May 16, 1950 D. G. KNOX ET AL 2,508,174

CONTROL FOR PLUNGER LIFTS

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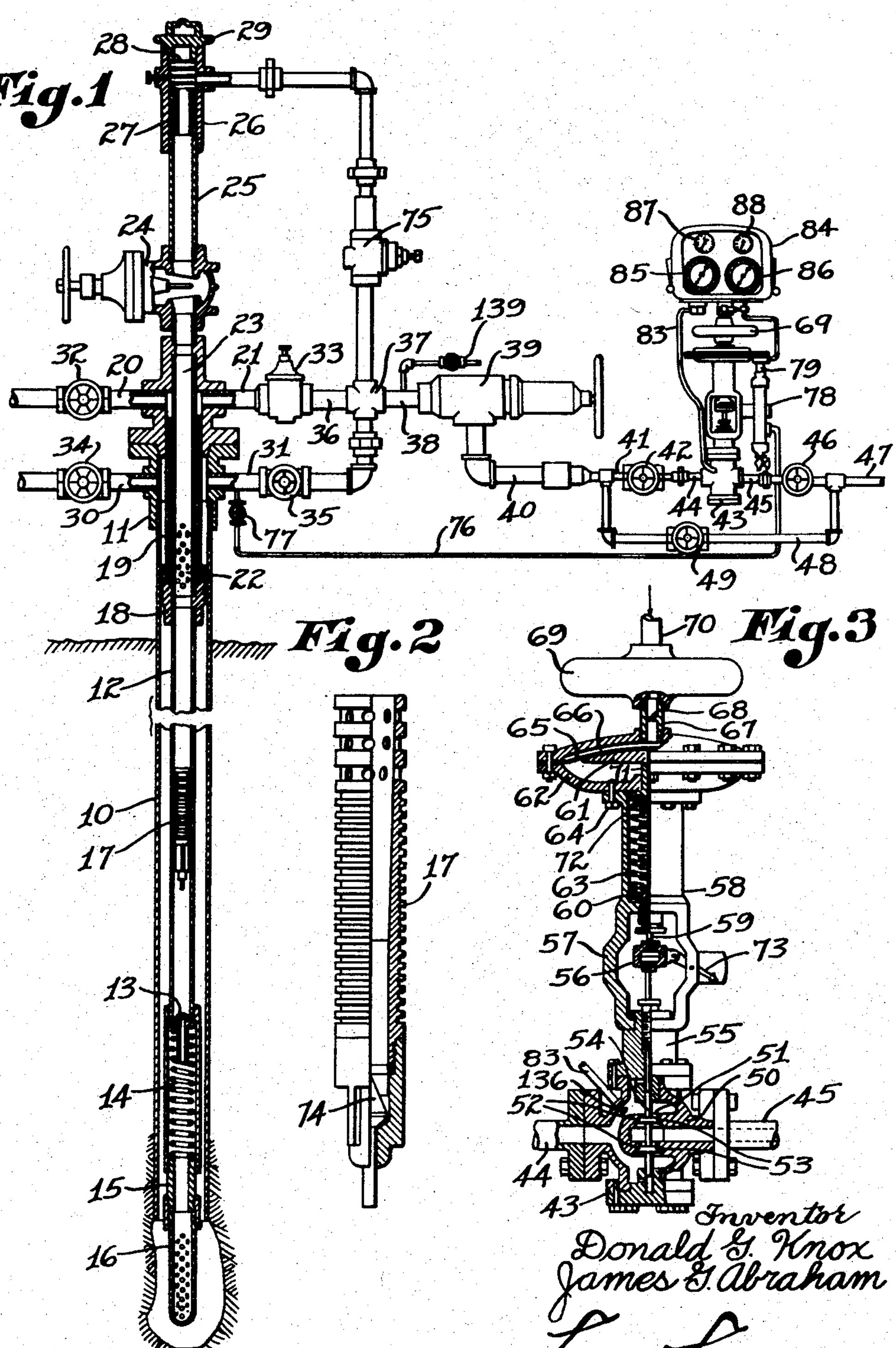

Fig. 1

Fig. 2

Fig. 3

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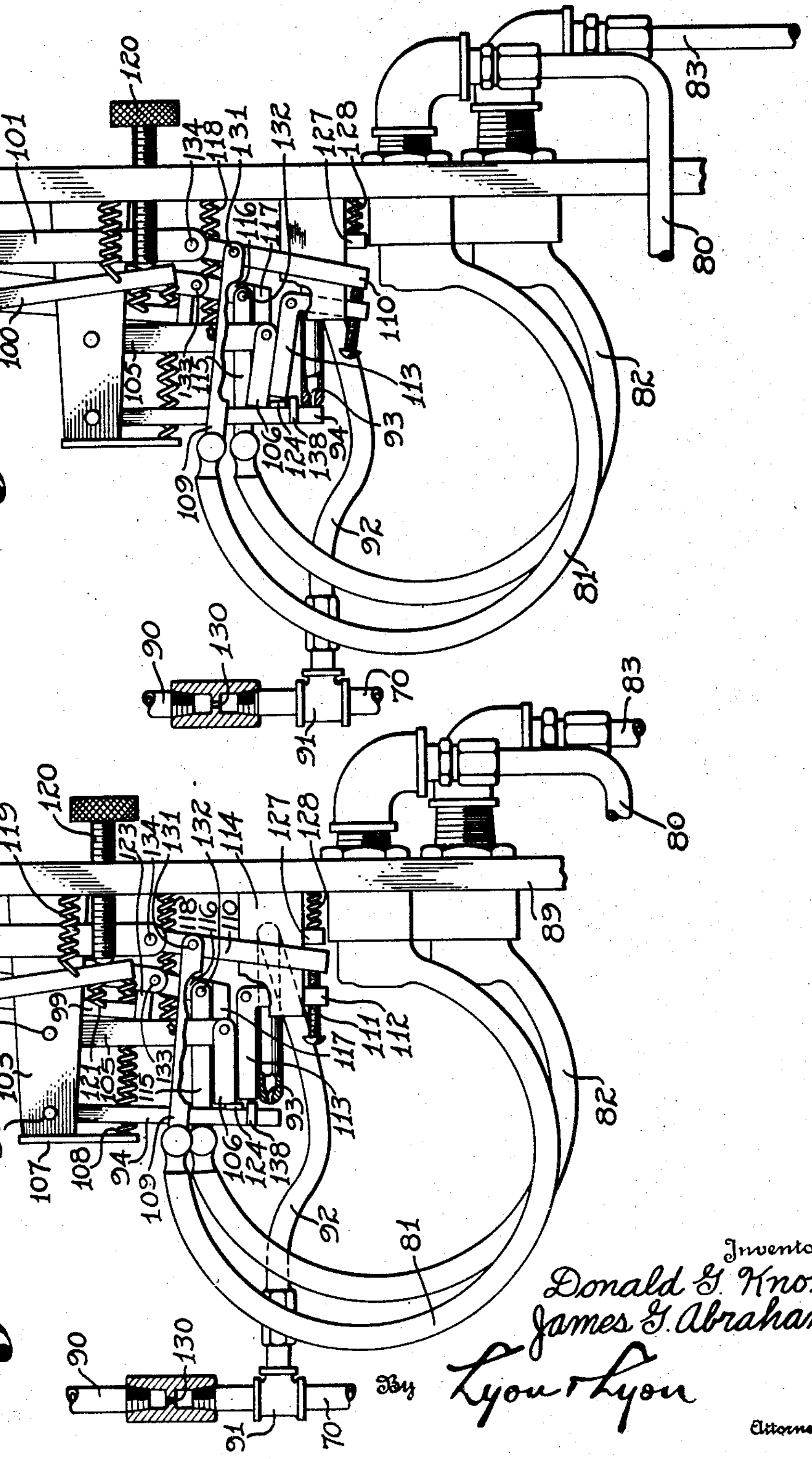

Fig. 5

Fig. 4

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Fig. 6

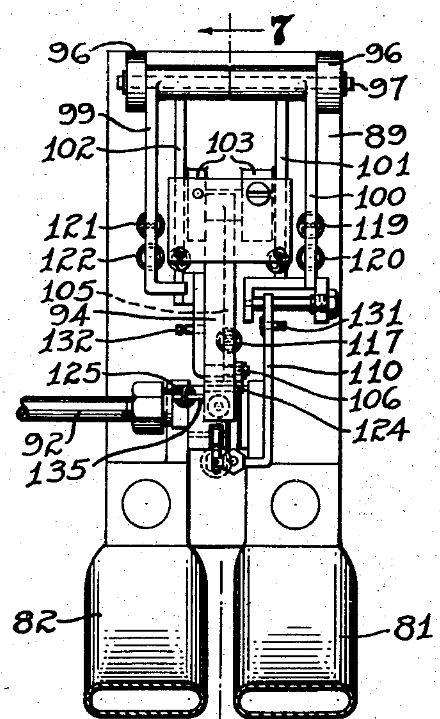
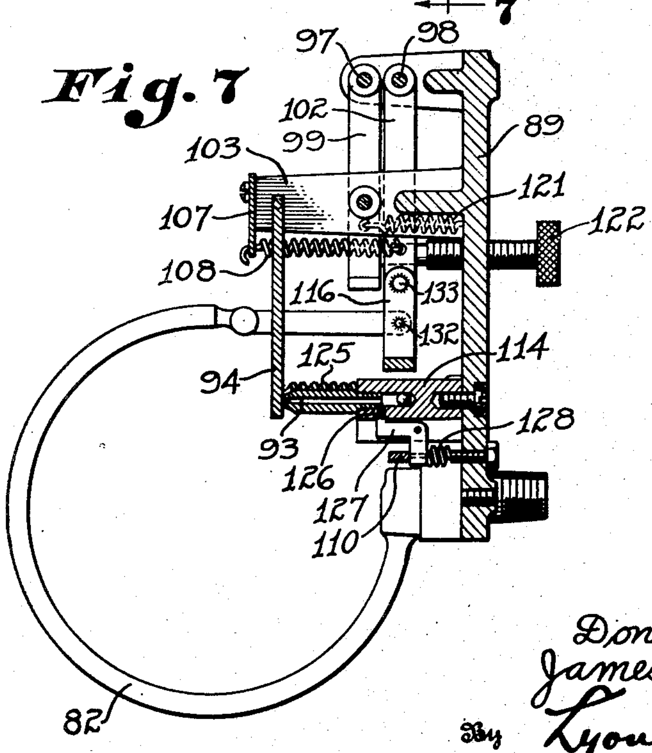


Fig. 7



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2,508,174

CONTROL FOR PLUNGER LIFTS

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13 Claims. (Cl. 103—52)

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This invention relates to the production of oil from wells and is particularly directed to an improvement in the plunger lift system normally used in raising oil in deep wells.

Plunger lift apparatus has been used for some time to produce oil from deep wells using only the energy of the formation gas or supplying additional gas from the surface where required. This method of lifting oil was devised to avoid the excessive maintenance expenses resulting from high pressures, close fits and severe alternating stresses encountered in deep well sucker rod pumps.

Essentially, plunger lift equipment comprises a string of tubing in which a plunger travels the entire distance from the top to the bottom of the tubing and back to the top each stroke. The tubing is connected at the surface to a flow head, which is adapted to receive the slug of oil lifted by the plunger and to direct it to the flow lines, and the tubing is fitted at its lower end with a foot-piece to stop the plunger and close a valve in the plunger at the end of the down stroke. The plunger generally has a comparatively free fit in the tubing and falls by gravity alone. It is raised by pressure of the gas under the plunger without the use of sucker rods or cable. The plunger does not lift a column of oil extending the full length of the tubing, but lifts the fluid in short heads, usually not over 300 feet long.

Up to the present time the plunger lift system of raising oil has found successful application to deep wells having comparatively low bottom hole pressure, but with comparatively high volume of oil available. In such cases, it is customary to use a comparatively large orifice or "bean" at the surface and relatively large production of oil is obtained. When it is desired to restrict the production from a well operated by a plunger lift, it has been necessary to reduce the size of the bean at the surface. It has been found that reduction in size of the bean sometimes results in failure of the plunger to operate. A very small bean in the flow pipe has been found to cause the valve in the plunger to stay closed when the plunger is at the top of its travel and positioned in the flow head. Failure of the valve to open when the plunger is in its top position results in failure of the plunger to drop back down through the tubing, and hence production of oil ceases.

Restrictions placed on productivity of wells have resulted in higher casing pressures being used for plunger lift applications, since it is necessary to cut down the number or cycles which the plunger makes during the 24-hour period in

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order to cut down production. Fewer plunger trips means that the formation pressure is given a longer time to build up the pressure in the casing between trips of the plunger. Since there is a limit to the amount of restriction which may be imposed by means of the bean, as pointed out above, it has been proposed to limit the number of trips of the plunger by means of a timer device. It has been the experience of applicants that none of these timers have proved successful because the plunger operation is dependent upon well conditions and cannot be satisfactorily operated with an arbitrary timing device which is independent of well pressures.

It is therefore the principal object of our invention to provide a control for plunger lift devices which can be used for varying the output from the well without disturbing regular cycling of the plunger.

Another object of our invention is to control the cycling of the plunger within the well in accordance with pressure variations within the well casing and the well tubing.

Another object of our invention is to provide a control for the operation of the plunger which does not restrict flow from the well during the interval while the plunger is causing the flow of well fluid through the well head.

Another object is to provide a control means for a plunger lift which will automatically return the plunger to its position in the bottom of the well in the event that the plunger should bring up an abnormally small slug of fluid.

Other objects and advantages of our invention will appear hereinafter.

In the drawings:

Fig. 1 is an elevation view, partly in section, showing a common form of plunger lift apparatus, together with a preferred embodiment of our invention for controlling the operation of the plunger.

Fig. 2 is a detail view partly in section on an enlarged scale, showing details of construction of the plunger.

Fig. 3 is a plan view, partly in section, showing a main control valve and its associated mechanism which we employ in connection with our invention.

Fig. 4 is a diagrammatic elevation having certain parts broken away, showing the Bourdon tubes and linkage mechanism for controlling the operation of the main control valve. The position of the various linkage parts as shown in Fig. 4 causes the main control valve to remain closed.

Fig. 5 is a diagrammatic view similar to Fig. 4

but with the linkage parts in position to cause the main control valve to remain open.

Fig. 6 is a front elevation of the mechanism diagrammatically illustrated in Figs. 4 and 5.

Fig. 7 is a sectional elevation taken substantially on the line 7—7 as shown in Fig. 6.

The general view of the apparatus shown in Fig. 1 includes a well casing 10 extending into the earth and terminating at its upper end in a control head structure generally designated 11. Supported by the control head structure is a well tubing 12 extending downwardly within the casing 10 and having a bumper element 13 at its lower end supported on the spring 14. A fitting 15 connects the lower end of the tubing 12 to a strainer device 16 in a manner common to the art. A plunger 17 is positioned within the tubing 12 and is adapted to travel the entire distance from the bumper element 13 near the bottom of the well to the control head 11 at the top of the well. The upper end of the tubing 12 is connected by a fitting 18 to a depending tube 19 suspended within the control head 11. Lateral ports 20 and 21 communicate with the tubing through the suspension nipple 19 and the discharge nozzles 22, which are formed through the wall of the pipe 23. The pipe 23 is positioned within the suspension nipple 19 and at its upper end communicates with the valve 24 and the trap pipe 25. The upper end of the trap pipe 25 is secured to the bumper housing 26, which encloses a rubber bumper 27 and a coil spring 28. The upper end of the bumper housing 26 is closed by a removable cap 29. Communication with the annular space within the casing 10 is provided by the lateral outlets 30 and 31, which are connected to the control head structure 11. The lateral ports 20, 21, 30 and 31 are each provided with a valve 32, 33, 34 and 35 respectively, for controlling flow through the lateral branches.

The valve 33 is connected by piping 36, crossover 37 and pipe 38 to a flow beam 39 having a variable restriction. A discharge line 40 from the flow bean 39 extends through the conduit 41 and shutoff valve 42 to the main control valve 43 by way of inlet 44. The outlet 45 from the main control valve passes through the shutoff valve 46, to the discharge pipe 47. A bypass line 48, including a shutoff valve 49, is provided for bypassing the main control valve 43 if desired.

The main control valve 43, together with its associated mechanism and piping, constitutes an essential part of the preferred embodiment of our invention. This valve 43 as shown in outline in Fig. 1 is illustrated on a larger scale in Fig. 3. The construction includes a valve body 50 having suitable ports 51 and provided with a double seat 52. A double valve 53 mounted on a valve stem 54 is slidably mounted within the body 50 and extends upwardly through the stuffing box 55 and is secured to a connector piece 56 within the open portion 57 of the bonnet 58. An actuating rod 59 also is connected to the element 56, and extends upwardly through the threaded sleeve 60 and into engagement with the diaphragm head 61 mounted within the enlarged casing 62. A double compression spring 63 is confined within the bonnet 58 and acts against the threaded sleeve 60 at its lower end and against the spacer 71 at its upper end. The spacer 71 encircles the actuating rod 59 and is provided with a flange 72 for contact with the double spring 63. The sleeve 60 is threaded to the bonnet 58 for the purpose of adjusting the compression in the spring 63. Bolts 64 secure the bonnet 58 to the enlarged casing 62. A flexible diaphragm 65 is provided within the casing 62 and overlies the diaphragm head 61 to define a chamber 66 within the casing 62 and above the diaphragm 65. A nipple 67 provided with a restricted orifice 68 connects the casing 62 with the oil reservoir 69.

The operation of this main control valve 43 is as follows:

Gas pressure admitted to the oil reservoir 69 through the inlet 70 forces oil to pass through the restricted orifice 68 within the nipple 67 and into the chamber 66 above the diaphragm 65. The pressure of the gas acting on the oil within the chamber 66 causes the diaphragm 65 and the actuating rod 59 to move downwardly against the action of the double spring 63. Downward movement of the control rod 59 moves the valve stem 54 downwardly and moves the double valve 53 to open the ports 52, and thereby permits flow from the inlet 44 to the outlet 45. When the gas pressure admitted into the inlet 70 of the oil reservoir 69 drops below a predetermined intensity, the spring 63 acts to return the rod 59 and valve stem 54 upwardly to a closed position. An indicator device 73, actuated by the connector element 56, may be provided if desired for visually indicating whether the valve is open or closed.

In the operation of the device so far described, the plunger 17 is placed within the trap 25 above the control head 11 and is retained in place by the valve 24. The valve 24 is then slowly opened, which first allows the valve 74 within the plunger 17 to drop open as the gate of the valve 24 is withdrawn, and then the plunger 17 itself is released and falls through the tubing 12 to the bumper 13 at the bottom of the hole. When the plunger 17 reaches the bumper element 13 at the bottom of the hole, the plunger valve 74 stops and the continuing motion of the plunger 17 closes the valve 74. The closing of the valve 74 prevents gas from the formation or from the casing from by-passing through the oil accumulated in the lower end of the tubing 12. When the pressure builds up sufficiently within the casing 10 and the lower end of the tubing 12, the pressure below the plunger valve 17 raises the plunger 17 within the tubing, carrying a slug of oil above it. When the oil reaches the nozzle openings 22, it enters the outlet branch 21 by way of the suspension nipple 19 and flows outwardly through the piping 36, 37, 38 and through the bean 39. As the oil flows outwardly through the discharge pipe just described, the weight of the oil remaining above the plunger 17 is reduced and, therefore, the plunger speed increases as the plunger 17 nears the control head 11. Oil also rises in the trap 25 above the nozzle openings 22, and as the entrapped gas within the housing 26 and trap 25 is compressed, it acts as a cushion to decelerate the plunger which finally passes the nozzle openings 22 at relatively high velocity. When the plunger 17 comes to a stop within the control head 11, just above the nozzle openings 22, the valve 74 within the plunger opens because the pressure above the plunger 17 is greater than the pressure below it. When the plunger valve 74 opens, the plunger 17 falls back downwardly past the nozzle openings 22 and falls through the rising column of gas in the tubing 12 until it seats on the bumper element 13 at the bottom of the hole. The cycle then repeats in the manner described.

The control means which is contemplated by our invention is provided for regulating the cycling action of the plunger 17. The control cycle which we have accomplished by our invention acts as set forth in the following steps:

1. When the plunger 17 is resting on the bottom, the tubing 12 is closed in by the main control valve assembly 43, thereby preventing escape of gas from the tubing 12. The valves 32, 35 and the by-pass valves 75 and 49 are all closed. If gas is being injected into the casing 10, the valve 34 remains open. If the plunger lift is being operated on formation gas alone, the valve 34 remains closed. The normal discharge path through bean 39 and piping 40 is closed by the main control valve 43. Formation gas or gas injected into the casing 10 causes a gradual rise in pressure in both the casing 10 and the tubing 12; for example, the casing pressure may rise from 100 p. s. i. to 110 p. s. i. while the tubing pressure rises from 0 to 80 p. s. i.

2. The main control valve 43 is opened in response to the casing pressure reaching a predetermined intensity, such as 110 p. s. i. This releases the pressure in the tubing 12 down toward 0 p. s. i. and therefore the pressure under the plunger 17 lifts the plunger with its load of oil upwardly through the tubing 12 to the surface, thereby causing the casing pressure to drop slowly; for example, from 110 p. s. i. to 100 p. s. i. The main control valve 43 remains open during this interval.

3. As the oil slug passes through the bean 39, piping 40 and through the control valves 52, 53, the tubing pressure gradually rises. When a predetermined tubing pressure is reached, the main control valve 43 closes slowly at a rate to permit substantially the entire slug of oil to pass through the valve 43 before the double valve 53 finally closes.

An important feature of the operations just described is that the main control valve 43 remains fully open during the passage of the larger portion of the slug of oil and remains completely closed during the period of accumulation of gas and oil within the lower end of the tubing 12 and in the casing 10, in order to prevent escape of gas during this interval.

The means provided for accomplishing the opening and closing of the main control valve 43 in response to pressure changes within the casing 10 and tubing 12, and in accordance with the operations set forth in steps 1, 2 and 3 above, are shown in detail in Figs. 4, 5, 6 and 7.

A pressure line 76 is provided with a shutoff valve 77 and communicates with the lateral port 31 leading to the casing 10 and this line 76 enters the side of a filter 78. The outlet from the filter 78 is at its upper end 79 and this outlet communicates with the inlet 80 for the casing Bourdon tube 81. A second Bourdon tube 82 for tubing pressure is connected with the line 83. The line 83 may be connected with the valve body 50 at the port 136 in the up-stream side of the double valve 53 or with the branch line 139 connected with the pipe 38 upstream from the adjustable bean 39. On certain high pressure wells, the latter location has been found to be preferable. The Bourdon tubes 81 and 82 and their associated mechanism is contained within a case 84 mounted on the upper end of the oil reservoir 69. Also connected to the case 84 are pressure gauges 85, 86, 87 and 88, which are adapted to indicate the tubing pressure, casing pressure, pilot-to-diaphragm pressure and pilot supply pressure, respectively. The linkage mechanism, which is mounted on the plate 89, which carries the Bourdon tubes 81 and 82, and which is mounted within the case 84, is provided for the purpose of controlling the admission of pressure into the oil reservoir 69 and hence controlling the opening and closing of the main control valve 43.

The general principle on which this mechanism operates is as follows:

A supply of pilot gas under substantially uniform pressure is admitted through a pilot supply pipe 90, and through a restriction 130. A T fitting 91 is provided in the pilot supply line 90 for directing pilot gas through the inlet line 70 to the oil reservoir 69, and also through the supply line 92 leading to the vent orifice 93. A flapper valve 94 pivotally supported at 95 is adapted in one position to close the vent orifice 93 and in another position to swing away from the orifice 93 to permit escape of gas therefrom. The opening in the vent orifice 93 is approximately twice the size of the opening in the restriction 130. When the orifice 93 is open the supply of pilot gas from the line 90 passes through the line 92 and out through the orifice 93. Therefore, no substantial pressure is applied through the line 70 to the oil reservoir 69 and hence the pressure of the oil within the chamber 66 above the diaphragm 65 is too low to overcome the pressure of the spring 63. Therefore, the double valve 53 in the main control valve assembly 43 remains closed. When the vent orifice 93 is closed by the flapper valve 94, the pressure of the pilot gas in the supply line 90 passes through the inlet 70 to the oil reservoir 69 and through the orifice 68 to the chamber 66. This pressure acting over the large area of the diaphragm 65 overcomes the spring 63 and opens the control valve 43. From this description, it will be apparent that when the vent orifice 93 is open the main control valve 43 is closed, and vice versa.

As shown in the drawings, the mechanism for opening and closing the vent orifice 93 includes a pair of ears 96 secured on a plate 89 carrying pivot shafts 97 and 98 extending therebetween. The pivot shaft 97 supports the tubing over-travel lever 99 and the casing over-travel lever 100. Pivotally mounted upon and depending from the pivot shaft 98 is the casing pressure adjustment lever 101 and the tubing pressure adjustment lever 102. A pair of outwardly extending stationary plates 103 carry the pivot shafts 95 and 104, which extend between the plates 103 supporting the flapper valve 94 and the arm 105. Pivotally connected with the lower end of the arm 105 is the lifting bar 106.

The casing Bourdon tube 81 is pivotally connected at its active end to the link 109. The other end of the link 109 is pivotally connected at 131 to the lever arm 110, which is pivotally connected at 134 to the lower end of the casing pressure adjustment lever 101. The lower end of the lever arm 110 contacts an adjustment screw 111 carried by the depending end 112 of the trigger 113. The trigger 113 is pivotally mounted on the valve element 114, which is secured to the base plate 89. The tubing pressure Bourdon tube 82 is pivotally connected at its active end to the link 115. The other end of the link 115 is pivotally connected at 132 to arm 116, which in turn is pivotally connected at 133 to the lower end of the tubing pressure adjustment lever 102. The lower end of the arm 116 is provided with a foot piece 117 adapted to abut the lower end of the arm 105. A tension spring 118 is secured to the arm 105 and to the stationary plate 89 and normally acts to maintain the foot piece 117 in contact with the arm 105. A spring 119 is provided for holding the casing over-travel lever 100 in engagement with the end of the adjustment screw 120 threaded through the plate 89. Similarly, a spring 121 is secured to the tubing over-travel lever 99 and to the plate 89 for maintaining the lever 99 in contact with the end of an adjustment screw 122, which is also threaded through the plate 89. The lower end of the tubing over-travel lever 99 carries a foot piece 123 adapted to contact the lower end of the tubing adjustment lever 102. One end of the spring 108 is secured to the cross plate 107 fixed on the plates 103 and the other end of the spring 108 is attached to the lower end of the tubing pressure adjustment lever 102.

It is to be understood that the purpose of the tubing over-travel lever 99 and the casing over-travel lever 100, together with their springs 121 and 119, and the adjustment screws 122 and 120, is to provide adjustable limit stops for positioning the locations for the pivotal connections 133 between the arm 116 and the lever 102, and the connection 131 between the arm 110 and the lever 101. The adjustment screws 120 and 122 serve to initially position the levers 99 and 100 and thereafter these adjustments are not changed during normal operation.

The operation of this linkage is as follows:

When the casing pressure admitted into the Bourdon tube 81 exceeds a pre-determined value, the active end of the Bourdon tube applies tension to the link 109, thereby causing the arm 110 to pivot about its connection 134 with the lever 101. This pivotal movement of the arm 110 causes the lower end of the arm 110 to move the adjustment screw 111 and hence the trigger 113 to lift the bar 106 upwardly as shown in Fig. 4. This moves the position of the various parts into the relationship illustrated in Fig. 5. As shown in Fig. 5, the trigger 113 has lifted the bar 106 out of engagement with the contact piece 124 which is secured to the flapper valve 94 and extends laterally to one side, and has permitted the flapper valve 94 to seat upon and close the vent orifice 93. With the flapper valve 94 in closed position as shown in Fig. 5, the pilot gas injected from the supply line 90 is directed to the oil reservoir 69 through the line 70 to open the main control valve 43.

When the plunger 17 approaches the control head 11 in its upward movement, the pressure in the casing 10 begins to drop, as pointed out above. The relatively slow drop in casing pressure commences while the plunger 17 is raising a slug of oil in the tubing 12, but a much faster drop in pressure occurs in the tubing 12 and discharge line after delivery of the oil slug to the surface. This lowering of pressure in the tubing 12 is reflected by the action of the Bourdon tube 82, which then acts on the link 115 to move the arm 116 and foot-piece 117 to the right, as viewed in Fig. 5. The spring 118 then pulls the arm 105 to the right, thereby pulling the lifting bar 106 away from the flapper valve 94. The bar 106 is then supported upon the trigger 113. The lowering of the casing pressure causes the active end of the Bourdon tube 81 to move the link 109 and arm 110 toward the right as viewed in Fig. 5. The arm 110 pivots around its connection 134 with the casing adjustment lever 101, and moves back to the position shown in Fig. 4. The trigger 113 turns counter-clockwise to rest on the lug 138. The flapper valve 94, however, remains seated to close off the vent passage 93. The flapper valve 94 is moved away from the vent orifice 93 to return the linkage to the position shown in Fig. 4 when the plunger 17 raises a slug of oil on the next trip. The cycle of operation then repeats as described.

As shown in Figs. 6 and 7, a tension spring 125 is secured to the element 114 at one end and to the finger 135 attached to the flapper valve 94 at the other end. The spring 125 acts resiliently to maintain the flapper valve 94 in contact with the vent orifice 93.

It has been found from field experience that the above linkage normally acts satisfactorily to open and close the vent orifice 93 and hence operate the main control valve assembly 43 under normal well conditions. However, in the event that through some abnormal condition of the well, the plunger 17 should raise an abnormally small slug of oil, the rise in tubing pressure might not be sufficient to cause the Bourdon tube 82 to initiate the action of opening the vent orifice 93 for effecting the delayed closing of the main control valve 43. In the event of this abnormal functioning of the plunger lift apparatus, the main control valve 43 would remain open and hence would bleed off pressure in the tubing 12 and the casing 10 with consequent loss of gas and pressure. In order to remedy this possibility and avert wasting of gas, as well as to maintain normal cycling of the plunger 17, we provide an auxiliary vent 126, as shown in Fig. 7. This vent 126 is formed within the valve element 114 and is connected to the supply line for the vent orifice 93. A closure member 127 is pivotally supported on the valve element 114 and is actuated by a compression spring 128, serving to close off the auxiliary vent 126 under normal operating conditions. In the event that the main control valve 43 should fail to close as described above owing to the delivery of an exceptionally small slug of oil by the plunger 17, followed by the escape of gas from the tubing 12 and casing 10, the casing pressure would fall below the pre-determined level, which would cause the arm 110 to rotate counter-clockwise with respect to its pivotal mounting as viewed in Fig. 4. Movement of the lower end of the arm 110 toward the right as viewed in Fig. 5 causes the arm 110 to engage the closure member 127 and causes it to turn on its pivotal mounting, thereby opening the auxiliary vent 126. The discharge of pilot gas through the auxiliary vent 126 serves to release pressure within the chamber 66 above the valve diaphragm 65 and hence the spring 63 operates to close the double valve 53. After the casing pressure gradually increases during the interval while the discharge line is closed by the main control valve 43, the casing Bourdon tube 81 moves the arm 110 clockwise as viewed in Fig. 4 to permit the spring 128 to move the closure member 127 to close the auxiliary orifice 126.

Having fully described our invention, it is to be understood that we do not wish to be limited to the details set forth, but our invention is of the full scope of the appended claims.

We claim:

1. In a plunger lift device including a well casing and a valved plunger adapted to travel freely under pressure substantially the full length of an eduction tube, and a flow conduit connected to receive flow from the eduction tube, the combination of a valve associated with the flow conduit

to control flow therefrom, pressure-responsive means associated with the well casing adapted to effect opening of the valve upon the casing pressure reaching a pre-determined magnitude, and means acting to effect a delayed closing of the valve in response to pressure changes in the flow conduit incident to raising of a slug by the plunger.

2. In a plunger lift device including a well casing and a valved plunger adapted to travel freely under pressure substantially the full length of an eduction tube, and a flow conduit connected to receive flow from the eduction tube, the combination of a valve associated with the flow conduit to control flow therefrom, pressure-responsive means associated with the well casing and adapted to effect opening of the valve upon the casing pressure reaching a predetermined magnitude, means normally acting to effect a delayed closing of the valve in response to the normal pressure increase in the flow conduit incident to raising of a slug by the plunger, and auxiliary means operable to close the valve in response to abnormally low pressure in the well casing.

3. In a plunger lift device including a well casing and a valved plunger adapted to travel freely under pressure substantially the full length of an eduction tube, the combination of a valve associated with the eduction tube to control flow therefrom, pressure-responsive means associated with the well casing and adapted to effect opening of the valve upon the casing pressure reaching a pre-determined magnitude, means normally acting to effect a delayed closing of the valve after raising of a slug by the plunger, and auxiliary means operable to effect closing of the valve in response to abnormally low pressure in the well casing.

4. In a plunger lift device including a pair of well pipes forming a well casing and an eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube, and a flow conduit operatively connected to the eduction tube, the combination of a valve in the flow conduit, the valve having an open position and a closed position, a spring normally acting to maintain the valve in one of said positions, pressure-responsive means operable to move the valve to the other position in opposition to the spring, a control conduit carrying fluid under pressure and associated with the pressure responsive means, a vent operatively associated with said control conduit and pressure-responsive means, means actuated by a pressure increase in one of the well pipes incident to action of the plunger and operable to close the vent whereby the valve is moved to one position by the pressure responsive means, and additional means actuated by a pressure increase in the other well pipe incident to action of the plunger and operable to open the vent whereby the valve is moved to the other position by the spring.

5. In a plunger lift device including a pair of well pipes forming a well casing and an eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube, and a flow conduit operatively connected to the eduction tube, the combination of a valve in the flow conduit, the valve having an open position and a closed position, a spring normally acting to maintain the valve in one of said positions, pressure responsive means operable to move the valve to the other position in opposition to the spring, a control conduit carrying fluid under pressure and associated with the pressure responsive means, a vent operatively associated with said control conduit and the pressure responsive means, a Bourdon tube associated with one of the well pipes, linkage means whereby the Bourdon tube may act to close the vent upon an increase in pressure in the said well pipe incident to action of the plunger, a second Bourdon tube associated with the other well pipe, and means including a portion of said linkage means whereby the second Bourdon tube may act to open the vent upon an increase in pressure in the latter said well pipe incident to action of the plunger.

6. In a plunger lift device including a well casing and an eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube, and a flow conduit operatively connected to the eduction tube, the combination of a valve in the flow conduit, a spring normally acting to maintain the valve in closed position, pressure responsive means operable to open the valve in opposition to the spring, a control conduit carrying fluid under pressure and associated with the pressure responsive means, a vent operatively associated with the control conduit and the pressure responsive means, means actuated by a pressure increase in the well casing incident to action of the plunger and operable to close the vent whereby the valve is moved to open position by the pressure-responsive means, and additional means actuated by a pressure increase in the eduction tube incident to action of the plunger and operable to open the vent whereby the valve is closed by the spring.

7. In a plunger lift device including a well casing and an eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube, and a flow conduit operatively connected to the eduction tube, the combination of a valve in the flow conduit, a spring normally acting to maintain the valve in closed position, pressure-responsive means adapted to open the valve in opposition to the spring, a control conduit carrying fluid under pressure and associated with the pressure-responsive means, a vent operatively associated with the control conduit and the pressure responsive means, a first Bourdon tube operatively connected to the well casing, linkage means whereby said Bourdon tube may act to close the vent upon a pressure increase in the well casing incident to action of the plunger, whereby the pressure-responsive means may open the valve, and a second Bourdon tube operatively connected to the flow conduit upstream from the valve, means including a portion of said linkage means whereby the second Bourdon tube may act to open the vent upon a pressure increase in the flow conduit incident to action of the plunger, whereby the spring may close the valve.

8. In a plunger lift device including a well casing, an eduction tube, a flow conduit leading from the eduction tube having a valve associated therewith to control flow therefrom and a valved plunger adapted to travel freely under pressure substantially the full length of the eduction tube, the combination of: pressure-responsive means associated with the well casing adapted to effect opening of the valve upon the casing pressure reaching a predetermined magnitude, and means acting to effect a delayed closing of the valve in response to pressure changes in the flow conduit incident to raising of a slug by the plunger.

9. In combination with a plunger lift device including a well casing, a valved plunger adapted to travel freely under pressure substantially the full length of an eduction tube, a flow conduit leading from the eduction tube, and a valve to control flow from the flow conduit, the improvement comprising: pressure-responsive means associated with the well casing and adapted to effect opening of the valve upon the casing pressure reaching a predetermined magnitude, and means normally acting to effect a delayed closing of the valve in response to the normal pressure increase in the flow conduit incident to raising of a slug by the plunger.

10. In a device of the class described for opening and closing a valve in response to cyclic variations in pressure in two separate pressure members, the combination of pressure-responsive means associated with the first pressure member and adapted to effect opening of the valve upon the pressure in that member reaching a predetermined magnitude, and means normally acting to effect a delayed closing of the valve in response to pressure increase in the second pressure member.

11. In a device including two separate pressure members subject to cycles of change in pressure normally occurring with substantially the same frequency, and including a valve adapted to be opened and closed each cycle in response to such pressure changes, the combination of pressure-responsive means associated with the first pressure member and adapted to effect opening of the valve upon the pressure in that member reaching a predetermined magnitude, and means normally acting to effect a delayed closing of the valve in response to pressure increase in the second pressure member.

12. In a device including two separate pressure conduits each subject to cyclic variations in pressure occurring with substantially the same frequency, and including a valve adapted to control the flow through the second of the conduits in response to such pressure changes, the combination of pressure responsive means associated with the first conduit and adapted to effect opening of the valve upon the pressure in the first conduit reaching a predetermined magnitude, and means normally acting to effect a delayed closing of the valve in response to pressure increase in the second pressure conduit.

13. In a device including two separate pressure members each subject to cyclic variations in pressure occurring with substantially the same frequency, the combination of an actuator conduit, a substantially constant pressure source, a controller device operatively connected to the pressure members, the actuator conduit and the constant pressure source, pressure responsive means associated with the controller device adapted to pressurize the actuator conduit upon the pressure in the first pressure member reaching a predetermined magnitude, and additional means associated with the controller device adapted to vent the actuator conduit in response to pressure increase in the second pressure member.

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JAMES G. ABRAHAM.

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