Dec. 12, 1961 D. G. KNOX 3,012,513

TIMER CONTROLLED FREE PISTON WELL PUMPING APPARATUS

Filed May 15, 1959 3 Sheets-Sheet 1

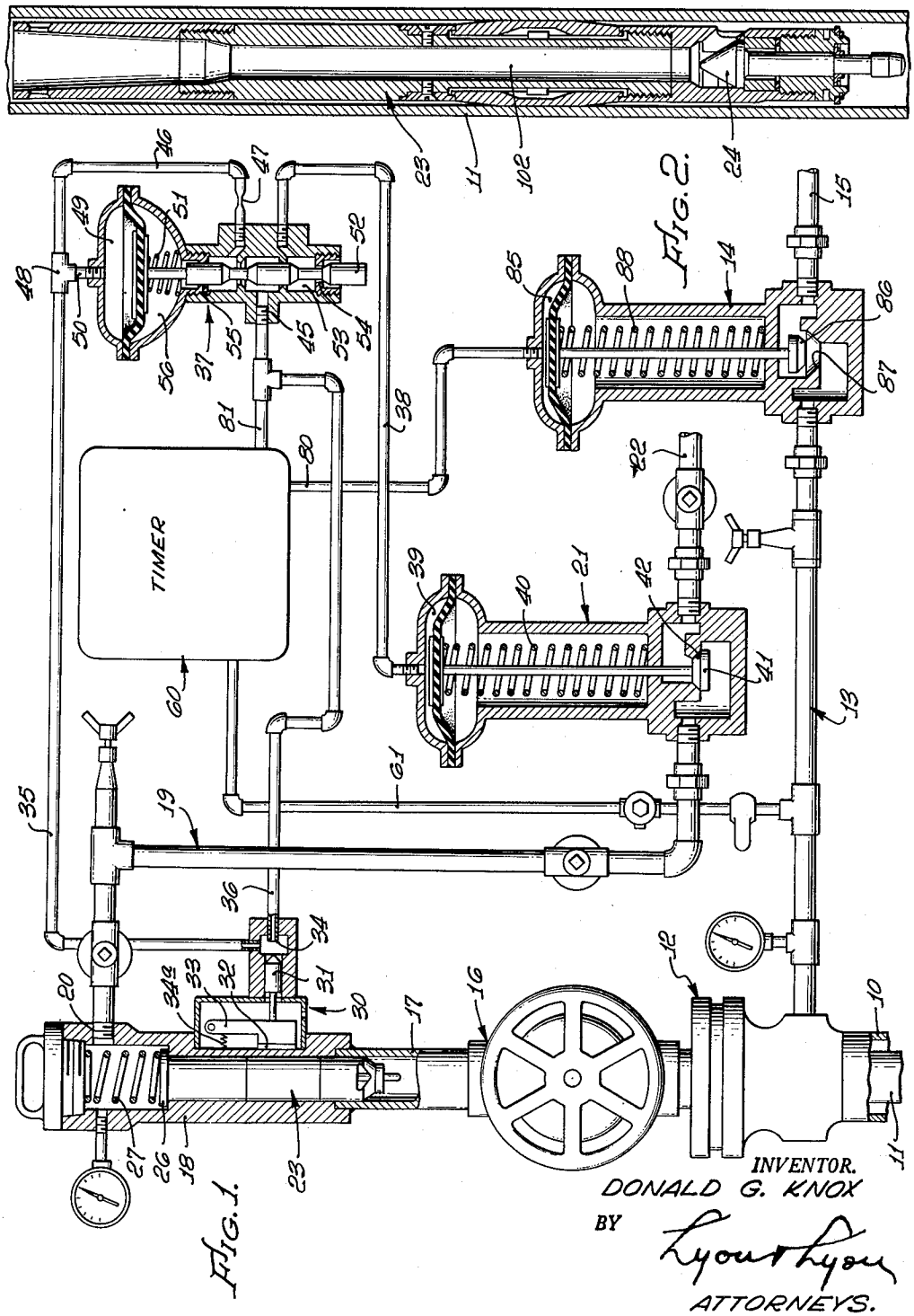


FIG. 1.

FIG. 2.

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TIMER CONTROLLED FREE PISTON WELL PUMPING APPARATUS

Filed May 15, 1959 3 Sheets-Sheet 2

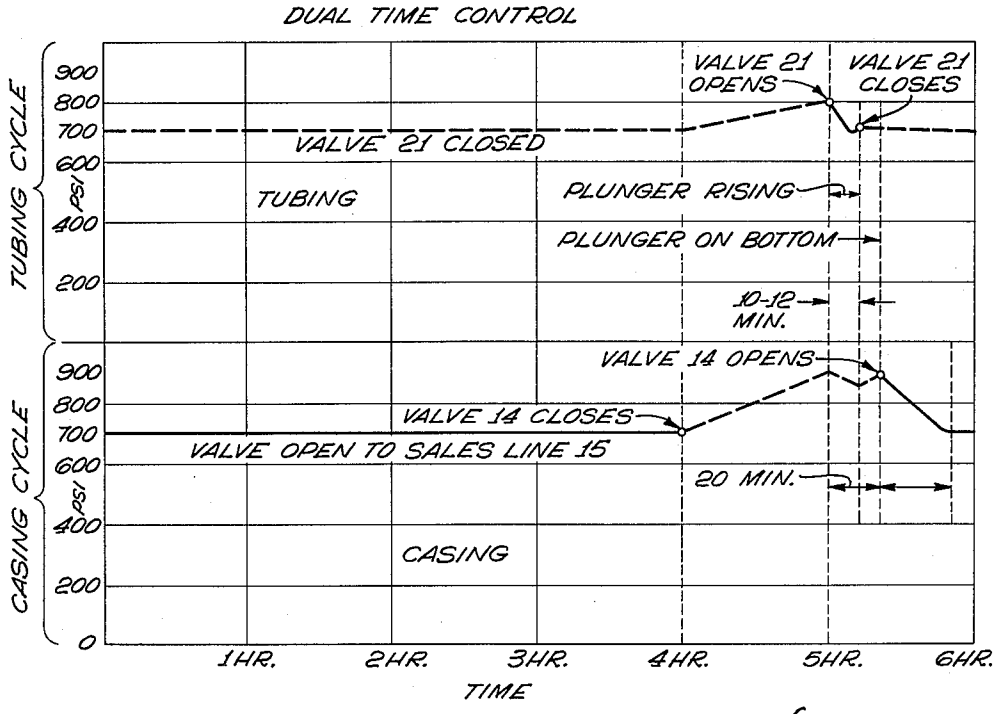


FIG. 4.

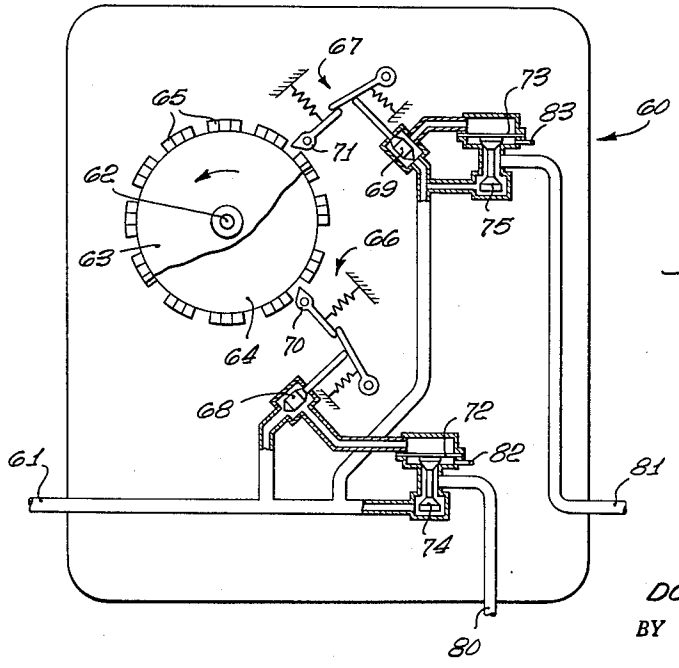


FIG. 3.

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TIMER CONTROLLED FREE PISTON WELL PUMPING APPARATUS

Filed May 15, 1959 3 Sheets-Sheet 3

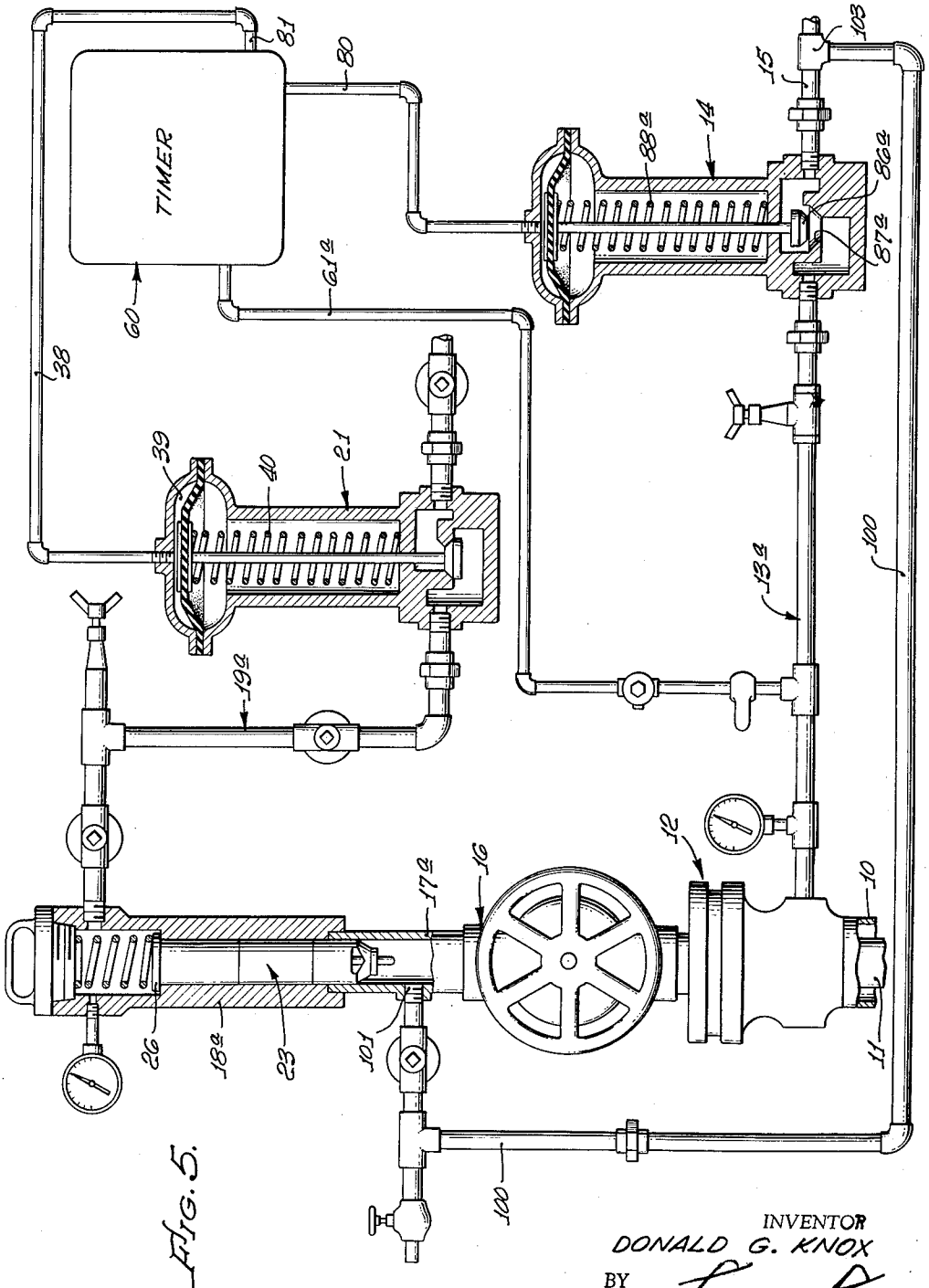


FIG. 5.

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United States Patent Office 3,012,513 Patented Dec. 12, 1961

3,012,513

TIMER CONTROLLED FREE PISTON WELL PUMPING APPARATUS

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Filed May 15, 1959, Ser. No. 813,436
9 Claims. (Cl. 103—52)

This invention relates to free piston well pumping apparatus of the general type shown in my prior Patents Nos. 2,699,121; 2,661,024; 2,642,002. This invention is particularly directed to improvements in the operating cycle of the free piston which travels the full length of the eduction tube to the well head to bring up a load of well fluid.

It is desirable that the rate of travel of the free piston, or plunger, be maintained above a certain minimum speed while it is travelling upward in the eduction tube with a load of well fluid, in order to minimize rapid gas expansion in bypassing the plunger. Gas expansion around a slow moving plunger may result in the formation of undesirable hydrates within the tubing which interfere with proper operation of the plunger. Also, if the plunger moves too slowly it may tend to "float" within the tubing with consequent delay or failure in reaching the well head.

Accordingly, it is an important object of the present invention to provide a free piston well pumping device which provides gas at sufficient pressure and volume below the plunger to raise it rapidly to the surface and thereby avoid the above-mentioned difficulties.

Another object of the present invention is to provide for transferring well liquid from the casing into the lower end of the tubing prior to each round trip of the plunger. By this means a maximum amount of gas is available in the casing for lifting the plunger and its load of well fluid to the surface and at the same time a maximum amount of well liquid is brought up on each trip of the plunger.

In a typical well installation employing a free piston pumping device, a well casing and an eduction tube within the casing both extend down into the well from a common well head. Gas produced from the well formation accumulates within the casing. Well fluid which comprises liquid carrying dissolved gas also accumulates within the casing and enters the eduction tube through the lower end thereof. At the well head the casing is connected to a gas delivery conduit and the eduction tube is connected to a discharge pipe.

In accordance with my invention, I provide timer controlled valves in the gas discharge conduit and in the fluid discharge pipe so that the following sequence of events takes place. Both valves are closed to permit build-up of gas pressure within the casing and to cause this pressure to transfer accumulations of well fluid into the interior of the eduction tube through the lower end thereof. The valve in the fluid discharge pipe is then opened to permit the plunger to raise a load of well fluid rapidly to the surface and to discharge the well fluid through the discharge pipe and said valve. Still later the valve on the gas delivery conduit is opened. The cycle is then repeated.

In one form of my invention the plunger remains at the bottom of the eduction tube during the major part of the operating cycle and returns promptly to the bottom of the eduction tube after raising a load of well fluid to the surface. Salt water commonly accumulates in gas wells and it is desirable to remove this salt water from time to time in order to prevent drowning of the well. This has been accomplished in the past by using relatively small tubing and periodically "blowing down" the casing

through this small diameter tubing to remove accumulated salt water. However, the available pressure diminishes in the normal life of the well to a point where insufficient casing pressure is available to raise the salt water liquid through the tubing to the surface. In accordance with one form of the present invention, the normally closed motor valve is placed in the discharge line leading from the tubing and a normally open motor valve is placed in the gas delivery conduit leading from the casing. The two motor valves are controlled from a single clock driven timer having separate timing wheels mounted on a timer shaft. In the general scheme of operation, the gas delivery conduit remains open for relatively long periods of time while the plunger is on bottom and while the discharge pipe remains closed. This condition may exist for several hours. The timer then closes the normally open motor valve in the gas delivery conduit to cause build-up of casing pressure. After a shorter time interval, for example, about two hours, the timer opens the normally closed motor valve in the discharge pipe, thereby causing the plunger to move rapidly upwardly through the tubing to discharge its load of salt water through the well head and through the open control valve in the discharge pipe. Upon arrival of the plunger at the well head, the motor valve in the discharge pipe is closed. The timer is set so that the motor valve in the gas delivery conduit closes a few minutes after the scheduled time of arrival of the plunger at the well head.

In another form of my invention, the plunger remains in the well head during the major portion of the operating cycle and makes a round trip to raise well fluid only at predetermined timed intervals. This form of the invention is used in certain types of oil wells or gas wells which produce quantities of sand along with the well fluid. In such a well it is undesirable to allow the plunger to remain on bottom for any considerable length of time because it tends to "sand up" and fails to operate properly. In this second form of the invention, the plunger is pneumatically held in the well head and is not allowed to remain on bottom. In the general scheme of operation the motor valves in the gas delivery conduit and the well fluid discharge pipe both remain open while the plunger is held in the well head. The timer then closes both motor valves to shut in both casing and tubing. The plunger falls to the bottom of the tubing and the lower part of its descent occurs through well fluid which enters the tubing from the casing. The timer then opens the motor valve on the discharge pipe. This causes the plunger to move rapidly upward through the tubing, raising a load of well fluid above it. The timer then opens the motor valve in the gas delivery conduit and this serves to supply gas pressure to hold the plunger in the well head. The cycle then repeats.

In the drawings:

FIGURE 1 is a schematic view partly in section, showing the first mentioned form of my invention.

FIGURE 2 is a section view showing a preferred form of plunger mounted within the eduction tube.

FIGURE 3 is a diagrammatic illustration of the clock-driven timer showing two timer wheels each operating a separate pilot valve device.

FIGURE 4 is a time-pressure chart of tubing and casing pressures in a typical well installation of the general type shown in FIGURE 1 of the drawings.

FIGURE 5 is a schematic diagram showing the second mentioned form of the invention in which the plunger is normally retained in the well head by pneumatic pressure.

Referring to the drawings, the casing **10** extends down into the well and the tubing **11** extends inside the casing. Both the casing and tubing **11** are connected at their

upper ends to the well head structure generally designated 12. A gas delivery conduit generally designated 13 is connected to the well head structure 12 and communicates with the annular space between the casing 10 and the tubing 11. A first motor valve 14 which is normally open controls flow through the gas delivery conduit 13 and to the sales line 15.

The tubing 11 communicates through the shut-off valve assembly 16 with the stack nipple 17 and bumper housing 18. A well fluid discharge pipe generally designated 19 connects with the interior of the bumper housing 18 through the lateral port 20. A second motor valve 21, which is normally closed, controls flow through the discharge pipe 19 and its continuation 22.

A free piston or plunger generally designated 23 travels the full length of the education tube 11 and passes through the well head structure 12 to enter the interior of the bumper housing 18. The plunger 23 is provided with a valve 24 and the plunger is preferably constructed in accordance with the disclosure of the Knox et al. Patent 2,642,002. The upward travel of the plunger 23 is arrested when it strikes the bumper ring 26 and compresses the spring 27. A trigger device generally designated 30 is mounted on the bumper housing 18 and serves to actuate a valve 31 upon entry of the plunger 23 into the bumper housing 18. This trigger device 30 may take any suitable or desirable form, and may comprise a mechanically actuated device as shown in the Spalding Patent 2,757,614, or a magnetically operated device as shown in the co-pending application of William A. Shaw, Serial No. 640,365, filed February 15, 1957. The device 30 shown in the drawings of the present application corresponds to the magnetic trigger device and employs a magnet 32 mounted on a swing arm 33. When the steel plunger 23 enters the non-magnetic bumper housing 18 the magnet 32 is attracted towards the magnetically responsive steel of the plunger 23 thereby causing the swing arm 33 to move in a clockwise direction against the action of the compression spring 34*a*. This movement of the arm 33 allows the valve 31 to move to the left as viewed in FIGURE 1 away from the seat 34 to establish communication between the lines 35 and 36. As described below, this action causes the diaphragm-operated four way valve 37 to vent the line 38 leading to the diaphragm chamber 39, thereby allowing the spring 40 to close the valve head 41 against the valve seat 42. From this description it will be understood that the motor valve 21 in the well fluid discharge pipe 19 is closed in response to entry of the plunger 23 into the bumper housing 18.

The four-way valve 37 is similar to that shown in my copending application Serial No. 758,211, filed September 2, 1958, now Patent No. 2,918,015. In the position of the parts shown in FIGURE 1 of the drawings, the gas inlet port 45 is connected to the line 46 having the restriction 47. The T fitting 48 connects the line 46 to the line 35 and also to the diaphragm chamber 49 by way of the connection 50. Pressure within the chamber 49 opposes the action of the compression spring 51. When the stem 52 is in the position shown, the line 38 is vented through the valve chamber 53 and the port 54. When the intensity of pressure in the chamber 49 is reduced sufficiently, the spring 51 lifts the stem 52 to change the porting to connect the gas in the port 45 with the line 38 and to connect the restricted line 46 to atmosphere by way of the port 55 and vented space 56.

Gas under pressure is supplied to the timer 60 by way of the supply pipe 61, and as shown in FIGURE 3 of the drawings, the timer 60 has a rotating shaft 62 driven from a clock-work mechanism (not shown). Two timer wheels 63 and 64 are mounted on the same shaft 62 to turn therewith. Removable segments 65 are mounted upon each of the wheels 63 and 64 in any desired position around the periphery. The wheel 64 and its segments cooperate with the trigger mechanism 66 and the wheel 63 and its segments cooperate with the trigger mechanism 67. Each of these trigger mechanisms 66, 67 includes a small pilot valve 68, 69 which opens whenever its respective trigger 70, 71 engages one of the segments 65. This action admits gas under pressure to act over a diaphragm 72, 73 to move a valve element 74, 75 to open position. Closing of the pilot valve 68, 69 causes the diaphragms to lift the movable valve element 74, 75 to closed position. From this description it will be understood that gas is supplied through pipe 80 whenever the trigger mechanism 66 encounters one of the segments 65 on the wheel 64. Similarly gas is supplied to the pipe 81 whenever the trigger mechanism 67 encounters one of the segments 65 on the timer wheel 63. At other times the lines 80 and 81 are vented through vent ports 82, 83.

In the operation of that form of the device shown in FIGURE 1 of the drawings, the motor valve 21 in the well fluid discharge line 19 normally remains closed while the motor valve 14 in the gas delivery conduit 13 remains open. Accordingly, gas produced from the well formation passing into the well casing 10 is delivered to the conduit 13 and motor valve 14 to the sales line 15. During this interval, the plunger 23 remains on bottom. Lines 80 and 81 are vented through ports 82 and 83 respectively in the timer 60 and line 38 is vented through port 45 and line 81 in the four-way valve assembly 37. The valve 31 remains closed against the seat 34 under action of the compression spring 34*a* acting on the swinging arm 33.

When one of the segments 65 on the timer wheel 64 engages the trigger mechanism 66, gas under pressure is admitted into the line 80 and this acts in the diaphragm chamber 85 to close the motor valve 14 by moving the valve head 86 downward into sealing engagement with the valve seat 87. This shuts in the casing 10 and allows gas pressure to build up in the casing. The condition of the system is then shown on the illustrative time-pressure chart of FIGURE 4 at the four hour (4 hr.) station. Both valves are then closed and the pressure rises in both the casing 10 and the tubing 11. If both valves 14 and 21 remain closed for an hour, the casing pressure may rise to about 900 p.s.i. and the tubing pressure rise to about 800 p.s.i., as shown by the chart.

One of the segments 65 on the timer wheel 63 then engages the trigger mechanism 67 and this action serves to deliver gas under pressure through line 81. Line 36 and port 45 are thus pressurized. This serves to pressurize line 38 and chamber 39 to cause the motor valve 21 to open by moving the valve head 41 downward away from the valve seat 42. The flow of gas from the discharge pipe 19 and motor valve 21 reduces the pressure in the tubing 11 above the plunger, and accordingly the plunger moves rapidly upward in the tubing carrying a load of well fluid above it. The parts are then in position corresponding to the five hour station as shown on the time-pressure chart in FIGURE 4. Opening of the motor valve 21 causes the tubing pressure to drop sharply and causes a somewhat smaller reduction in casing pressure. During the ten or twelve minutes that the plunger 23 is rising from the bottom of the eduction tube 11 to the well head 16, motor valve 21 is open, motor valve 14 is closed, valve 31 is closed and the valve stem 52 remains in its upper position.

When the plunger 23 enters the bumper housing 18 the magnet 32 swings the arm 33 toward the plunger 23 against the action of the compression spring 34*a*, thereby permitting the valve 31 to be moved by pressure in the line 36 away from the seat 34. Gas pressure then enters the line 35, passes through the T fitting 48 and connection 50 into the diaphragm chamber 49, thereby depressing the stem 52 of the four-way valve 37 and changing the porting. The line 38 is then vented through the port 54, allowing the spring 40 to raise the valve head 41 into sealing engagement with the valve seat 42 thereby closing

the motor valve **21** and shutting in the tubing **11**. The parts are then in the position shown in FIGURE 1 of the drawings. The plunger **23** then drops back down the hole, and the casing pressure begins to build up. After allowing eight to ten minutes for the plunger to reach bottom, the timer wheel **64** moves its segment **65** out of engagement with the trigger mechanism **66** with the result that gas pressure through line **80** is shut off and the line is vented through port **82**. The spring **88** in motor valve **14** then raises the valve head **86** away from the valve seat **87**, opening the gas delivery conduit **13** to the sales line **15**. The casing pressure falls off to a stable value of approximately 700 p.s.i. as shown by the time-pressure chart. The cycle then repeats.

In the modified form of my invention shown in FIGURE 5, the plunger **23** is retained in the upper portion of the well head during the normal flow cycle and does not remain for long periods of time at the lower end of the eduction tube **11**. The casing **10**, tubing **11**, casing head structure **12**, plunger **23**, motor valve **21** and timer **60** are substantially the same as previously described. The motor valve **14** in the gas delivery conduit **13***a* however, is preferably of the normally open type rather than normally closed. In other words, the action of the spring **88***a* is to raise the valve head **86***a* away from the valve seat **87***a*. In this form of the invention, the four way valve **37** and the valve **31** with its associated magnet **32** and arm **33** are not used. Instead a bypass line **100** connects to the sales line **15** downstream from the control valve **14** and serves to deliver gas into the stack nipple **17***a* at a location below the plunger **23** when the latter is in its uppermost position engaging the bumper ring **26**.

The timer **60** is substantially the same as that previously described and is supplied with gas under pressure through line **61***a*. At predetermined timed intervals the timer **60** pressurizes the lines **80** and **81** as described above to control the operation of the motor valves **14** and **21** respectively.

In the operation of this form of my invention the motor valve **14** is normally open so that gas which accumulates from the well and which passes into the casing **10** is delivered through conduit **13***a* and through motor valve **14** to the sales line **15**. A portion of the gas so delivered passes through the bypass line **100** and into the stack nipple **17***a* through lateral port **101**. The gas passes through open valve **24** in the plunger **23** and through the central opening **102** and out through the discharge pipe **19***a* when the motor valve **21** is open. If necessary, the sales line **15** downstream from the bypass connection **103** may be closed so that all of the gas from the casing is required to pass through the bypass line **100**. The gas passing through the plunger **23** creates suffiicent pressure drop to hold the plunger **23** against gravity and prevents it from dropping back down the eduction tube **11**.

After a predetermined time interval, the clock driven timer **60** closes both the motor valves **14** and **21** thereby shutting in both the tubing **11** and casing **10**. The plunger **23** promptly drops to the lower end of the eduction tube **11**, the lower portion of its travel occurring through well fluid which has accumulated in the tubing. The pressure in the casing and in the tubing builds up. The timer **60** then acts to pressurize the lines **81** and **38** so that pressure in the diaphragm chamber **39** may open the motor valve **21** and thereby permit flow through the discharge pipe **19***a*. The plunger **23** thereupon moves rapidly upward in the tubing **11** carrying a load of well fluid above it. After a sufficient time interval has elapsed to permit the plunger **23** to move into the bumper housing **18***a* the timer **60** acts to reopen the motor valve **14** in the gas conduit **13***a*. The plunger **23** is held in the bumper housing **18***a* by the flow of gas from the bypass **100** through the interior of the plunger. Both motor valves **14** and **21** are open. The cycle then repeats.

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

I claim:

1. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: means including a first valve connected to the well head for controlling flow from the casing, means including a second valve connected to the well head for controlling flow from the eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, a timer, the timer having a pair of wheels rotatable in synchronism and provided with replaceable segments, first means operated by the segments on one of the timer wheels for actuating said first valve, second means operated by the segments on the other of said timer wheels for actuating said second valve, said first and second means operating to close the first valve to permit build up of gas pressure in the casing and subsequently to open the second valve to permit the plunger to raise liquid through the eduction tube and discharge it from the well head through said second valve.

2. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: means including a first valve connected to the well head for controlling flow from the casing, means including a second valve connected to the well head for controlling flow from the eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, a timer having two timing wheels mounted upon a common rotary shaft, means controlled by one of the timing wheels and operatively connected to actuate said first valve, means controlled by the other of the timing wheels and operatively connected to actuate said second valve whereby turning of the shaft acts to close the first valve to permit build up of gas pressure in the casing and subsequently to open the second valve to permit the plunger to raise liquid through the eduction tube and discharge it from the well head through said second valve.

3. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: a gas delivery conduit connected to the well head and communicating with the casing, a first valve within said gas delivery conduit, a discharge pipe connected to the well head and communicating with the eduction tube, a second valve in said discharge pipe, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, a timer, the timer having a pair of wheels rotatable in synchronism and provided with replaceable segments, first means operated by the segments on one of the timer wheels for actuating said first valve, second means operated by the segments on the other of said timer wheels for actuating said second valve, said first and second means operating to close the first valve to permit build up of gas pressure in the casing and subsequently to open the second valve to permit the plunger to raise liquid through the eduction tube and discharge it from the well head through said discharge pipe and second valve.

4. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising in combination: a gas delivery conduit connected to the well heading and communicating with the casing, a first valve in said gas delivery conduit, a discharge pipe connected to the well head and communicating with the eduction tube, a second valve in said discharge pipe, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the

well, means operatively connected to both said valves for sequentially closing the first valve and thereafter opening the second valve, and means including an element actuated by arrival of the plunger at the well head for closing the second valve.

5. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: a gas delivery conduit connected to the well head and communicating with the casing, a first valve in said gas delivery conduit, a discharge pipe connected to the well head and communicating with the eduction tube, a second valve in said discharge pipe, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, timer controlled means operatively connected to both said valves, said means operating to close the first valve to permit buildup of gas pressure in the casing, open the second valve to cause the plunger to rise in the eduction tube, and re-open the first valve in that order of sequence, and means including an element actuated by arrival of the plunger at the well head for closing the second valve.

6. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: a gas delivery conduit connected to the well head and communicating with the casing, a first valve in said gas delivery conduit, a discharge pipe connected to the well head and communicating with the eduction tube, a second valve in said discharge pipe, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, timer controlled means operatively connected to both said valves and adapted to close the first valve and open the second valve, in that order of sequence, whereby the casing pressure is permitted to build up prior to the beginning of upward travel of the plunger in the eduction tube, and means including a movable element positioned adjacent the well head and actuated by arrival of the plunger at the well thead for closing the second valve, said timer cotnrolled means also acting to re-open said first valve.

7. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: a gas delivery conduit connected to the well head and communicating with the casing, a first valve in said gas delivery conduit, a discharge pipe connected to the well head and communicating with the eduction tube, a second valve in said discharge pipe, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, means adapted to close the first valve and subsequently open the second valve, and means including an element actuated by arrival of the plunger at the well head for closing the second valve, the first said means also acting to re-open the first valve.

8. In a gas well installation having a casing and an education tube therein, both connected to a well head, the improvement comprising, in combination: means including a first valve connected to the well head for controlling flow from the casing, means for delivering gas from the first valve into the well head, means including a second valve connected to the well head for controlling flow from the eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, the plunger having a central opening extending therethrough and having valve means for closing the opening, a timer, means controlled by the timer and operatively connected to said first and second valves, said means acting sequentially to close the first valve to permit build up of gas pressure in the casing, and subsequently to open the second valve to permit the plunger to raise liquid through the eduction tube, and then to open the first valve to deliver gas into the well head below the plunger, whereby the gas may pass through the central opening in the plunger and act to hold the plunger within the well head.

9. In a gas well installation having a casing and an eduction tube therein, both connected to a well head, the improvement comprising, in combination: means including a valve connected to the well head for controlling flow from the casing, a discharge pipe connected to the well head and communicating with the eduction tube, a plunger adapted to travel freely under pressure substantially the full length of the eduction tube to remove accumulations of liquid in the well, the plunger having a central opening extending therethrough and having valve means for closing the opening, means for delivering gas from said valve into the well head below the plunger, a timer, means controlled by the timer and operatively connected to actuate said valve, whereby the plunger may be retained within the well head by the pressure drop of gas passing through its central opening.

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