April 27, 1954 D. G. KNOX 2,676,547

TWO-STAGE PLUNGER LIFT DEVICE

Filed March 5, 1951 2 Sheets-Sheet 1

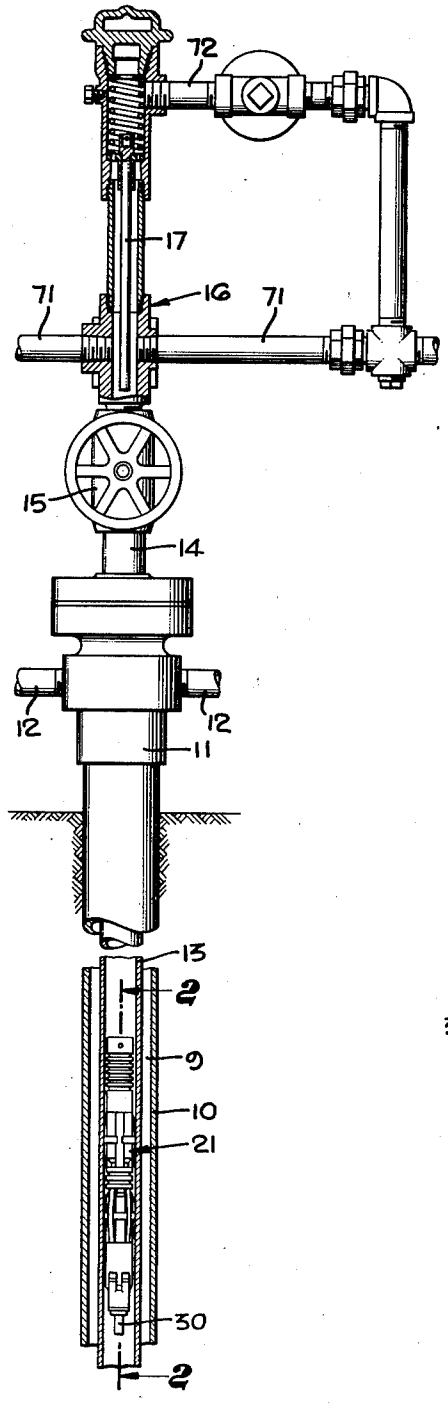

FIG. 1a.

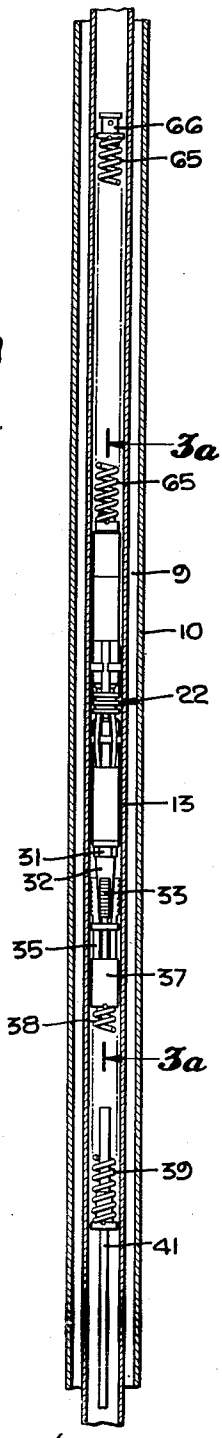

FIG. 1b.

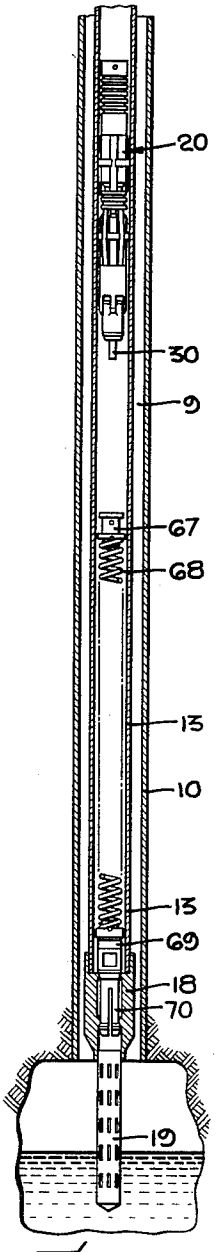

FIG. 1c.

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TWO-STAGE PLUNGER LIFT DEVICE

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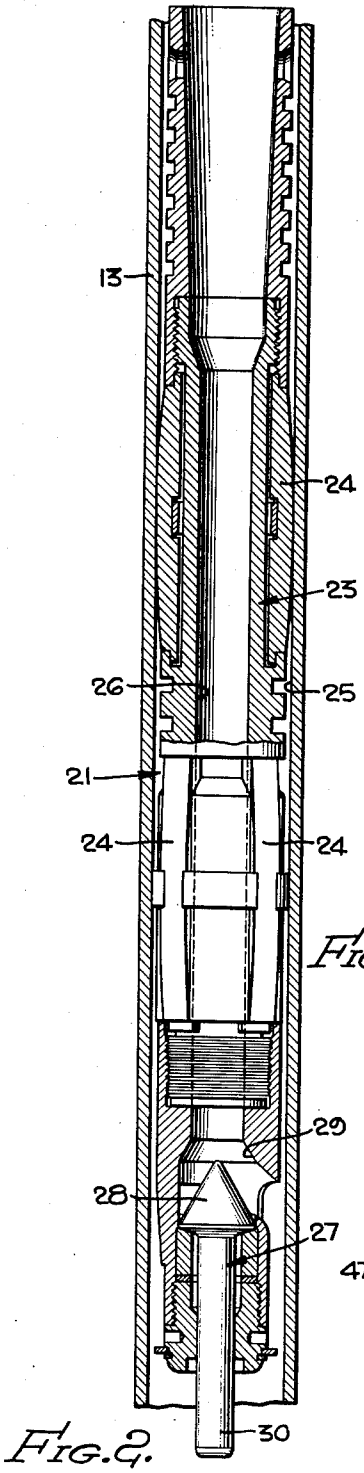

FIG. 2.

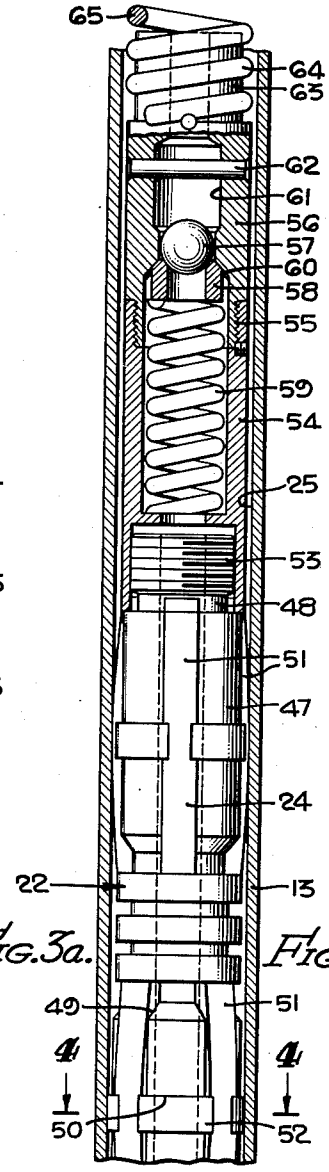

FIG. 3a.

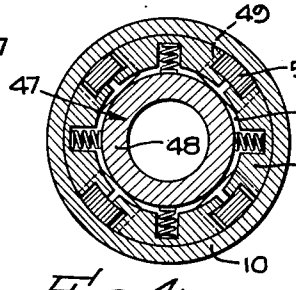

FIG. 4.

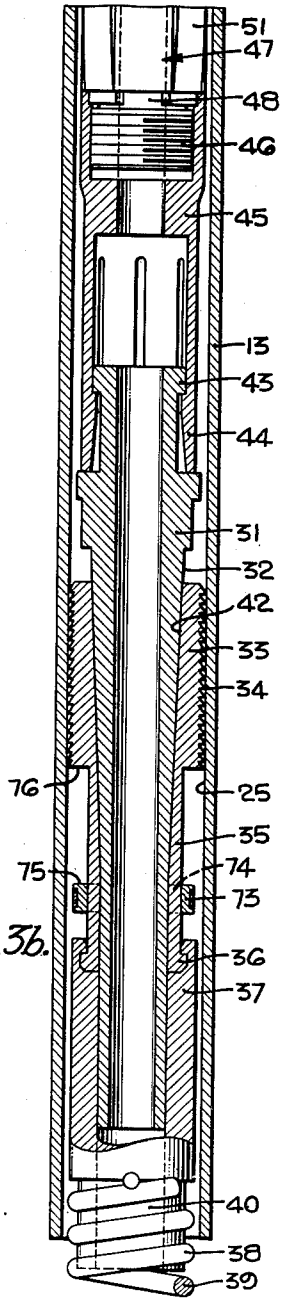

FIG. 3b.

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Patented Apr. 27, 1954

2,676,547

UNITED STATES PATENT OFFICE

2,676,547

TWO-STAGE PLUNGER LIFT DEVICE

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Application March 5, 1951, Serial No. 213,885

14 Claims. (Cl. 103—46)

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This invention relates to apparatus for raising oil or other fluid from wells, and is particularly directed to improvements in plunger lift devices of the general type shown in my United States Patent No. 2,508,174.

The principal object of the present invention is to provide plunger lift apparatus capable of increased production capacity without changing the size of the eduction tubing.

Another object is to reduce the amount of injection gas required per barrel of oil produced.

Another object is to provide a dual or two-stage plunger lift apparatus in which a first plunger travels from the bottom of the eduction tubing to a midway point and then returns to the bottom while the second plunger picks up the fluid unloaded at the midway station and carries it to the surface of the ground, with both plungers moving simultaneously.

In plunger lift devices now in use, a single plunger travels the full length of the eduction tubing from the bottom of the well to the ground surface. In present field practice a single plunger lifting fluid from eight thousand feet can bring up a maximum of about one hundred fifty barrels per day. If the depth is ten thousand feet only about one hundred twenty five barrels per day can be produced. The reason for the lower rate of production is that a longer time is required for the plunger to travel the greater distance, and also, at near maximum production rates the number of cycles per day are reduced because of the greater height of fluid column in the eduction tubing that the plunger must fall through each time it returns to the bottom of the tubing string.

Other factors limiting the production rate are the height, density and viscosity of the fluid column itself. As the plunger travels to the surface with its load of fluid at an estimated average speed of one thousand feet per minute, gas and oil are entering into the lower end of the eduction tubing. It is the slippage or passage of gas through the incoming well fluid that makes it possible for the plunger to continue its trip to the surface. If the column of fluid in the lower end of the eduction tubing becomes too high the propelling gas fails to break through and the plunger will slow down or stop. Within limits pressure and volume of the gas supplied from the surface into the well casing can be increased to break through high fluid columns in order to maintain average plunger speed. The upper limit is approached when flow velocities of the gas drop below that required for efficient plunger operation.

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In accordance with my invention, the production rate on deep wells is increased by using a plurality of plungers within the same eduction tube, each of the plungers travelling only part of the length of the eduction tube. Assuming that two plungers are used, the lower plunger discharges its load at a midway station about half way up from the lower end of the eduction 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 that 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 1*a* 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 eduction tubing.

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

Figure 1*c* is a sectional elevation constituting an extension of the lower end of Figure 1*b* and showing the lower end of the bore hole and the lower end of the plunger lift device.

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

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

Figure 4 is a sectional plan view taken substantially along the line 4—4 of Figure 3*a*.

Referring now to the drawings, the sectional well casing 10 extends into the bore hole and the upper end of the casing is connected to a conventional casing head 11 having lateral outlets 12. The sectional eduction tubing 13 extends through the casing head 11 and is connected by

means of a nipple 14 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. 106,579.

The lower end of the eduction tubing 13 is connected to a footpiece 18 from which is suspended a perforated liner pipe 19. Oil and gas entering the eduction pipe 13 pass inward through the perforations in the liner pipe 19. A lower plunger generally designated 20 travels in the lower portion of the eduction tubing 13 while an upper plunger generally designated 21 travels in the upper portion of the same eduction tubing 13. A barrier device generally designated 22 is anchored within the eduction tubing at a midway station located about half way from the lower end of the eduction 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 eduction 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. 33,350, filed March 28, 1949, now Patent No. 2,642,002, 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 eduction tubing 13. For clarity of illustration the couplings joining adjacent sections of the tubular eduction pipe are omitted, but it will be understood that the construction of the radially movable sealing devices 24 is such that they pass over the joints between adjacent sections of the eduction 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 eduction tubing 13, and any fluid in the interior of the eduction tubing passes upward through the passageway 26 to permit the plunger to fall through the fluid. When the valve 27 is closed, the plunger is lifted within the eduction 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 eduction tubing occurs when 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 eduction tubing 13 and may be lowered on a wire line 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 eduction 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 slips 33 which engage the inner surface of the eduction 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 fingers 44 extending downwardly from the collar 45. Threads 46 connect the collar 45 with a sealing device generally designated 47 which seals against the inner wall 25 of the eduction 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 with the interior of the eduction tubing 13.

Threads 53 connect the upper end of the tubular body 48 to the sleeve 54. The sleeve 54 is connected by threads 55 to the valve cage 56. A ball valve 57 is mounted within the cage 56 and normally rests on the upper end of the annular seat 58. A coil spring 59 maintains the valve seat in engagement with the tapered shoulder 30 on the cage 56. The cage is provided with a central chamber 61. A bar 62 mounted on the cage extends diametrically across the chamber 61 to limit upward travel of the ball 57. An upper extension 63 on the cage 56 provides a mounting for the lower end 64 of the coil spring 65. The upper end of the coil spring 65 carries a bumper 66 against which the valve stem 30 on the upper plunger 21 rests when the plunger 21 is in its lowest position. Another bumper 67 is mounted at the upper end of a coil spring 68 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 line. The lower section comprising the mandrel 31, slip assembly, spring 39 and spear 41 are lowered first. The slips 33 are set by suddenly increasing the rate of downward travel. The upper section comprising the bumper 66, spring 65, valve cage 56, body 47 and collar 45 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 eduction tubing 13 through the perforations in the liner pipe 19. Well fluid passes upwardly through the interior of the support 69 into the interior of the eduction tubing. Formation gas in the annulus 9 between the casing 10 and eduction tubing 13 forces the column of well fluid upwardly within the eduction tubing 13. The gas pressure within the annulus 9 may be supplemented 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 eduction tubing 13, the

plunger 20 continues its downward movement until the valve stem 30 engages the spring mounted bumper 67. This closes the valve 27 in the plunger 20. The pressure in the eduction 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 spear 41 extends into the central opening 26 in the plunger and mechanically engages the upper end of the valve head 28 to open the valve. The load of well fluid above the plunger 20 passes upward through the interior of the hollow collar 37, hollow mandrel 31, collar 45, hollow body 43 and past the check valve 57 into the eduction 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 eduction tubing 13 to begin another cycle of operations.

The upper plunger 21 drops by gravity through the upper portion of the eduction tubing and down through the column of well fluid previously raised by the lower plunger 20. The valve stem 30 engages the spring mounted bumper 66 to close the valve and arrest downward movement of the plunger 21. Pressure within the eduction 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 28 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 eduction tubing 13. While only two plungers have been shown and described, more than two can be employed in the same eduction tubing if desired.

In the event that it should be desirable to reduce the height of the fluid column above the check valve 57, 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 66. An upwardly directed force applied to the bumper 66 raises the spring 65, valve cage 56, hollow body 43, sleeve 45, and mandrel 31. Raising of the mandrel 31 releases the slips 33 from contact with the inner wall of the eduction tubing 13. The ring 73 which encircles the slip support arms 35 is fixed to the mandrel by means of fingers 74 located between adjacent arms 35. When the mandrel moves upwardly the shoulder 75 on the ring 73 engages the abutments 76 on the wedge slips 33 so that the wedge slips 33, collar 37, spring 39 and spear 41 are withdrawn from the eduction tubing 13 along with the mandrel 31.

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 overshot again run into the hole to engage the bumper 67. An upwardly directed force applied to the bumper 67 by means of the overshot tensions the spring 68 and serves to disengage the spring fingers 70 on the support 69 from the footpiece 18. The parts 67, 68, 69 and 70 are then 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 eduction tubing, the combination of: a barrier device adapted to be fixed in said eduction tubing, the barrier device having a passageway extending therethrough, a first plunger adapted to travel in the eduction tubing from the lower end thereof 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 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.

2. In a multiple-stage plunger lift device for raising well fluid in an eduction tubing, the combination of: a barrier device adapted to be fixed in said eduction 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 eduction tubing from the lower end thereof to the barrier device to raise a load of 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.

3. In a multiple-stage plunger lift device for raising well fluid in an eduction tubing, the combination of: a barrier device in said eduction tubing, 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 check valve preventing flow of fluid downwardly through the barrier device, a first plunger adapted to travel in the eduction tubing from the lower end thereof to the barrier device to raise a load of 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.

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 travelling 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 barrier 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 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.

6. In a two-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 check valve preventing flow of fluid downwardly through the barrier device, 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, an upper plunger in the eduction tubing traveling 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 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 barrier device in said eduction tubing, means including wedge slips on the barrier device engaging the inner surface of the eduction tubing for releasably anchoring the barrier device in the eduction tubing, the barrier device having a check valve preventing flow of fluid downwardly through the barrier device, 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, an upper plunger in the eduction tubing travelling 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 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 raising well fluid in an eduction tubing, the combination of: a barrier device in said eduction tubing, 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 check valve preventing flow of fluid downwardly through the barrier device, a first plunger adapted to travel in the eduction tubing from the lower end thereof to the barrier device to raise a load of well fluid through the check valve into the eduction tubing above the barrier device, a bumper element resiliently mounted on the barrier device for arresting downward movement of the first plunger, 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.

9. For use in multiple-stage plunger lift apparatus employing a plurality of 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 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 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 apparatus employing a plurality of 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, 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 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-

paratus 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.

14. Multiple stage plunger lift apparatus having in combination: a single eduction tubing, a pair of swab plungers travelling freely within said single eduction tubing, each plunger being tubular and having a valve near the lower end thereof adapted to move upwardly to closed position, a barrier device positioned within the eduction tubing between the 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 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.

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