after the plunger arrives at the top the motor valve will be closed and fluid under pressure from beneath the plunger will then flow past the plunger to equalize the pressure above and beneath the plunger to allow the plunger to return to bottom.

The pumping apparatus may also be employed with a plunger of somewhat modified construction, such as that illustrated in Figure 3, wherein the plunger 42' has a body portion 108' whose external diameter is slightly smaller than the internal diameter of the well tubing and formed or otherwise provided with alternately arranged right and left hand external threads 110' and 110'' to form a more effective partial seal between the plunger and

the internal wall of the tubing. This form of the plunger has a longitudinal passageway 114 therethrough and an internal valve seat 116 surrounding the passageway. A check valve 118 is movably positioned in the plunger for movement into and out of closing relation to the valve seat 116, and this valve is provided with a downwardly extending stem 120 whose lower end is positioned below the lower end of the plunger when the valve is open, and an upwardly extending stem 122 whose upper end extends above the upper end of the plunger when the valve is closed.

It will be apparent that by this construction when the plunger reaches bottom the lower stem 120 will engage the retainer 22 to close the valve 118 to permit the pressure in the well below the plunger to move the plunger upwardly, and when the plunger arrives at the limit of its upward movement the upper stem 122 will engage the follower 36 in extension 32 to open the valve to permit the pressure above and beneath the plunger to become equalized, whereupon the plunger will return to bottom.

To place the equipment in operation the timing mechanism is first set to open and close the motor valve 44 at selected intervals dependent upon previously determined well conditions. For this purpose the rotatable member 88 may be provided with the necessary number of pins 90 spaced at the proper intervals peripherally of the member, so that the extension 92 of arm 82 will be engaged by a pin to first move arm 82 horizontally and then raise the arm at the end of each time interval to open the valve 96 to admit pressure to chamber 60 beneath piston 62 to open the valve 64. The plunger 42 is released in the well tubing with the motor valve closed. As the plunger moves downwardly in the tubing it passes downwardly through the column of well fluid in the tubing, the fluid flowing around the plunger and through the sealing groove 110 until the plunger reaches bottom.

With the plunger at bottom, one of the pins 90 will engage the extension 92 of arm 82 to first move arm 82 horizontally and then raising arm 82 to permit, at the end of the time, valve 96 to open to admit pressure to the motor valve mechanism to open the motor valve, whereupon the pressure of fluid in the well beneath the plunger will move the plunger upwardly with the column or slug of fluid in the tubing above the plunger. As the plunger approaches the upper end of the tubing the column or slug of fluid above the plunger passes out through the outflow line 24.

When the plunger reaches its uppermost position the upper end of the plunger causes a reduction in the outflow of fluid through the opening 30 in the coupling 28, causing a reduction in the pressure in the outflow line 24, whereupon fluid under pressure from the tubing 20 flows through pipe 104 into cylinder 102 to move the piston rod 100 outwardly into engagement with abutment 98 to move weight arm 82 to the right, as seen in Figure 2, so that the arm moves downwardly to close the valve 96 allowing the pressure in chamber 60 beneath piston 62 to pass out through pipe 80 to permit the motor valve to close.

Upon closing of the motor valve the pressure in tubing 20 may leak past the plunger to cause equalization of the pressure above and beneath the plunger, whereupon the plunger again returns to bottom where it remains until the motor valve is again opened by the timing mechanism.

As soon as the motor valve has closed the pressure in the cylinder 102 on opposite sides of the piston will be equalized through pipes 104 and 106 to allow spring 103 to retract the piston rod 100 to permit arm 82 to be moved to the left by the engagement of the next successive pin 90 with extension 92, as seen in Figure 2, at the close of the next time interval to cause the motor valve to open.

It will be apparent that the invention, constructed and operated in the manner described above, possesses the advantage that the motor valve will be closed upon the occurrence of a fall in the pressure in the outflow line 24, so that loss of well pressure during the time that the plunger is in the lubricator is prevented, and in the event of sticking of the plunger in the lubricator or failure of the timing mechanism the pressure of the well will be shut in by closing of the motor valve.

The invention has been disclosed herein in connection with certain specific construction and arrangement of the parts, but it will be understood that these are intended by way of illustration only, and that various changes can be made in the equipment within the spirit of the invention and the scope of the appended claims.

Having thus clearly shown and described the invention, what is claimed as new and desired to secure by Letters Patent is—

1. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a valve for controlling the flow of fluid through the outlet, means for periodically opening and closing the valve, a plunger loosely fitted into the tubing for movement in the tubing between the inlet and outlet and movable upwardly in response to pressure in the tubing beneath the plunger when the valve is open and downwardly under the influence of gravity when the pressure above and beneath the plunger is equalized, means on the plunger positioned to close the outlet when the plunger reaches the limit of its upward movement to cause a decrease in the pressure in the outlet, and means for causing the valve to close upon the occurrence of a decrease in the pressure in the outlet to permit the pressure beneath the plunger to bypass the plunger to equalize the pressure above and beneath the plunger.

2. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a valve for opening and closing said outlet, a plunger loosely fitted into the tubing for movement in the tubing between the inlet and outlet, timing means for periodically opening and closing the valve, said plunger being movable upwardly under the influence of pressure in the tubing beneath the plunger upon opening of the valve and downwardly under the influence of gravity upon equalization of the pressure above and beneath the plunger when the valve is closed to permit the pressure beneath the plunger to bypass the plunger, and means for causing the valve to close independently of said timing means when the plunger reaches the limit of its upward movement.

3. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a valve for controlling the flow of fluid through the outlet, a plunger loosely fitted into the tubing for movement in the tubing between the inlet and outlet, means for periodically opening the valve to permit the plunger to be moved upwardly in response to pressure in the tubing beneath the plunger, means on the plunger positioned to close the outlet when the plunger reaches the limit of its upward movement, and means responsive to a decrease in the pressure in the outlet for closing the valve, to permit an upward flow of fluid from beneath the plunger to above the same to equalize the pressure above and beneath the plunger.

4. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a valve for controlling the flow of fluid through the outlet, a plunger loosely fitted into the tubing for movement in the tubing between the inlet and outlet, means for opening the valve to permit the plunger to be moved upwardly in response to pressure in the tubing beneath the plunger and for closing the valve after the valve has been open for a predetermined time, means on the plunger for

closing said outlet when the plunger reaches the limit of its upward movement and means for causing the valve to close in response to closing of said outlet to permit an upward flow of fluid from beneath the plunger to above the same to equalize the pressure above and beneath the plunger to allow the plunger to move downwardly under the influence of gravity.

5. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a valve for controlling the flow of fluid through the outlet, a plunger loosely fitted into the tubing for movement in the tubing between the inlet and outlet, means for opening the valve to permit the plunger to be moved upwardly in response to the pressure of fluid entering said inlet and for closing the valve after the valve has been open for a predetermined time, means on the plunger for closing said outlet when the plunger reaches the limit of its upward movement and means for closing the valve in response to a reduction in the pressure of fluid in said outlet to permit an upward flow of fluid from beneath the plunger to above the same to equalize the pressure above and beneath the plunger to allow the plunger to move downwardly under the influence of gravity.

6. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a motor valve for controlling the flow of fluid through the outlet, timing mechanism for opening and closing the motor valve, a tubular plunger movable in the tubing between the inlet and outlet, a check valve movably mounted on the plunger for movement under the influence of pressure in the tubing beneath the plunger to close the plunger to cause the plunger to move upwardly in the tubing when the motor valve is open, said plunger having a portion shaped to close the outlet when the plunger reaches the upper limit of its movement, means positioned for engagement with the check valve to open the check valve when the plunger reaches said upper limit to cause equalization of the pressure in the tubing above and beneath the plunger to allow the plunger to move downwardly under the influence of gravity when the motor valve is closed, and means for causing the motor valve to close independently of the timing mechanism upon closing of the outlet.

7. Well pumping apparatus comprising a well tubing having an inlet and an outlet above the inlet, a motor valve for controlling the flow of fluid through the outlet, timing mechanism for opening and closing the motor valve, a tubular plunger movable in the tubing between the inlet and outlet, a check valve movably mounted on the plunger for movement to a position under the influence of pressure in the tubing beneath the plunger to close the plunger when the motor valve is open to cause upward movement of the plunger, said plunger being movable downwardly under the influence of gravity upon equalization of the pressure in the tubing above and beneath the plunger when the motor valve is closed, means positioned for engagement with the check valve to open the check valve when the plunger reaches the upper limit of its movement to cause equalization of the pressure in the tubing above and beneath the plunger, said plunger having a portion shaped to close the outlet when the plunger reaches said upper limit to cause a reduction in the pressure in said outlet when the motor valve is open and means for causing the motor valve to close independently of said timing mechanism upon the occurrence of a reduction of the pressure in the outlet.

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