In accordance with my invention, the production rate on deep wells is increased by using a plurality of plungers within the same ejection tube, each of the plungers travelling only part of the length of the ejection tube. Assuming that two plungers are used, the lower plunger discharges its load at a midway station about halfway up from the lower end of the ejection tube. The upper plunger carries the load from the midway station to the surface. The cycle time is about one-half that required for a single plunger to complete the round trip from the bottom of the tubing to the surface. The fluid loads for each of the dual plungers is about half the corresponding load for a single plunger, and splitting the load permits a more rapid rate of upward travel of the plungers. Furthermore, the dual plungers take less time to pass down through the shorter fluid columns. The ratio of injected gas to oil produced may be reduced in certain wells where maximum production rates are not required. This may be accomplished because the stored up gas energy which is trapped below the second plunger at the time the well is shut in is fully utilized in lifting a fluid load each cycle.

In the drawings:

Figure 1a is a side elevation partly in section showing the surface equipment of a plunger lift device embodying my invention and also showing the upper portion of the well casing and ejection tubing.

Figure 1b is a sectional view constituting a continuation of the lower end of Figure 1a and showing the midway station at the upper end of the travel of the lower plunger and the lower end of the plunger lift device.

Figure 2 is a sectional view taken substantially along the line 2--2 of Figure 1a showing a preferred form of construction of one of the plungers.

Figures 3a and 3b are sectional elevations taken substantially along the lines 3a--3a of Figure 1b. Figure 3b is a continuation of the lower end of Figure 3a.

Figure 4 is a sectional plan view taken substantially along the line 4--4 of Figure 3a.
means of a nipple to the master gate or trap valve 15. The valve 15 is in turn connected to the stack assembly generally designated 16. This assembly 16 includes a spring mounted spear 17 of the type described in my copending application, Ser. No. 105,570.

The lower end of the education tubing 13 is connected to a footpiece 18 from which is suspended a perforated liner pipe 19. Oil and gas entering the education tubing 13 pass inward through the perforations in the liner pipe 19. A lower plunger generally designated 20 travels in the lower portion of the education tubing 13 while an upper plunger generally designated 21 travels in the upper portion of the same education tubing 13. A barrier device generally designated 22 is anchored within the education tubing at a midway station located about half way from the lower end of the education tubing to the surface. The upper plunger 21 travels from this barrier device 22 to the surface and returns while the lower plunger 20 travels from the lower end of the education tubing 13 to the barrier device 22 and returns.

The plungers 20 and 21 may be substantially duplicates and are preferably of the form shown in my copending application, Ser. No. 105,570, filed March 29, 1946, which was assigned to the assignee of the patentee, and issued June 16, 1953. As shown in Figure 2, these plungers each comprise a body 23 having spaced sets of radially movable sealing elements 24 adapted to seal against the inner surface 25 of the education tubing 13. For clarity of illustration, the coupling joints of the tubular education pipe are omitted, but it will be understood that the construction of the radially movable sealing device 24 is such that they pass over the joints between adjacent sections of the tubular pipe without interference or possibility of "hanging up." The body 23 is provided with a central passage 26 extending from end to end, and this passage may be closed by means of the vertically movable poppet-type valve 27 which has a head 28 adapted to seal against the seat 29. The lower end of the valve stem 30 projects below the lower end of the body 23. When the valve is in open position as shown in Figure 2, the plunger falls downwardly through the education tubing 13, and any fluid in the interior of the education tubing passes upward through the passageway 28 to permit the plunger to fall through the fluid. When the valve 27 is closed, the plunger is lifted within the education tubing 13 by the pressure of the gas below the plunger, and the lowering of gas pressure above it. The lowering of the gas pressure in the education tubing causes the motor valve (not shown) in the discharge line is opened. A motor valve of this type is shown in my Patent No. 2,503,174, granted May 16, 1950.

The barrier device 22 may be anchored at any selected point within the education tubing 13 and may be lowered on wire lines extending from the surface into position. As shown in the drawings, this barrier device includes a tubular mandrel 31 having an externally tapered surface 32. A plurality of wedge slips 33 are mounted on the surface 32 and are provided with wicker teeth 34 for engaging the inner surface 25 of the education tubing 13. A supporting arm 35 extends downwardly from each of the wedge slips 33. The lower end 36 of each arm is secured relative to a collar 37. The upper end 38 of a coil spring 39 is fixed on the lower extension 40 of the collar 37. The lower end of the spring 39 is fixed to the upper end of the spear tube 41. From this description it will be understood that the spear 41, spring 39, and collar 37 are suspended from the slip 38 which engage the inner surface of the education tubing 13.

The tapered mandrel 31 is supported within the tapered bore 42 of the slips 33 and the upper end of the mandrel is provided with a flange or head 43 which is engaged by a plurality of spring-dingering clips 44 to secure the slips 33 to the mandrel 45. Threads 46 connect the collar 45 with a sealing device generally designated 47 which seals against the inner wall 50 of the education tubing 13. While any conventional or desirable form of seal may be employed, I have found that one of the sealing units of the type employed on the plungers 20 and 21 may be used to good advantage. Accordingly, the sealing device 47 includes a tubular body 48 having a plurality of longitudinally extending radially spaced slots 49 and a circumferential groove 50 intersecting the slots. Radially movable bars 51 are positioned within the slots 49, and ring segments 52 are mounted in the groove 50. The central portions of the bars and the ring segments cooperate to form an uninterrupted circular seal within the interior of the education tubing 13.

The body 53 may be secured to the lower end of the tubular body 48 to the sleeve 54. The sleeve 54 is connected by threads 55 to the valve case 56. A ball valve 57 is mounted within the case 56 and normally rests on the upper end of the annular seat 58. A coil spring 59 maintains the valve seat 57 in abutting contact with the tapered shoulder 32 on the case 56. The case is provided with a central chamber 61. A bar 62 mounted on the case extends diametrically across the chamber 61 to limit upward travel of the ball 57. An upper extension 63 on the case 56 provides a mounting for the lower end 64 of the coil spring 59.

The upper end of the coil spring 59 carries a bumper 65 against which the valve stem 33 on the upper plunger 21 rests when the plunger 21 is in its lowest position. Another bumper 67 is mounted at the upper end 65 of a coil spring 66 and the lower end of this coil spring is mounted on the support 69 which is detachably connected to the footpiece 18 by means of the spring fingers 70. The barrier device 22 is lowered into position on a wire line and is preferably lowered in two sections in order to reduce the weight on the wire line. The lower section comprising the mandrel 31, slip assembly, spring 30 and spear 14 are lowered first. The slips 33 are set by suddenly increasing the rate of downward travel. The upper section comprising the bumper 65, spring 66, valve case 56, body 48 and collar 37 is then lowered. The two sections are joined when the spring fingers 44 engage the fishing neck at the upper end of the mandrel 31.

In operation, well fluid enters the lower end of the education tubing 13 through the perforations in the liner pipe 19, the discharge line extending from the lower end of the education tubing 13 through the interior of the support 63 into the interior of the education tubing. Formation gas in the annulus 9 between the casing 10 and education tubing 13 forces the column of well fluid upwardly within the education tubing 13. The gas is supplelemented by gas pumped into the annulus from the surface through the side outlets in the casing head 11, if desired. Assuming that the lower plunger 20 is dropping by gravity through a column of well fluid in the lower end of the education tubing 13, the
plunger 20 continues its downward movement until the valve stem 30 engages the spring mounted bumper 21. This closes the valve 27 in the plunger 20. The pressure in the education tubing below the plunger 20 thereupon raises the plunger 20 to lift a column of well fluid above it. The plunger and its load of well fluid continues upward until the spring 4 delivers its load to the plunger 20. The erudite motion of the plunger 20 passes upward through the interior of the hollow collar 37, hollow mandrel 31, collar 45, hollow body 46 and past the check valve 51 into the education tubing 13 above the location of the barrier device 22. The seal afforded by the bars 51 and ring segments 52 prevents the well fluid from leaking downwardly around the exterior of the barrier device. When the valve 27 in the lower plunger 20 is opened, the plunger 20 again drops by gravity downward toward the lower end of the education tubing 13 to begin another cycle of operations.

The upper plunger 21 drops by gravity through the upper portion of the education tubing and down through the column of well fluid previously raised by the lower plunger 20. The valve stem 31 connected to the plunger 21 engages the collar 37 to close the valve and arrest downward movement of the plunger 21. Pressure within the education tubing 13 below the plunger 21 then raises the plunger upwardly toward the surface, carrying the load of well fluid above it. When the plunger 21 approaches the surface, the column of well fluid above it passes out through discharge pipes 71 and 72 connected to the stack assembly 16. The spring mounted spear 17 mechanically engages the valve head 33 to open the valve, and the plunger 21 thereupon descends by gravity down toward the barrier device 22 to begin a new cycle. From the above description it will be understood that the upper and lower plungers 20 and 21 operate simultaneously, and that each travels back and forth in its respective portion of the education tubing 13. While only two plungers have been shown and described, more than two can be employed in the same education tubing if desired.

In the event that it should be desirable to reduce the height of the fluid column above the check valve 51, gas under pressure can be applied to the interior of the tubing at the well head. When a pressure of sufficiently great intensity is reached, the spring 59 is compressed, allowing the seat 58 to move away from its sealing shoulder 60, thereby permitting downward flow of fluid in the tubing past the check valve.

If it should become necessary to remove the plungers and barrier device 22 from the well for servicing or cleaning, or for any other reason, the upper plunger 21 may be trapped at the surface by closing the valve 15 and thereafter an overshot device of conventional form may be lowered from the surface on a wire line to engage the bumper 63. An upwardly directed force applied to the bumper 63 raises the spring 51, valve cage 66, hollow body 60, sleeve 56, and mandrel 21. Raising of the mandrel 21 releases the wedge slips 33 from the wedging ring 9, and the education tubing 13. The ring 13 which encircles the slip support arms 35 is fixed to the mandrel by means of fingers 34 located between adjacent arms 35. When the mandrel moves upwardly the shoulder 15 on the ring 13 engages the abutments 49 on the wedge slips 33 so that the wedge slips 33, collar 37, spring 39 and spear 41 are withdrawn from the education tubing 13 along with the mandrel 21.

When the barrier device 22 has been lifted to the surface on the wire line, it may be set aside and the wire line and over-shot again run into the hole to engage the bumper 63. An upwardly directed force applied to the bumper 67 by means of the over-shot tensions the spring 66 and serves to disengage the spring fingers 70 on the support 69 from the foot plate 18. The parts 61, 66, 69 and 70 then are withdrawn on the wire line.

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 multiple-stage plunger lift device for raising well fluid in an education tubing, the combination of: a barrier device adapted to be fixed in said education tubing, the barrier device having a passageway extending there-through, a first plunger adapted to travel in the education tubing from the lower end thereof to the barrier device to raise a load of well fluid through said passageway into the education tubing above the barrier device, a second plunger adapted to travel in the education tubing from the lower end thereof to the barrier device to a location in the education tubing spaced above the barrier device for raising well fluid upwardly from the barrier device, each of the plungers having a passageway extending longitudinally therethrough and each having an upwardly closing valve for closing the passageway, and means at the lower end of the education tubing constituting the sole means for introducing motive fluid into the education tubing.

2. In a multiple-stage plunger lift device for raising well fluid in an education tubing, the combination of: a barrier device adapted to be fixed in said education tubing, the barrier device having a check valve preventing flow of fluid downwardly through the barrier device, a first plunger adapted to travel in the education tubing from the lower end thereof to the barrier device to raise a load of well fluid through the check valve into the education tubing above the barrier device, a second plunger adapted to travel in the education tubing from the barrier device to a location in the education tubing spaced above the barrier device for raising well fluid upwardly from the barrier device, each of the plungers having a passageway extending longitudinally therethrough and each having an upwardly closing valve for closing the passageway, and means at the lower end of the education tubing constituting the sole means for introducing motive fluid into the education tubing.

3. In a multiple-stage plunger lift device for raising well fluid in an education tubing, the combination of: a barrier device in said education tubing, means including wedge slips on the barrier device engaging with the inner surface of the education tubing for releasably anchoring the barrier device in the education tubing, the barrier device having a check valve preventing flow of fluid downwardly through the barrier device, a first plunger adapted to travel in the education tubing from the lower end thereof to the barrier device to raise a load of well fluid through the check valve into the education tubing above the barrier device, a second plunger adapted to travel in the education tubing from the barrier device to a location in the education tubing spaced above the barrier device for raising well fluid upwardly from the barrier device.
from the barrier device, each of the plungers
having a passageway extending longitudinally therethrough and each having an upwardly clos-
ing valve for closing the passageway at the lower end of the passageway constit-
tuting the sole means for introducing motive fluid into the eduction tubing.

4. In a multiple-stage plunger lift device for wells, the combination of: an eduction tubing, a barrier device fixed in said eduction tubing, the
barrier device having a passageway extending therethrough, a first plunger in the eduction tubing traveling from the lower end of the eduction tubing to the barrier device to raise a load of well fluid through said passageway into the eduction tubing above the barrier device, a second plunger in the eduction tubing traveling from the barrier device to a location in the eduction tubing spaced above the barrier device for raising well fluid upwardly from the barrier device, each of the plungers having a passageway extending longitudinally therethrough and each having an upwardly closing valve for closing the passageway, and means at the lower end of the eduction tubing constituting the sole means for introducing motive fluid into the eduction tubing.

5. In a two-stage plunger lift device for wells, the combination of: an eduction tubing, a bar-
rier device fixed in said eduction tubing, the barrier device having a passageway extending therethrough, a lower plunger in the eduction tubing adapted to travel from the lower end of the eduction tubing to the barrier device to raise a load of well fluid through said passageway into the eduction tubing above the barrier device, an upper plunger in the eduction tubing adapted to travel from the barrier device to the upper end of the eduction tubing for raising well fluid to the surface, each of the plungers having a pass-
ageway extending longitudinally therethrough and each having an upwardly closing valve for closing the passageway, and means at the lower end of the eduction tubing constituting the sole means for introducing motive fluid into the eduction tubing.

6. In a two-stage plunger lift device for wells, the combination of: an eduction tubing, a bar-
rier device fixed in said eduction tubing, the barrier device having a passageway extending therethrough, a lower plunger in the eduction tubing travelling from the lower end of the eduction tubing to the barrier device to raise a load of well fluid through the check valve into the eduction tubing above the barrier device, a first plunger in the eduction tubing travelling from the barrier device to the upper end of the eduction tubing for raising well fluid through the eduction tubing to the surface, each of the plungers having a passageway extending longitudinally therethrough and each having an upwardly closing valve for closing the passageway, and means at the lower end of the eduction tubing constituting the sole means for introducing motive fluid into the eduction tubing.

7. In a two-stage plunger lift device for wells, the combination of: an eduction tubing, a bar-
rier device fixed in said eduction tubing, the barrier device having a passageway extending therethrough, a lower plunger in the eduction tubing travelling from the lower end of the eduction tubing to the barrier device to raise a load of well fluid through the check valve into the eduction tubing above the barrier device, a first plunger in the eduction tubing travelling from the barrier device to the upper end of the eduction tubing for raising well fluid through the check valve into the eduction tubing above the barrier device, a second plunger adapted to travel in the eduction tubing from the barrier device to a location in the eduction tubing spaced above the barrier device for raising well fluid upwardly from the barrier device, each of the plungers having a passageway extending longitudinally therethrough and each having an upwardly closing valve for closing the passageway, and means at the lower end of the eduction tubing constituting the sole means for introducing motive fluid into the eduction tubing.

8. In a multiple-stage plunger lift device for wells, the combination of: a barrier device in said eduction tubing, means including wedge slips on the bar-
rier device engageable with the inner surface of the eduction tubing for releasably anchoring the barrier device in the eduction tubing, the bar-
rier device having a check valve for closing the passageway, and means at the lower end of the eduction tubing constituting the sole means for introducing motive fluid into the eduction tubing.

9. For use in multiple-stage plunger lift appara-
20 tus employing a plurality of swab plungers travelling freely within a single eduction tubing, the combination of: a barrier device inserted into the eduction tubing from the upper end thereof, means on the barrier device for releas-
ably anchoring it within the eduction tubing, the barrier device having a passageway extending therethrough, a check valve in said passage-
way preventing passage of fluid downwardly in said passageway, a bumper element resiliently mounted on the barrier device for arresting downward movement of an upper plunger, and an element resiliently mounted on the barrier device for arresting upward movement of a lower plunger.

10. For use in multiple-stage plunger lift appa-
20 rus employing a plurality of swab plungers travelling freely within a single eduction tubing, the combination of: a barrier device inserted into the eduction tubing from the upper end thereof, means on the barrier device for releas-
yably anchoring it within the eduction tubing, the barrier device having a passageway extending therethrough, a check valve in said passage-
way preventing passage of fluid downwardly in said passageway, a bumper element resiliently mounted on the barrier device for arresting downward movement of an upper plunger, and an element resiliently mounted on the barrier device for arresting upward movement of a lower plunger.

11. For use in multiple-stage plunger lift ap-
2,676,547

2,676,547 apparatus employing a plurality of valved swab plungers travelling freely within a single eduction tubing, the combination of: a barrier device insertable into the eduction tubing from the upper end thereof, means including wedge slips on the barrier device engageable with the inner surface of the eduction tubing for releasably anchoring the barrier device in the eduction tubing, means establishing a seal between the barrier device and the inner surface of the eduction tubing, the barrier device having a passageway extending therethrough, a check valve in said passageway preventing passage of fluid downwardly in said passageway, a bumper element resiliently mounted on the barrier device for arresting downward movement of an upper plunger and for closing its valve, and a spear element resiliently mounted on the barrier device for arresting upward movement of a lower plunger and for opening its valve.

12. Multiple-stage plunger lift apparatus having in combination: an eduction tubing, a pair of swab plungers travelling freely within the eduction tubing, a barrier device positioned within the eduction tubing between said plungers, means on the barrier device for releasably anchoring it within the eduction tubing, the barrier device having a passageway extending therethrough, a check valve in said passageway preventing passage of fluid downwardly in said passageway, a bumper element resiliently mounted on the barrier device for arresting downward movement of one of the plungers, and an element resiliently mounted on the barrier device for arresting upward movement of the other plunger.

13. Multiple-stage plunger lift apparatus having in combination: an eduction tubing, a pair of swab plungers travelling freely within the eduction tubing, a barrier device positioned within the eduction tubing between the plungers, means including wedge slips on the barrier device engageable with the inner surface of the eduction tubing for releasably anchoring the barrier device in the eduction tubing, the barrier device having a passageway extending therethrough, a check valve in said passageway preventing passage of fluid downwardly in said passageway, a bumper element resiliently mounted on the barrier device for arresting downward movement of one of the plungers, and an element resiliently mounted on the barrier device for arresting upward movement of the other plunger.

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