

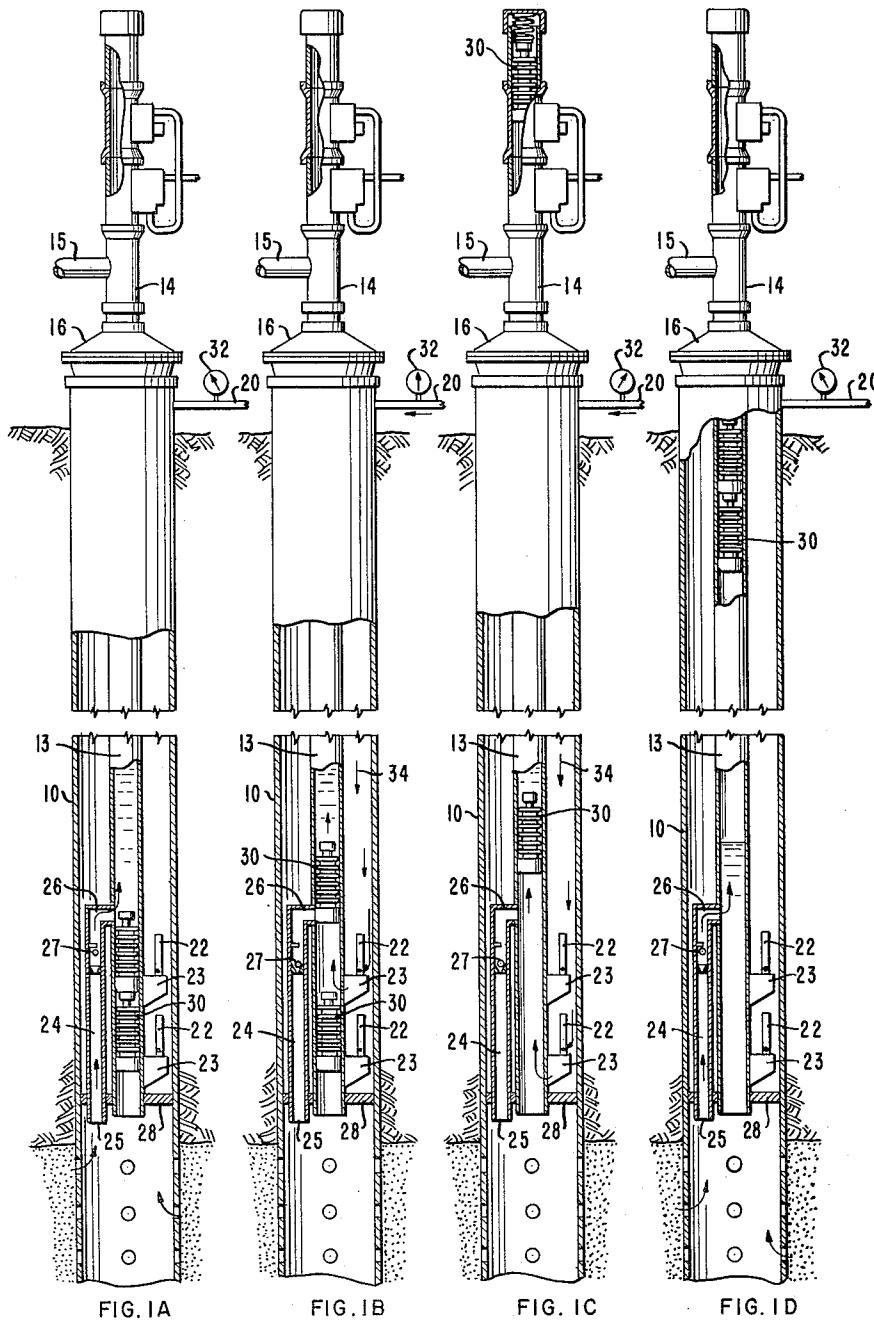
May 21, 1963

N. E. MONTGOMERY
GAS LIFTING SYSTEM

3,090,316

Filed Nov. 24, 1961

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

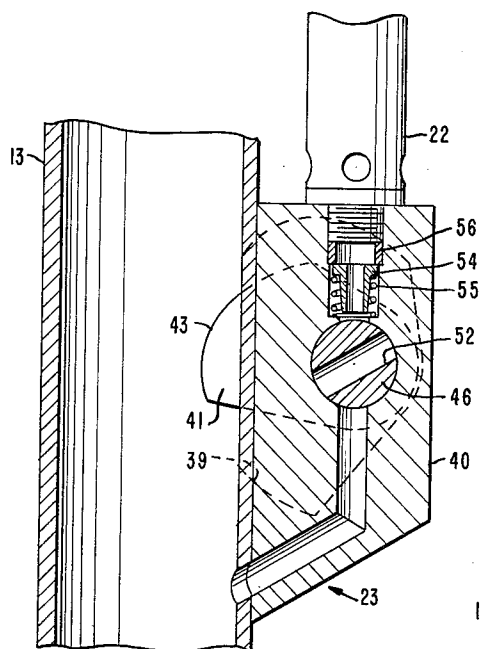


FIG. 2A

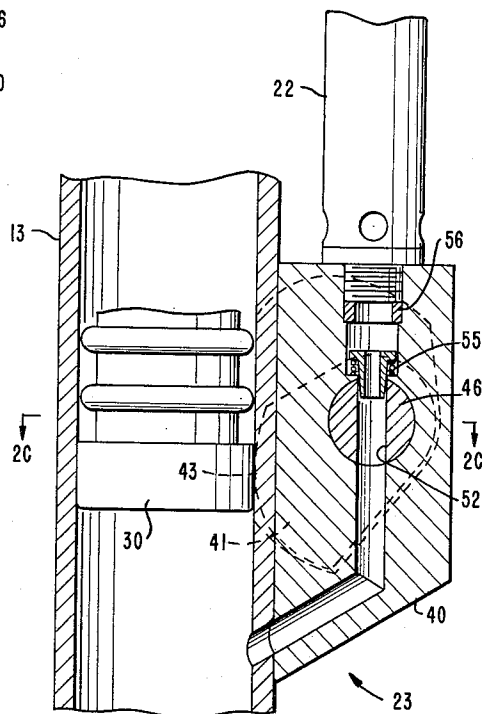


FIG. 2B

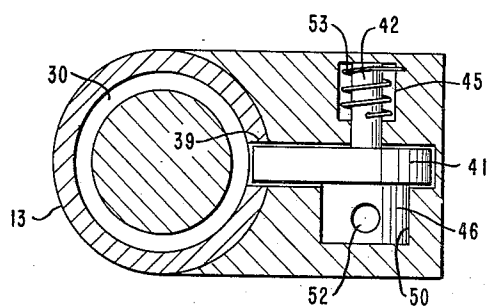


FIG. 2C

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3 Sheets-Sheet 3

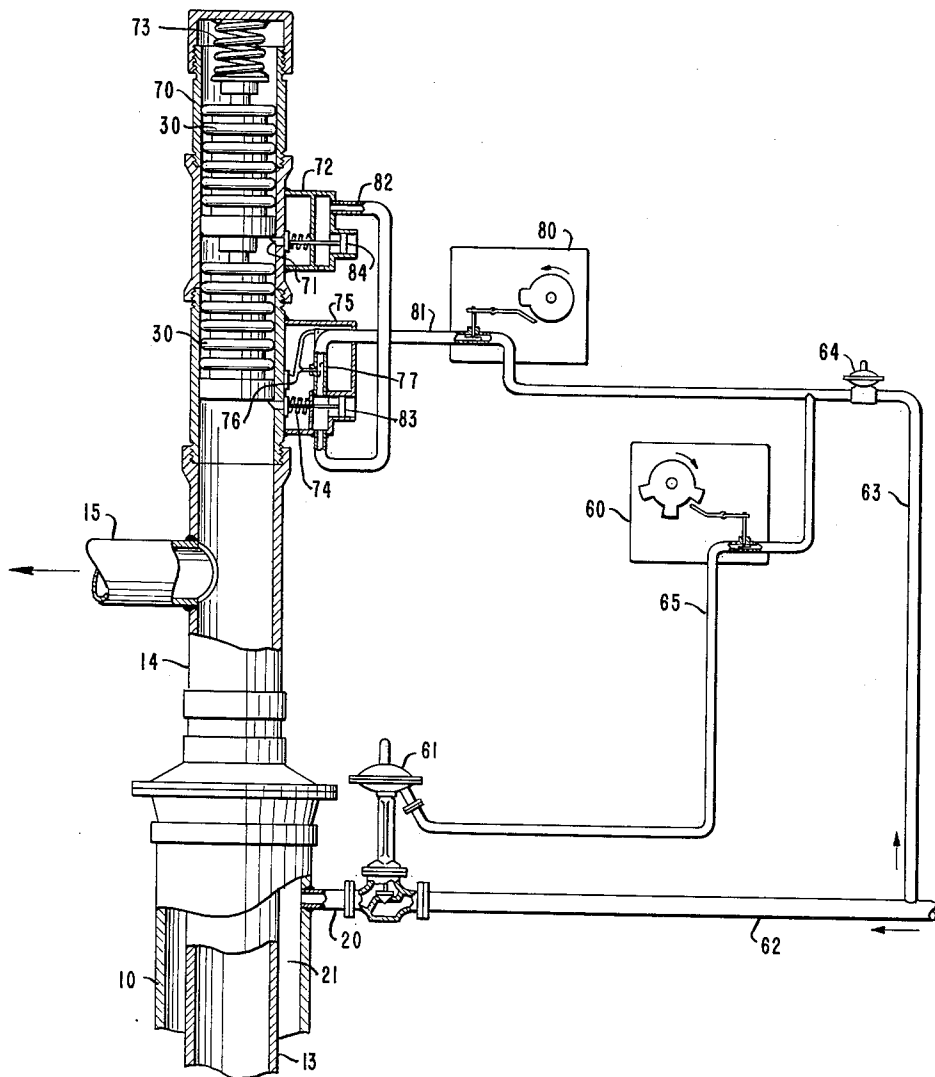


FIG. 3

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1

3,090,316

GAS LIFTING SYSTEM

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9 Claims. (Cl. 103—52)

This invention relates to oil wells and more particularly to artificially produced oil wells, and is a continuation-in-part of an application, Serial No. 88,841, filed February 13, 1961, and entitled "Gas Lifting System."

In most cases, when oil wells are first completed they produce by means of natural drive created by the reservoir pressure. After the reservoir energy declines to a certain level the oil well ceases to produce and artificial means must be provided for lifting the oil from the reservoir to the surface. These means may be one of several forms, for example mechanical pumping means, gas drive means or plungers which are lifted by the gas to produce the oil. This invention relates particularly to wells which are artificially produced by means of a combination of plungers and gas lifting operations.

When a well is produced by means of gas lift, a gas is intermittently admitted to the production tubing string to lift a trapped slug of oil to the surface. This type of operation has approximately a 40% efficiency and requires 20 to 30 minutes to lift a slug of oil from a 10,000 foot depth. In a plunger operation, a plunger which effectively seals the production tubing string is lifted to the surface by pressurized gas. The plunger, of course, traps a slug of oil in the production tubing string which it lifts to the surface. The efficiency of a plunger is approximately 70% to 80% and requires approximately 40 to 60 minutes for the plunger to reach the surface and then be released to fall back to the bottom of a 10,000 foot well.

From the above discussion, it can be appreciated that more cycles can be completed with a gas lifting operation, but that the efficiency is very low. While the efficiency is improved with a plunger operation, the time per cycle is substantially double that required for a gas lift operation. Gas lift operations also require a larger quantity of pressurized gas and thus they increase the over-all cost of operation.

Accordingly, it is a principal object of this invention to provide a novel system for artificially producing an oil well which has both improved production and efficiency.

A further object of this invention is to provide a novel means for artificially producing a well which means utilizes a plurality of plungers which are individually transported to the surface by means of pressurized gas and then are allowed to fall back to the bottom of the well in a single group.

The above objects and advantages of this invention are achieved by providing a plurality of plungers in a well. The number of plungers used is controlled by the length of the catching device installed at the wellhead as well as the particular characteristics of the well. The uppermost plunger is lifted from the bottom of the well first and transported to the surface by means of pressurized gas. After this plunger reaches the surface it is retained and the pressurized gas in the well is bled down. Additional pressurized gas is then admitted to lift the next plunger to the surface where it is retained. After all of the plungers have been transported to the surface the well pressure is bled down and all of the plungers are released to fall back to the bottom of the well as a group.

From the above discussion it can be appreciated that

2

only one fall-back cycle is required for a plurality of plungers. Thus, the over-all time cycle for the plunger lift is reduced and the production is increased. The efficiency of the system is likewise increased due to the inherent efficiency of plunger lift over other means for artificially lifting oil wells.

The above objects and advantages of this invention will be more easily understood from the following detailed description of a preferred embodiment when taken in conjunction with the detailed drawings, in which:

FIGURES 1A to 1D are cross-sections of an oil well embodying this invention and showing four different stages of the operating cycle thereof;

FIGURES 2A to 2C are vertical sections of a valve suitable for controlling the admission of gas to the well to permit the plungers to be individually lifted to the surface; and

FIGURE 3 is a schematic view of the surface timing means that controls the various cycles of operation.

Referring now to FIGURE 1, there is shown a well which is provided with an outer casing 10. The outer casing extends to a production zone 11 and is provided with a plurality of perforations 12 in order that the crude oil may pass from the production zone into the interior of the casing. Disposed within the casing 10 is a production tubing string 13 whose lower end terminates adjacent the production zone 11. The upper end of the production tubing 13 terminates in a wellhead assembly 14 which is provided with an outlet pipe 15. The outlet pipe 15 transports the crude oil product to a storage tank or other disposal means. The wellhead assembly 14 includes a plunger catching mechanism which is capable of catching and retaining all of the plungers utilized in the system. Plunger catching mechanisms are well known in the art and any desired type may be used. The casing 10 is provided with a cap 16 to insure a gas-tight volume 21 between the casing 10 and the production tubing 13. A source of pressurized gas is supplied to the annulus 21 by means of supply pipe 20. In addition to supplying pressurized gas the source should control the operating cycle of the system. Many well known timing means which may be actuated by various means are available for controlling the operating cycle of a gas lift system to meet any requirement. The particular requirements of the system of this invention will be explained in detail below.

The gas is admitted to the production string 13 by means of gas inlet valves 22 and a mandrel or plunger-operated valve 23. The plunger-operated valve 23 will be described with reference to FIGURE 2 while the gas inlet valve 22 is of well known construction. Several gas lifting valves are available on the market which may be set to open whenever the gas pressure within the volume 21 reaches a predetermined level. A suitable gas lift valve would be a Camco type "C" described on page 1083, volume 1 of the 1960 edition of the composite catalog of Oil Field Equipment. Such valves in addition include features for maintaining them open once a gas flow through the valve has been established. A conduit 24 is provided for transporting the crude oil from the lower end of the casing 10 to the portion of the production string 13 located above the uppermost plunger 30. The lower end 25 of the conduit 24 extends below a packing member 28 while the upper end 26 opens into the interior of the production string 13. The conduit 24 is also provided with a check valve 27 which is illustrated as being a simple ball check valve. The check valve 27 should be disposed to permit flow in an upward direction while preventing flow in a downward direction. A plurality of plungers 30 are disposed in the production string 13 and while any desired num-

3

ber of plungers may be used, only two are illustrated in FIGURE 1. The plungers 30 are of well known construction and are provided with a plurality of outwardly projecting sections 31 which effectively seal off the production string 13. The plungers in effect are free pistons which effectively seal off the production tubing string 13 when travelling in an upward direction and are provided with an internal valve means which opens when they fall to permit them to readily fall downwardly to the bottom of the well.

Referring now to FIGURE 2, there is shown a vertical section of the cam operated valve 23 which controls the admission of gas from the annulus 21 to the production string 13. The cam operated valve is provided with a valve body 40 having a cam 41 pivoted about a shaft 42 and disposed in a pocket 45 formed in the body. The cam 41 is provided with an operating surface 43 which projects through an opening 39 in the side wall of the production string 13 and contacts the plunger 30. The cam 41 is also provided with a circular plug type valve 46 that rotates within a cylindrical valve chamber 50 formed in the valve body 40. The cylindrical valve 50 is provided with a valve port 52 that is positioned with relation to the cam surface 43 as shown. The cam 41 is biased to return to the position shown in FIGURE 2A by a torsion spring 53 after the passage of a plunger has displaced it. The torsion spring 53 has one end secured or anchored to the valve body 40 and the other end secured to the shaft 42.

As shown in FIGURE 2B, when the plunger 30 is opposite the plunger-operated valve 23 it will move the cam 41 down. The cam 41 in turn will rotate the plug valve 46 counter-clockwise to align the port 52 with the ports 54 and 55 formed in the valve body 40. With the plunger-operated valve 23 in this position gas will be admitted to the interior of the production string 13 when the inlet valve 22 opens. When the plug valve has been rotated to the position shown it is retained in this position by a locking means operated by the inlet valve 22. The locking means consists of a velocity locking pin 54 that seats in the port 52 of the plug valve 46 when gas is injected through the valve 22. The velocity locking pin is retracted by a compression spring 55 and a magnetic sleeve 56 when the inlet valve 22 closes. When the velocity locking pin is in the position shown in FIGURE 2B it will be impossible for the torsion spring 53 to rotate the cam 41 and the plug valve 46 to the position shown in FIGURE 2A when the plunger 30 is lifted off the bottom. The locking means insures that the gas will be admitted to the interior of the production string 13 until the plunger completes its trip to the surface. After the plunger reaches the surface the gas pressure in the annulus will be reduced to permit the inlet valve 22 to close. When the valve 22 closes the velocity locking pin will be withdrawn by the spring 55 and magnetic sleeve 56 and the torsion spring 53 will return the cam 41 to the position shown in FIGURE 2A. Of course, when subsequent plungers pass the upper plunger-operated valve 23 it will merely rotate the cam 41 clockwise. This rotation will not align the port 52 in the plug valve 46 with the ports 54 and 55 in the valve body 40, thus the locking means will not be engaged and no gas will be admitted to the production string 13 through the upper valve even though the inlet valve 22 opens.

In FIGURE 3 there is shown a surface timing system for controlling the injection of gas to the annulus 21. The timing system uses a time cycle controller 60 and a motor valve 61. The time cycle controller may be one of the commercially available models that have provisions for changing the number and duration of the injection cycles, for example a Camco type B described on page 1100 of the above described reference. The motor valve 61 may be any well known design of pressure operated valve. The high pressure gas supply is connected by a

4

line 62 to the motor valve 61 that in turn is connected to the annulus 21 by the line 20. A small branch line 63 having a pressure regulator 64 disposed therein connects the gas supply to the controller 60. The pilot valve in the controller 60 in turn is connected to the motor valve by a line 65.

When the pilot valve in the controller 60 opens the motor valve 61 to permit the injection of gas into the annulus 21 the uppermost inlet valve 22 will open providing a plunger 30 is disposed adjacent to the valve as explained above. Through trial and error the length of the injection period required to lift the plunger to the surface can be determined and then the set on the controller 60. At the end of this period the gas injection is stopped and the pressure in the annulus 21 allowed to decline. After the elapse of a predetermined period of time the cycle is repeated by the controller 60 to lift the next plunger to the surface.

As the first plunger is lifted to the surface with the load of fluid, the oil and gas are produced through a flow line 15 and transported to the storage tanks (not shown). The velocity of the gas beneath the plunger carries it up into the plunger catcher 70 and is retained by the uppermost spring loaded latch 71 in the housing 72. The spring on the latch 71 allows the plunger to pass by the latch and then returns the latch to the locking position. The bumper spring 73 in the top part of the catcher acts as a shock absorber.

When the last plunger arrives at the surface it is also caught by the spring loaded latch 74 contained in the housing 75. The housing 75 is similar to housing 72 but is made of a non-magnetic material and contains a magnet type switch 76 that operates the valve 77. With the last plunger in place the magnet switch 76 is attracted toward the plunger thereby opening the gas valve 77 in the housing to permit the flow of gas to the housing to retract the latches holding the plungers at the surface. Gas is supplied only during the interval preset on the time cycle controller 80, that may also be a Camco type B referred to above. The controller 80 is connected to the same regulated gas supply as controller 60 and is disposed to inject gas on a timed cycle. The controller 80 is connected to housing 75 by a line 81 with the housing 75 being connected to the housing 72 by a line 82. Thus when the controller admits gas to the line 81 the latches 71 and 74 will be retracted by the piston means 83 and 84 in the housings 75 and 72, respectively, providing the valve 77 is open. In case the last plunger has not arrived at the surface to open valve 77 the latches will not be retracted. Accordingly the controller 80 should have a relatively long cycle to insure that the gas will be admitted to retract the latches and release the plungers. In addition, the valve 77 should be of a design that remains open as a result of gas pressure acting against an area of the valve to insure that all the plungers are released. The valve 77 will of course close when the controller 80 completes its cycle and shuts off the gas supply. When the valve 77 closes the latches 71 and 74 will be returned to their normal position as shown in FIGURE 3 to start a new cycle of operation.

The operation of this invention will be more easily understood by referring to FIGURES 1A to 1D and FIGURE 3. In FIGURE 1A, all of the plungers are shown disposed at the bottom of the production string 13 and the gas pressure within the annulus 21 is at a low level as shown on the pressure gage 32. The gas pressure within the annulus 21 is then raised by the operation of the controller 60 until the uppermost inlet valve 22 opens. This will cause the uppermost plunger 30 to raise off the bottom and start its trip to the surface as shown in FIGURE 1B. As the plunger 30 travels to the surface it will transport the slug of oil trapped above it to the surface. The uppermost inlet valve 22 should be adjusted so that it opens at a lower pressure than any of the remaining inlet valves. After the plunger 30 has reached the surface the

5

controller 60 will stop the injection of gas and the gas pressure within the annulus 21 will decline to permit the uppermost valve 22 to close. As explained above with reference to FIGURE 2, when the inlet valve 22 closes the plunger-operated valve 23 will also close. After the gas pressure has declined it is again increased by the operation of the controller 60 to a value higher than that shown in FIGURE 1B in order to open the lower inlet valve 22. When the lower inlet valve 22 opens it will cause the second plunger to rise off the bottom and start its trip to the surface as shown in FIGURE 1C. As described above with reference to FIGURE 2, when the lowest plunger passes the upper plunger-operated valve 23 it will merely rotate the cam 41 clockwise without admitting gas through the upper valve to the production string. After the second plunger has reached the surface the controller will again stop the injection of gas and the gas pressure will again decline. The plungers will be released by the controller 80 to start their return trip to the bottom of the production string 13. As shown in FIGURE 1D, when the plungers reach the bottom of the production string the cycle can be repeated.

From the above description of the operation, it can be seen that the plungers are individually lifted to the surface starting with the uppermost plunger and progressing downwardly. While but two plungers are shown in the attached drawing, any number may be used. Of course, as additional plungers are used the inlet valves associated with the individual plungers should be set so that they open in the proper sequence to cause the plungers to be lifted from the bottom in the proper sequence. As explained above, many inlet valves are available on the market which may be adjusted to readily open at any predetermined pressure. Also, once these valves are open they will remain open until the pressure is lowered below their opening pressure. Likewise, suitable plungers are well known as well as arrangements for catching the plungers at the surface and releasing them to fall back to the bottom of the production string.

While but a single embodiment of this invention has been described in detail it should not be limited to the details described but only to its broad spirit and scope.

I claim as my invention:

1. A method of producing an oil well by means of fluid lifting, said oil well having a production string and a string for introducing gas into the well, said method comprising:
 - introducing gas into the well to increase the pressure to lift the uppermost of a plurality of plungers disposed at the bottom of the well, continuing to inject said gas to transport said plunger and the slug of oil trapped above it to the surface;
 - catching and retaining the plunger at the surface;
 - injecting additional gas to raise the next plunger and continuing to inject the gas to transport said next plunger and slug of oil trapped above it to the surface, catching and retaining the next plunger at the surface;
 - continuing to inject the gas until all of the plungers have been transported to the surface;
 - discontinuing the injection of gas and permitting all of the plungers to fall to the bottom of the well as a group.
2. A method for producing an oil well by means of fluid lifting, said well having a production string and a means located exteriorly of said production tubing for conveying a lifting fluid to the bottom of the production string, said method comprising:
 - introducing the lifting fluid into the production string to individually transport through the production string a plurality of plungers to the surface;
 - catching and retaining the plungers at the surface until the last plunger arrives;
 - discontinuing the injection of gas and permitting all of the plungers to simultaneously fall back to the bottom of the production string.

6

3. A system for producing an oil well by plunger lifting comprising:

- a production tubing string;
- a plurality of plungers disposed in said production tubing;
- a fluid-operated intermittent gas lift valve associated with each plunger and disposed on said production tubing to control the introduction of lifting fluid from an area located exteriorly of the production string to the interior of the production string, said valves in addition being adjusted to open in a descending order at progressively higher pressures;
- the gas lift valve associated with each plunger opening to transport its associated plunger to the surface;
- a valve means operable by the removal of said plungers to close a port between its associated gas lift valve and the production string when it reaches the surface;
- a catching means disposed in said production string at the surface to catch and retain all of said plungers;
- control means associated with said catching means to trip said catching means to permit said plungers to fall to the bottom of the string as a unit after the last plunger reaches the surface.

4. A system for producing an oil well by plunger lifting, said system comprising:

- a production tubing string having a plurality of plungers disposed therein;
- a fluid-operated intermittent gas lift valve associated with each plunger and disposed on said production tubing adjacent the lower end thereof to control the injection of lifting fluid from an area located on the exterior of the production string to the interior of the production string, said valves in addition being adjusted to open in a descending order at progressively higher pressures;
- a plunger-controlled valve associated with each intermittent gas lift valve, said plunger-controlled valve being operated by the travel of the plunger associated with the intermittent gas lift valve;
- a controller located adjacent the top of said oil well to control the admission of gas to the area located on the exterior of said production string to individually transport the plungers to the top of the oil well;
- a catching means disposed adjacent the top of the oil well to catch and hold said plungers after they have been transported to the top;
- and a second controller located at the top of said oil well to release said plungers after the last plunger has reached the surface to permit said plungers to fall to the bottom of the production string as a unit.

5. The system of claim 4 in which the plunger-controlled valve is opened by a plunger being disposed adjacent thereto and closed by a biasing means.

6. The system of claim 4 in which the gas lift valve is operably connected to its associated plunger-controlled valve to hold said associated plunger-controlled valve open when said gas lift valve opens to lift the associated plunger to the surface.

7. A system for producing an oil well by plunger lifting, said system comprising:

- a production tubing string having a plurality of plungers disposed therein;
- a fluid-operated intermittent gas lift valve associated with each plunger and disposed on said production tubing adjacent the lower end thereof to control the injection of lifting fluid from an annulus surrounding the production string to the interior of the production string, said valves in addition being adjusted to open in a descending order at progressively higher pressures;
- a plunger-controlled valve associated with each intermittent gas lift valve and disposed to control communication between said gas lift valve and said production string, said plunger-controlled valve being a cam-operated valve that is spring biased to a closed

7

position and moved to an open position when the plunger associated therewith engages said cam;
 a controller located adjacent the top of said oil well to control the admission of gas to the area located on the exterior of said production string, said controller having a preset cycle to inject gas to individually transport the plungers to the top of the oil well and then stop the injection to permit the gas pressure in the annulus to decrease below the closing pressure of said gas lift valves;
 a catching means disposed adjacent the top of the oil well to catch and hold said plungers;
 and a second controller located at the top of said oil well to release said plungers after the last plunger has reached the surface to permit said plungers to fall to the bottom of the production string as a unit.
 8. The system of claim 7 in which the gas lift valve

8

is a cam-operated plug type valve, the cam of said valve being disposed to be moved by the downward motion of a plunger in the production tubing to open the plug valve and spring biasing means to close the plug valve.

5 9. The system of claim 8 in which the plug valve is held in an open position by a velocity latching pin that is moved to a locking position by the opening of the gas lift valve associated with the plunger-controlled valve.

10

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15