

May 5, 1942.

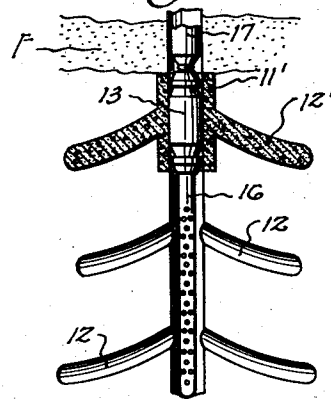
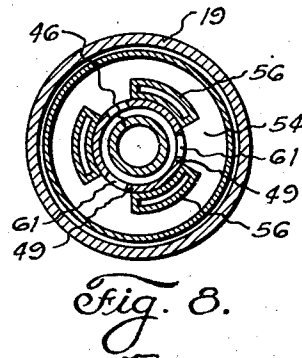
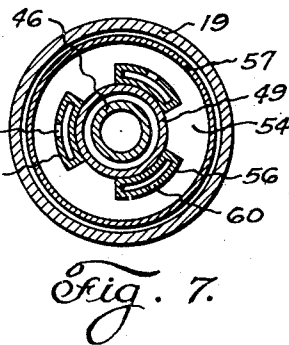
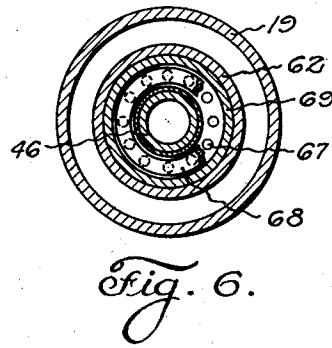
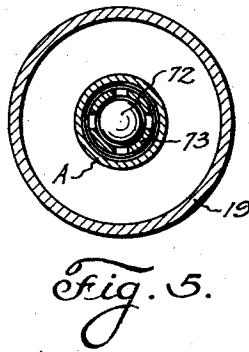
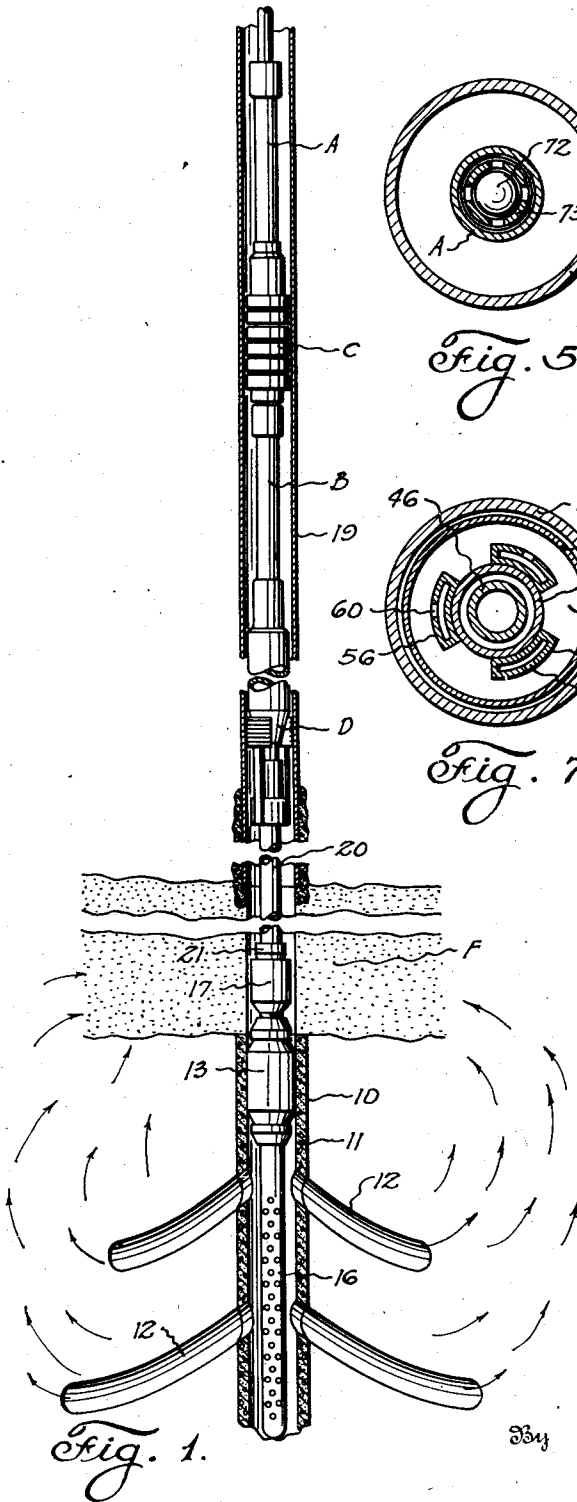
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2,281,801

METHOD OF AND MEANS FOR PUMPING WELLS

Filed Dec. 20, 1938

4 Sheets-Sheet 1



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METHOD OF AND MEANS FOR PUMPING WELLS

Filed Dec. 20, 1938

4 Sheets-Sheet 2.

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METHOD OF AND MEANS FOR PUMPING WELLS

Filed Dec. 20, 1938

4 Sheets-Sheet 3

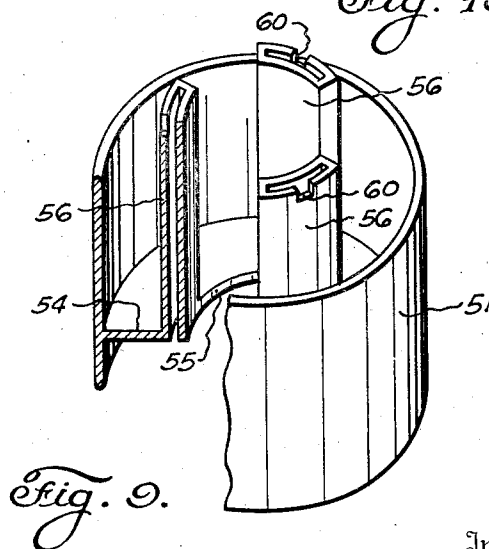
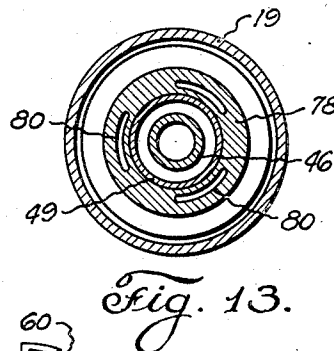
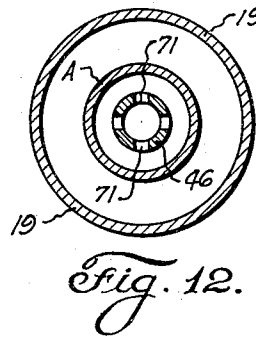
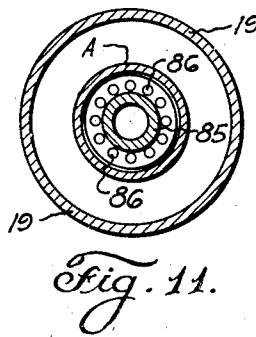
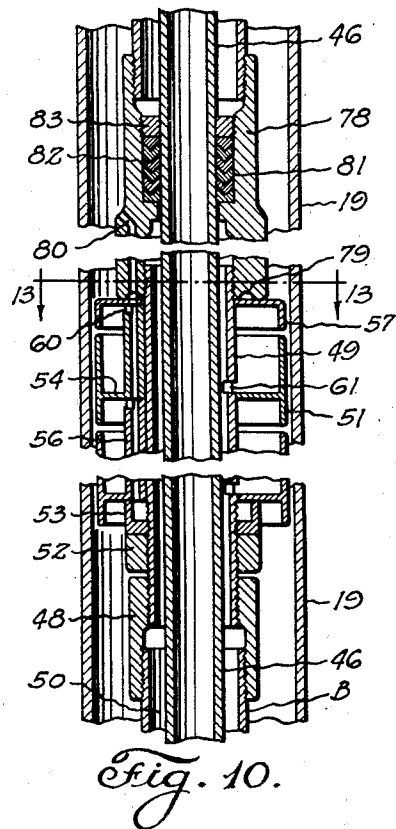
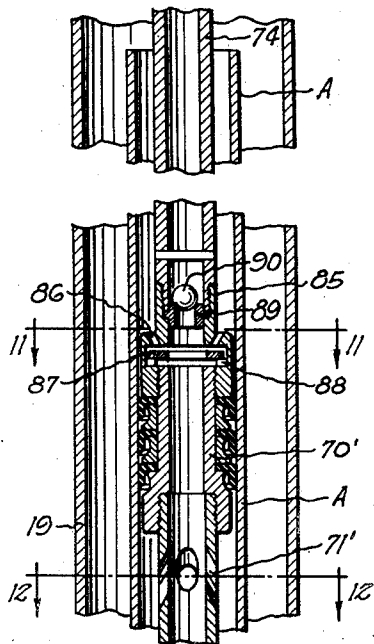


Fig. 9.

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METHOD OF AND MEANS FOR PUMPING WELLS

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4 Sheets-Sheet 4

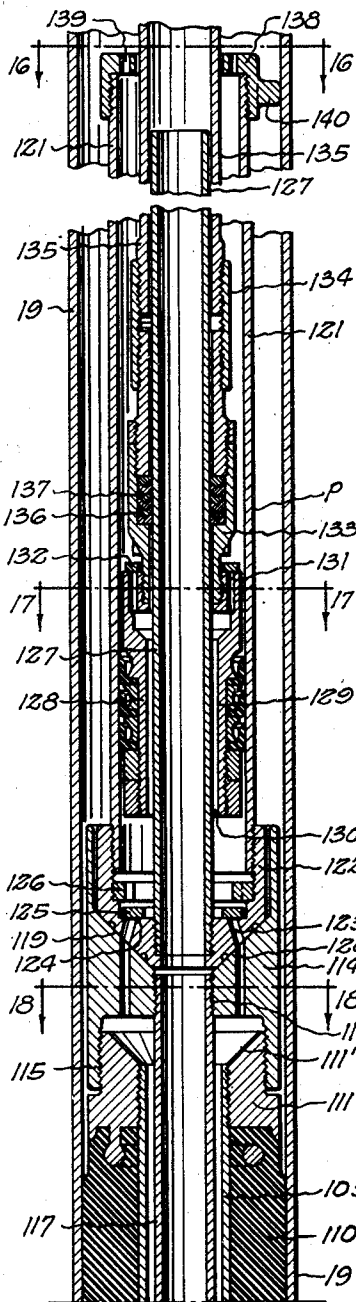


Fig. 14.

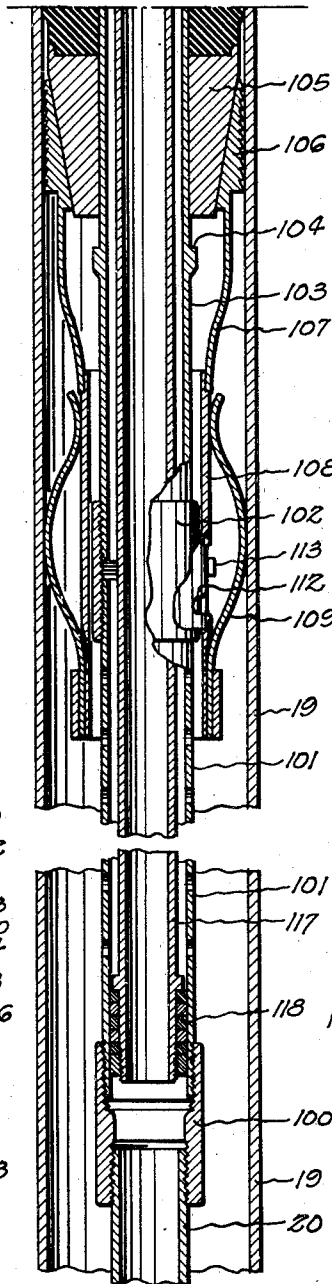


Fig. 15.

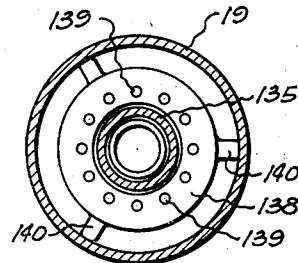


Fig. 16.

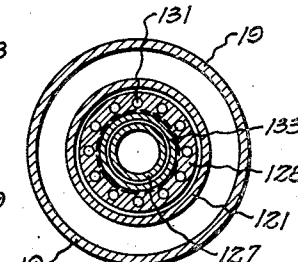


Fig. 17.

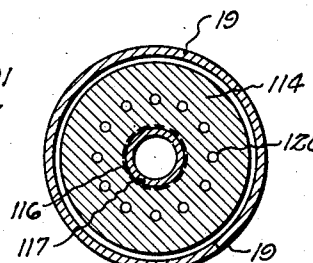


Fig. 18.

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UNITED STATES PATENT OFFICE

2,281,801

METHOD OF AND MEANS FOR PUMPING
WELLSJoseph H. Reynolds and Arthur Sandhofer,
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Application December 20, 1938, Serial No. 246,801

17 Claims. (Cl. 166—2)

This invention relates to new and useful improvements in methods of and means for pumping wells.

As is well known, well fluids contain a considerable amount of water which is lifted to the surface with the oil and although it is not desirable to lift such water, it has been substantially impossible to separate the same in the well bore and, therefore, to recover the oil, the water must be brought to the surface. It has been the practice to separate the water at the surface and drain said water into a slush pit or other disposal. This method is satisfactory so long as the well is not producing large volumes of water but whenever water in a great volume is brought to the surface, disposal of this water becomes a problem. In some instances, the water which is separated at the surface is pumped back into the formation through an offset or other well which is located near the producing well. By returning the water to the formation in this manner, the same is disposed of and also said water acts more or less as a repressuring medium to aid in maintaining the bottom hole pressure and in driving the well fluids toward the producing well. However, in this method an offset or other well is necessary and, further, expensive pumping equipment for forcing the water back into the formation must be used.

It is one of the objects of this invention to provide an improved method of returning water to a well formation simultaneously with the removal of the well fluids from said formation, whereby an offset well is not necessary to conduct the water to said formation and also whereby the production of the well fluids may continue uninterrupted during such return of said water.

An important object of the invention is to provide an improved method of well pumping which includes, lifting the well fluids through the well bore, separating the oil from the water in said well fluids, and returning the water to the formation at a point below the producing strata, whereby the water is returned to the reservoir and aids in maintaining bottom hole pressure and in driving or moving the remaining well fluids to the well bore.

A particular object of the invention is to provide an improved method wherein the water and oil are separated in the well bore, after which the oil is lifted to the surface while the water is returned to the reservoir, the latter two steps being accomplished simultaneously, whereby production of the oil may continue during the return of the water.

Another object of the invention is to provide an

improved method for simultaneously lifting oil to the surface and returning water to the reservoir through the same well bore which includes packing off the bore below the producing strata and conducting the water to the reservoir below said packing, whereby the returned water does not interfere with normal production of well fluids from the producing area.

A further object of the invention is to provide an improved apparatus of the character described, wherein two pumps having a separator associated therewith are employed, with means for conducting the well fluids from the formation to the separator to separate the oil and water, after which the oil is lifted to the surface by one pump while the water is returned to the reservoir by the other pump; said pumps being arranged so as to be operable simultaneously by a single string of pump rods.

Still another object of the invention is to provide an improved pumping apparatus of the character described, having an air chamber associated with the water return line, whereby a substantially constant pressure of the water may be maintained and surging or pulsation is eliminated, which makes for a substantially even flow of said water.

Another object of the invention is to provide an improved apparatus employing a casing pump for lifting the well fluids to the surface and having an axial conductor extending therethrough, whereby water separated from the oil at the surface may be returned to the formation during the pumping operation.

Still another object of the invention is to provide an improved well pumping apparatus, of the character described, which may be run into and anchored in the well casing and which may be readily removed at any desired time.

A particular object of the invention is to provide an improved separator which will effectively separate the oil from the water in the well bore, whereby the water need not be lifted to the surface to be separated.

A construction designed to carry out the invention will be hereinafter described, together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings, in which an example of the invention is shown, and wherein:

Figure 1 is a transverse, vertical, sectional view of a well bore showing the pumping apparatus,

constructed in accordance with the invention, mounted therein,

Figure 2 is a transverse, vertical, sectional view of the upper portion of the apparatus,

Figure 3 is a continuation of Figure 2 and illustrating the intermediate portion of the apparatus,

Figure 4 is a continuation of Figure 3 and showing the lower portion of said apparatus,

Figure 5 is a horizontal, cross-sectional view, taken on the line 5—5 of Figure 2,

Figure 6 is a horizontal, cross-sectional view, taken on the line 6—6 of Figure 2,

Figure 7 is a horizontal, cross-sectional view, taken on the line 7—7 of Figure 2,

Figure 8 is a horizontal, cross-sectional view, taken on the line 8—8 of Figure 2,

Figure 9 is a partial isometric view of one section of the oil and water separator.

Figure 10 is a view similar to Figure 2, and showing a slightly modified form of the device,

Figure 11 is a horizontal, cross-sectional view, taken on the line 11—11 of Figure 10,

Figure 12 is a horizontal, cross-sectional view, taken on the line 12—12 of Figure 10,

Figure 13 is a horizontal, cross-sectional view, taken on the line 13—13 of Figure 10,

Figure 14 is a transverse, vertical, sectional view of the upper portion of a modified form of the apparatus,

Figure 15 is a continuation of Figure 14 showing the lower portion of this modified form of construction,

Figure 16 is a horizontal, cross-sectional view, taken on the line 16—16 of Figure 14,

Figure 17 is a horizontal, cross-sectional view, taken on the line 17—17 of Figure 14,

Figure 18 is a horizontal, cross-sectional view, taken on the line 18—18 of Figure 14, and

Figure 19 is a transverse, vertical, sectional view of the lower portion of the well bore, showing another method of providing a cement wall within which the packer may be set.

In the drawings, the numeral 10 designates a well bore which extends through the oil sands or producing formation F and which has its lower end terminating at a point below said producing formation. That portion of the bore 10 which is below the producing formation F has an annular wall of cement 11 formed therein and this wall may be formed in any suitable manner. A plurality of radially extending passages 12 are drilled so as to extend outwardly from the lower end of the bore 10 and, as is clearly shown in Figure 1, the inner ends of these passages communicate with the bore, whereby a flow from said bore into said passages may occur. In forming the radial passages 12, an angular drill of the usual construction may be employed, said drill boring through the cement wall 11. Any desired number of passages 12 may be provided below the oil sand or producing formation F.

A bottom hole packer 13 is located within the lower end of the bore 10 and includes an elastic packing element 14 which is confined between the usual confining thimbles or collars 15. The lower collar is made integral with a supporting mandrel 15' which is slidable with relation to the upper collar. A perforated section of pipe 16, which forms a well screen, has its upper end threaded into the lower thimble 15 (Figure 4), while its lower end rests on the bottom of the well bore. The section of pipe 16 forms a screen and also serves to support the lower thimble 15 of the packer 13. Obviously, with the lower thim-

ble held stationary, the upper thimble may be moved downwardly with relation thereto, which movement will apply a longitudinal pressure to the elastic packing element 14, whereby the same is moved radially outwardly into engagement with the cement wall 11 so as to pack off therein. A seating nipple 17 has its lower end threaded into the upper confining thimble 15 of the packer and this nipple is provided with an annular tapered seat 18 located internally thereof at its upper end. The bore 17' of the nipple communicates with the tubular mandrel 15' of the packer and with the bore of the perforated pipe section 16, whereby a flow through these parts may occur.

The well bore 10 above the oil sand or producing formation F has the usual well casing 19 mounted therein and this casing is cemented in place at its lower end. The pump assembly, which will be hereinafter described, is arranged to be run into the well through the casing and is arranged to be supported on the seating nipple 17 which extends upwardly from the well packer 13. The weight of the pump assembly resting on the nipple serves to distort the elastic packing element into packing position.

The pump assembly includes an upper working barrel A and a lower working barrel B, which barrels are connected together by an oil and water separator C. A slip assembly D is connected to the lower end of the lower working barrel B and an elongate tubular conductor or pipe 20 has its upper end secured to the lower end of the slip assembly. The lower end of the pipe 20 carries a tapered collar 21 (Figure 4) which is adapted to engage the tapered seat 18 of the nipple 17, whereby the assembly is supported in said nipple.

The upper end of the pipe or conductor 20 is threaded into the axial bore 22 of a slip supporting collar 23. A plurality of gripping slips 24 are supported by the collar 23, said slips being fastened to said collar by means of elongate, flexible elements 25, which are preferably constructed of spring steel and which have their upper ends secured to the slips, with their lower ends fastened to the exterior of the collar 23. The bore 22 of the collar 23 is enlarged at its upper end and receives the lower end of a cylinder 26 which is disposed between the slip supporting elements 25. The upper end of the cylinder 26 is open and a piston 27 is movable vertically within said cylinder, the piston carrying suitable packing rings 28 which contacts the bore of said cylinder. The piston 27 is tubular and is formed with an upwardly extending tubular piston rod 29, which rod has its upper end threaded into the axial bore 30 of a tapered slip head 31. As is clearly shown in Figure 3, the tapered slip head 31 is disposed between the slips 24 which have their rear surfaces riding on the tapered surface of the head.

With the above arrangement, it will be manifest that the slip head 31 is capable of a vertical movement with relation to the gripping slips 24. When the piston 27 is in the upper portion of the cylinder 26, the slips 24 are at the lower end of the slip head and are, therefore, in a retracted position, being held so by the inherent resiliency of the spring elements 25 which support said slips. When it is desired to set the slip, the collar 23 is held stationary due to the engagement of the tapered collar 21 within the seating nipple 17 and, since said collar carries the slips 24, said slips are also held stationary. The slip

head 31 may then be moved downwardly, such movement being permitted by the piston moving downwardly in the cylinder 26. Obviously, as the larger upper end of the slip head 31 moves between the slips 24, said slips are moved radially outwardly into engagement with the wall of the well casing 19. When the slips engage said casing, upward movement of the pump assembly is prevented and the same is locked within the well casing.

Upward movement of the piston 27 within its cylinder is prevented by a stop ring 26' which is threaded into the upper end of the cylinder. This ring not only serves to prevent displacement of the piston from the cylinder, but also acts to connect the head 31 with the cylinder and the parts connected to said cylinder. Therefore, when it is desired to release the gripping slips 24, it is only necessary to move the slip head 31 upwardly which causes the lower or smaller end of said head to move between the slips, whereby said slips may move radially inwardly to a retracted position. As soon as the upper end of the piston 27 strikes the ring 26', continued upward movement of the slip head will raise the pipe 20 and disengage the tapered collar 21 from the seating nipple 17. Obviously, continued upward movement of the head will remove the slips and their associate parts from the well casing.

Immediately above the slip head 31 an air chamber 32 is provided and, if desired, this chamber may be made integral with said head. An upwardly extending tubular sleeve 33 is preferably made integral with the chamber and the upper end of this sleeve is connected by suitable screw threads to the lower end of the working barrel B. The lower end of the bore of the sleeve 33 is internally screw-threaded to receive the upper end of a tubular conductor or pipe 34 which extends axially through the air chamber 32 and which has its lower end terminating just above the slip head 31. Since the sleeve 33 is connected to the lower working barrel B, it will be manifest that a flow may occur from the bore of the barrel B through the sleeve 33 and then downwardly through the conductor 34, through the slip head 31, piston 27 and finally through the pipe 20 to the bore of the seating nipple 17. From the seating nipple, the flow continues downwardly through the well packer 13 and finally escapes through the perforated section of pipe 16 which is located below the packer.

A standing valve 34' is mounted in the upper portion of the sleeve 33 and this valve is of the usual construction including a valve seat 35 and a spring pressed ball 36. The ball is normally held on its seat by the spring 36' and both ball and spring are confined within the usual valve cage 37. Manifestly, when the ball 36 is seated, a flow cannot occur upwardly past the valve. When the pressure above the ball is sufficient to unseat said ball under tension of the spring 36', a downward flow of fluid past the valve is permitted.

A tubular pump plunger 38 having the usual cups 39 on its outer surface is mounted to reciprocate within the lower working barrel B. The lower end of the plunger is provided with an ordinary travelling valve 40 which includes a valve seat 41, spring pressed ball 42 and valve cage 43. As is clearly shown in Figure 3, the ball 40 is adapted to seat on the downstroke, whereby any fluid below the plunger 38 is forced downwardly to unseat the standing valve 34', after

which said fluid may pass downwardly through the lower portion of the assembly, as has been explained, and escape outwardly through the perforated section of pipe 16.

The upper end of the plunger 38 has a coupling sleeve 44 connected thereto and this sleeve is formed with a plurality of elongate, radial slots 45 which establish communication between the bore of the barrel B and the bore of the pump plunger 38. With this arrangement, upon the upstroke of the plunger 38, any fluid above said plunger may flow downwardly through the slots 45 and enter the bore of said plunger. This fluid will act downwardly on the travelling valve 40, unseating the ball 42, whereby said fluid may flow into the lower end of the barrel B below said plunger. Upon the next downstroke, the fluid which has by-passed the plunger in this manner on the upstroke, is forced downwardly past the standing valve 34' as has been explained.

The upper end of the plunger 38 is connected, through the sleeve 44, with the lower end of a tubular pump rod 46 which extends axially and upwardly through the separator C, as will be hereinafter explained. The lower end of the bore of said pump rod 46 is closed by a transverse partition 47, whereby any fluid which might enter the tubular rod cannot pass downwardly through the plunger 38 in the barrel B. Manifestly, when the rod 46 is reciprocated, the lower plunger 38 is reciprocated within the barrel B to pump the fluid downwardly to the perforated pipe at the lower end of the well bore 10.

The upper end of the working barrel B is connected by means of a coupling collar 48 with the lower end of a tubular mandrel 49, which mandrel serves as the support for the separator C. The inner diameter of the mandrel 49, as well as the inner diameter of the barrel B, is greater than the external diameter of the pump rod 46 which extends axially therethrough, whereby an annular flow space or passage 50 is provided between the rod and said mandrel and barrel.

The separator C comprises a plurality of annular elements or collars 51 which are mounted in superposed relation on the mandrel 49. As is clearly shown in Figure 2, a supporting ring 52 is threaded onto the lower end of the mandrel 49 and a flange supporting ring 53 is also threaded on the mandrel immediately above and in contact with the ring 52. The lowermost separator element or collar 51 is provided with a transverse partition 54 which is located nearer its lower end, as clearly shown in Figure 9. The partition is formed with an axial opening 55 and the diameter of this opening is substantially equal to the external diameter of the mandrel, whereby the element 51 is slidably mounted on said mandrel. The underside of the partition 54 engages and is supported upon the upper end of the flange of the ring 53, whereby the element 51 is supported in its proper position on the mandrel. A plurality of upstanding conductors 56 are preferably formed integral with the partition 54 and three of such conductors have been illustrated (Figures 7 and 8). Each conductor 56 is open at its upper and lower end whereby a vertical flow therethrough is permitted. The upper ends of the conductors 56 terminate in a plane above the upper end of the side wall of the element, whereby when the element is in position on the mandrel the conductors 56 have their upper ends extending above the upper end of said side wall of the element. It is preferable

that the conductors be arcuate in cross-section so that their inner surfaces will substantially conform to the curved or cylindrical outer surface of the mandrel 49.

As explained, the lowermost element 51 of the separator C is supported on the flanged ring 53. The next above element of the separator is constructed in the same manner as the first element and has the underside of its partition resting on the upper end of the vertical conductor 56. The projection of the conductors 56 above the side wall of the element is such that when the next above element is supported on said conductors, the lower peripheral edge of said next above conductor is spaced slightly from the upper peripheral edge of the wall of the lower element. The conductors of adjacent elements or collars 51 are aligned vertically so that they form a continuous vertical passage through the elements, as is clearly shown in Figure 2. Any desired number of the elements 51 may be mounted one above the other on the mandrel 49 and in Figure 1 four of such elements have been shown. The vertical conductors 56 of the uppermost elements in the series support a flanged cap member 57 which has its lower end spaced from the upper end of said upper element. The various elements of the separator C are clamped in position on the mandrel 49 by means of a locking ring 58 which is threaded onto the upper end of the mandrel, said ring being tightened sufficiently to prevent rotation of the various elements or collars 51 and thereby holding conductors 56 thereof in alignment with each other. The ring 58 is formed with a plurality of vertical ports 59, which ports register with the vertical passages formed by the conductors 56.

Each element or collar 51 of the separator forms an individual chamber and thus the separator comprises a plurality of superposed chambers. The well fluid which flows from the oil sand or producing formation F enters the bore of the well above the packer 13. This well fluid passes upwardly through the casing around the lower working barrel and finally enters the chambers of the separator through the spaces between the individual elements or collars 51. Upon entering the chamber, the water, being heavier than the oil, will settle downwardly onto the partitions 54 of the elements 51, while the oil will rise upwardly below the partition of the next above element 51. This oil may enter the conductor 56 through radial inlet ports 60 which are formed in the upper ends of said conductors. Thus, the oil may enter the vertical passages formed by the conductors 56 and may flow upwardly therethrough and escape through the vertical ports 59 in the locking ring 58. The water which settles downwardly onto the partitions 54 may escape from the separating chamber through radial ports 61 which are formed in the mandrel adjacent said partitions. Thus, the water may flow into the bore of the mandrel and then downwardly through the floor space 50 formed between the working barrel B and the pump rod 46. This water may then enter the slots 45 at the upper end of the pump plunger 38 and said plunger will serve, when reciprocated, to pump this water back to the formation below the packer 13.

The lock ring 58 which fastens the elements of the separator C in position on the mandrel 49, has the lower end of an annular housing 62 threaded thereto. This housing is reduced at its upper end and has the lower end of the upper

working barrel A connected thereto. The pump rod 46 which is secured to the lower pump plunger 38 extends axially through the housing 62 and upwardly into the lower end of the upper working barrel A. A packing sleeve 63 is threaded onto the upper end of the mandrel 49 above the locking ring 58 and this sleeve houses suitable packing rings 64, whereby a leakage around the pump rod 46 cannot occur. The sleeve 63 has a diameter less than the diameter of the housing 62, whereby an annular chamber 65 is formed within the housing. As is clearly shown in Figure 2, the chamber 65 communicates with the vertical ports 59 in the ring 58 and, therefore, the oil which has been separated from the water in the separator C and which passes upwardly through the ports 59 may flow into the chamber 65.

An annular seating member 66 is mounted within the housing 62 and surrounds the pump rod 46, said member being supported on the upper end of the packing sleeve 63. This seating member is provided with a plurality of vertical ports 67 which extend entirely therethrough and the upper ends of these ports are adapted to be closed by a valve ring 68 which is movable relative to the upper end of the seating member. The upward movement of the valve ring 68 is limited by an annular flanged member 69 which is mounted within the upper end of the housing 62 above said ring.

The valve ring 68 and the seating member 67 provide a standing valve and, obviously, a flow from below the valve ring will unseat said ring and permit fluid to pass upwardly through the ports 67 and into the lower end of the upper working barrel A. When the valve ring 68 is engaging the upper end of the seating member, the ports 67 are closed and the flow from the working barrel A downwardly into the chamber 65 cannot occur.

The upper end of the tubular pump rod 46 which is attached to the lower plunger 38, is secured to a tubular plunger 70 which is slidable vertically in the upper working barrel A. Immediately below its connection with the plunger 70, the pump rod is provided with a plurality of radial openings or slots 71, whereby communication between the bore of the rod and the bore of the working barrel A is established. The upper end of the plunger 70 has a valve seat 71 arranged to be engaged by a ball valve 72 which is confined within a valve cage 73 in the usual manner. The upper end of the valve cage is connected to a tubular pump rod 74 which extends upwardly to the surface of the well and which is reciprocated in any desired manner (not shown). A suitable packing 75 surrounds the rod 74 and is confined in a packing chamber 76 formed at the upper end of the working barrel A. The packing 75 is preferably of the pressure seal type and is retained in the packing chamber by the usual threaded packing gland 77.

It will be manifest that when the pump rod 74 is reciprocated the upper plunger 70 will be reciprocated within the upper working barrel A and since this upper plunger is connected to the lower plunger 38 by means of the pump rod 46, said lower plunger will also be reciprocated in its working barrel B. As the upper plunger 70 moves upwardly in the working barrel A, the oil is drawn from the chamber 65 and upwardly through the port 67 in the seating member 66, said ring being unseated by the suction. The oil will flow upwardly into the working barrel

A, then through the slot 71' in the upper end of the rod 46 and into the bore of the plunger 70. Upon the downstroke of said plunger, the fluid which has entered the valve rod and the bore of the plunger 70, will unseat the ball 72 and flow upwardly into the pump rod 74 above the plunger 70. Upon the next subsequent upstroke of the plunger 70, the fluid thereabove is lifted upwardly through the rod 74.

In operation, the lower end of the bore 10 of the well is first cemented so as to provide the concrete sleeve or wall 11, as has been explained. The radially extending passages 12 are then formed by means of an angular drill or other suitable apparatus, whereby the formation below the producing area F communicates with the lower end of the bore 10 through said passages. The packer assembly 13, which carries the perforated section of pipe 16 is then lowered into the well by any suitable means and the length of the section 16 is such that the packer 13 will be located just below the producing area F when the lower end of the pipe 16 rests on bottom. It is pointed out that in some instances, it may not be desirable to provide the elongate cement wall 11 and in such case a cement collar 11' may be mounted within the bore opposite the point at which the packing element 14 of the packer 13 is to be set. This construction is shown in Figure 19 and in order to firmly hold the cement collar 11' in place radial passages 12' may be formed opposite the point at which the collar is supported. These passages 12' will receive the cement and will act as a tie or a positive holding means for preventing displacement of the collar 11'. In this case, the collar 11' provides a surface against which the packing element 14 may seal. In either event, it will be manifest that when the packing element 14 is distorted the lower end of the well bore 10 is packed off from the producing area or oil sand F.

After the packer 13 has been lowered into the bottom of the well bore 10, the pump assembly is then lowered through the well casing 19 until the tapered collar 21 at the lower end of this assembly enters the seating nipple 17. When said collar engages the seat 18 of said nipple, as shown in Figure 4, the entire weight of the pump assembly is placed on the packer 13, with the result that the packing element 14 is distorted radially outwardly into sealing position with the cement wall 11. As soon as this occurs the oil sands F from which the well fluids are produced, are sealed off from the lower end of the bore 10. After the packer has been set, the upper portion of the pump assembly is further lowered, with the result that the slip head 31 and all of the parts thereabove move downwardly with relation to the gripping slips 24, said slips being held stationary since they are directly connected with the collar 21 which is seated in the nipple 17. The slip head 31 may move downwardly due to the piston 27 which is carried thereby being slidable within the cylinder 26 located between the slip elements 24, as has been explained. As the slip head 31 moves downwardly, the gripping slips 24 are expanded radially whereby the gripping teeth on their outer surfaces move into engagement with the bore of the well casing 19. Thus, the slips are moved to a set or gripping position and the pump assembly is secured axially within the well casing.

The well fluid from the oil sands or producing formation F will rise upwardly in the well casing around the pump assembly and the level to

which said fluid will normally rise, depends on the particular condition of the well. In some cases, the fluid may rise above the upper working barrel A, whereas in other fluids they may rise only above the separator. In all cases, it is necessary that the standing liquid level of the well be above the separator and the disposition of the separator may be controlled by varying the length of the pipe section 20 which connects the slip assembly B with the seating collar 21. Obviously, by varying the length of this pipe the disposition or location of the separator with relation to the producing formation may be varied.

As the well fluids rise upwardly in the casing, they enter the separating chambers of the separator C, as has been explained, and in such chambers, the water is settled out of the oil. This water flows through the ports 61 in the mandrel 49 of the separator and passes downwardly into the lower working barrel B. At the same time, the oil passes through the ports 60 and into the vertical conductors 55 in the separator. This oil flows upwardly into the chamber 65 below the standing valve 68 of the upper working barrel A. When the valve ring 68 is unseated, the oil may then enter the lower end of the working barrel and flow through the slots 71' in the valve rod 46 and into the bore of said valve rod, as well as into the bore of the upper pump plunger 70.

The pump rod 74 which is attached to the upper plunger 70 is reciprocated from the surface of the well in any suitable manner and as this rod reciprocates the upper plunger 70, as well as the lower plunger 38, are reciprocated in their respective working barrels A and B. As the upper plunger moves downwardly, the oil which has been drawn into the bore of the pump rod 46 and the plunger 70, rises upwardly past the valve 72 and into the bore of the upper pump rod 74. At the same time, the lower plunger 38 is moving downwardly in its bore and any water which is below said plunger is forced downwardly to unseat the standing valve 34' and pass downwardly through the slip assembly D and packer 13 to the perforated section of pipe.

The water which is forced outwardly through the perforated section of pipe 16 flows into the radially directed passages 12 and back into the formation below the producing sand F. This water enters the formation and will generally follow the line of the arrows shown in Figure 1 because of the reduction of pressure by the well fluids entering the bore above the packer. This water which is pumped back into the formation, not only serves as a repressuring medium to maintain the bottom hole pressure of the well, but also serves to drive or force the well fluid toward the bore of the well above the packer 13.

Upon the upstroke of the valve rod 74 the plungers 70 and 38 are raised in their respective working barrels. Upward movement of the plunger 70 lifts the fluid thereabove towards the surface of the well and at the same time creates a suction therebelow which draws additional oil into the working barrel below the plunger 70. Upward movement of the lower plunger 38 causes the water which has entered the upper end of the working barrel B to flow through the slot 45 and into the bore of said plunger 38. This water will unseat the valve 40 and will flow into the working barrel B below said plunger, whereby upon the next downstroke this water is forced downwardly to the perforated section of pipe 16, as has been explained.

An important feature of the invention is the provision of the air chamber 32 which is located just below the standing valve 34 and just above the slip head 31. This chamber serves to provide a more or less constant pressure, whereby surging or pulsating of the water being pumped into the formation is prevented. It will be manifest that upon the downstroke of the plunger, the water is forced under pressure downwardly through the conductor 34 which extends axially of the air chamber 32. The pressure of the water will tend to compress the air in the chamber 32 during such downstroke of the plunger 36. Upon the upstroke of the plunger 36, there is no pressure or force against the water in the conductor leading to the perforated section of pipe and during the upstroke of the plunger 36, the air in the chamber 32 tends to expand, whereby a continuous pressure is exerted against the water below the air chamber. In this manner, the pulsations due to the sudden change of the stroke of the plunger 36, are more or less overcome and a substantially even flow of water into the formation is had.

The packer 13 may be located at any point between the oil sands or producing formation F and the bottom of the well bore 10 but it is preferable that the same be located immediately below said producing formation. It is pointed out that although it is desirable to form a cement wall or collar within the well bore and against which the packer may be set, this is not essential and in a particularly hard formation, said packer could be distorted against the wall of the well bore. Further, it is noted that although an angular drill has been found suitable for forming the passages 12, such passages could be formed in any suitable manner; also, in some instances, the passages may not be necessary and could be entirely eliminated in which case the water would be directed into the formation adjacent the wall of the well bore. Although the separator has been illustrated and described as located between the pumps, it is obvious that said separator may be mounted at any desired point in the assembly.

In Figures 10 to 13, a slightly modified form of the invention is shown. In this form, the separator C as well as all of the parts therebelow are constructed in exactly the same manner as has been explained. In place of the annular housing 62, an elongate sleeve or collar 78 is secured to the upper end of the separator mandrel 49 and the lower end of this sleeve clamps against the upper collar or element 57 of the separator. An annular groove 79 is formed in the lower edge of the collar 78 and this groove communicates with the vertical passages formed by the conductors 56 of the separator, whereby the oil which flows from the separator enters this groove. A plurality of outlet ports 80 lead from the groove 79 and have their upper ends open to the bore of the well casing 19. With this arrangement, the separated oil enters the casing 19 instead of entering the chamber 65 which is formed in the housing 62, hereinbefore described.

The pump rod 46 which extends upwardly from the lower plunger 38 extends through the elongate collar 78 and has its upper end connected with a plunger 70', which plunger is similar to the upper plunger 70 of the first form. A suitable packing chamber 81 is formed within the collar and receives packing rings 82 which surround the pump rod 46 and pack off therearound. A suitable packing nut 83 maintains the rings 82 within

the packing chamber. The upper end of the collar 78 is directly connected to the lower end of the working barrel A.

It will be obvious that the separated oil rises in the well casing 19 on the outside of the working barrel A. The upper end of the working barrel A is left open, the packing 75 shown in Figure 2, being eliminated, whereby the oil which rises in the casing may flow downwardly through the upper end of said working barrel.

The pump plunger 70' is similar in construction to the plunger 70 and is provided with a cap member 84 which is threaded onto its upper end. The cap member is reduced at its upper end to form an upwardly extending collar 85 and vertical inlet ports 86 extend through the offset formed in said cap member. A valve ring 87 is confined within an annular space 88 formed within the cap member and this ring is adapted to seat so as to close the openings 86. Located within the reduced collar 85 is a valve seat 89 having a ball valve 90 arranged to engage the same.

The operation of this form with respect to the lower pump plunger 38 and the separator C is exactly the same. As the upper pump plunger 70 moves upwardly, the ball 90 is seated, whereby any fluid in the pump rod 74 is lifted. During such upstroke of the plunger 70', the valve ring 87 is lowered or unseated, whereby the ports 86 are opened and thus the oil from the upper end of the working barrel A may flow into the bore of the plunger 70' as well as into the lower end of the working barrel A through the slot 71' in the valve rod 46. Upon the downstroke of the plunger 70', the valve ring 87 is seated, while the ball 90 is unseated and thus the fluid which has been drawn into the lower end of the working barrel and into bore of the pump rod 46 may pass upwardly into the pump rod 74. Upon the next succeeding upstroke, this oil or fluid is lifted while additional oil is drawn into the lower end of the working barrel by the unseating of the valve ring 87. In this form, the housing 62 and its associate parts, as well as the packing 75 at the upper end of the working barrel A, may be eliminated, which makes for a cheaper construction. The operation of the two forms is substantially the same and in both instances, the oil is lifted to the surface, while the water is returned to the formation below the oil sands.

In the forms hereinbefore described, the well fluids are separated in the separator C, that is, the water is separated from the oil. The oil is then pumped upwardly to the surface at the same time that the water is pumped downwardly back into the formation. In many instances, it might not be desirable to separate the water and oil in the bore of the well and in such case the well fluid would be lifted to the surface where the water would be separated from the oil and then returned back to the formation. An apparatus for lifting the well fluid to the surface and then returning the separated water to the formation is shown in Figures 14 to 18.

In this form, the conductor 20 has its lower end connected to the seating collar 21 and is supported on the packer 13, as has been explained. The upper end of the conductor is connected by means of a coupling collar 100 to a perforated section of tubing 101 (Figure 15). The upper end of the perforated section 101 is connected by a coupling collar 102 with a tubular mandrel 103. This mandrel is formed with an external annular shoulder 104 on which is nor-

mally supported a slip head 105. Gripping slips 106 are slidable on the exterior surface of the head 105 and are supported by links 107 which have their lower ends secured to a slip carrying sleeve 108, which sleeve surrounds the mandrel and the perforated section 101. Suitable friction springs 109 are secured to the sleeve 108 and are curved so as to have their outer surfaces frictionally engaging the bore of the well casing 19.

A packing element 110 has its lower end confined within the upper end of the slip head and surrounds the tubular mandrel 103. The upper end of the packing element is confined within a cap member 111 which is threaded onto the upper end of the mandrel. The gripping slips operate in the usual manner being normally supported at the lower end of the slip head 105 which head normally rests on the shoulder 104. The sleeve 108 is held in a lowered position with relation to the mandrel by means of an ordinary J-slot 112 and a pin 113, the latter being formed on the collar 102 which connects the mandrel to the perforated section 101. When it is desired to set the slip, the mandrel is rotated so as to align the pin with the vertical portion of the J-slot 112, after which the mandrel may be lowered with relation to the sleeve. During such lowering the slips 106 are held in a stationary position by means of the friction springs 109 and as the mandrel and slip head 105 is lowered with relation to said slips, the slips are expanded radially into gripping position with the well casing. Continued lowering of the mandrel and the upper confining cap 111 will distort the packing element 110 outwardly into sealing position with the wall of the well casing. This is the usual construction of setting a well packer.

A nipple 114 is formed with an annular depending flange 115 which is threaded onto the upper end of the confining cap 111. This nipple is provided with an axial bore 116 which receives the upper end of a tubular conductor 117. The conductor has a diameter less than the diameter of the mandrel 103 and the perforated section 101 and extends axially through these elements. The extreme lower end of the conductor 116 is provided with a plurality of packing rings 118 which seal off the annular space between said conductor and the perforated section 101. With this arrangement, and with the packing element 110 in its set position, it will be manifest that well fluids rising upwardly in the casing from the producing sand will enter the perforations in the section 101 and will flow upwardly through the annular space between the mandrel 103 and the tubular conductor 117. These well fluids will then flow into the space above the confining cap 111 which has the upper end of its bore reduced at 111' to form a chamber into which these fluids may flow.

The upper end of the nipple 114 is formed with an annular inclined seat 119 and a plurality of vertical ports 120 establish communication between this seat and the chamber formed above the cap 111, whereby the well fluid may flow upwardly through the ports 120.

A pump assembly P is adapted to be seated within the nipple 114 and this assembly includes a working barrel 121 which has an enlarged collar 122 secured thereto. The underside of the collar 122 is tapered complementary to the seat 119, whereby said collar may engage said seat. The collar is formed with inclined ports 123 which register with the vertical ports 120 in the nipple

114 and the upper ends of these ports 123 are surrounded by a flat valve seat 124. A valve ring 125 is arranged to engage the seat 124 to close the ports 123 and a confining ring 126 which is located within the collar 122 above the ring acts to limit the upward movement of said ring. Manifestly, when the ring 125 is unseated the well fluids which have entered the mandrel 103 and which have flowed upwardly through the ports 120 and 123, may pass said valve ring and enter the lower end of the working barrel 121. Of course, when the valve ring is seated, the ports 123 are closed and a downward flow of fluid from the working barrel into the mandrel 103 is prevented. This valve ring 125 acts as a standing valve for the pump assembly P.

A tubular conductor 127 has its lower end connected in the enlarged collar 122 and it extends upwardly and axially therefrom. A pump plunger 128 surrounds the tubular conductor 127 and is provided with a bore 129 which has a diameter larger than the external diameter of said conductor, whereby an annular vertical flow passage 130 is provided between the conductor and the plunger. The plunger is formed with vertical ports 131 at its upper end and these ports communicate with the annular passage 130, whereby well fluids flowing upwardly through the plunger may pass upwardly through said ports. The ports are adapted to be closed by a valve ring 132 which overlies the upper ends of said ports. The plunger is connected by means of a coupling member 133 and coupling collar 134, with the well tubing 135, which tubing extends upwardly to the surface of the well. The coupling member 133 has a packing chamber 136 within which suitable packing rings 137 are confined. The tubular conductor 127 which extends through the plunger 128 has its upper end terminating within the tubing or tubular pump rod 135. The upper end of the working barrel 121 is closed by a flanged cap 138 which has a plurality of ports 139 therein, whereby the upper end of the working barrel communicates with the bore of the well casing. The upper end of said working barrel is held in axial alignment within the well casing by radial lugs 140 formed on the flanged cap 138.

The operation of this form is obvious. The tubing or tubular pump rod 135 is reciprocated, whereby the plunger 128 is reciprocated within its working barrel 121. The well fluid from the producing formation which has risen in the well casing enters the perforated section 101 and flows upwardly to the annular space between the tubular conductor 117 and the mandrel 103. From the mandrel, this fluid flows through the ports 120 and 123 and upon the upstroke of the plunger 128, lifts the valve ring 125 and enters the lower end of the working barrel 121. Upon the downstroke of the plunger, this fluid flows upwardly through the annular passage between the plunger 128 and the tubular conductor 127 and then escapes through the ports 131, unseating the valve ring 132. This flow passes upwardly through the upper end of the working barrel 121 and outwardly into the casing through the ports 139. Upon the next subsequent upstroke of the plunger, the fluid above said plunger is lifted through the well casing. The well fluids are taken to the surface of the well where the water may be separated from the oil in any suitable manner. The water is then returned by pumping or otherwise through the well tubing or the tubular pump rod 135. This water flows downwardly through said rod, then

through the conductor 127, then through the conductor 117 and finally through the pipe 26 and then to the perforated section 16, as has been explained. In this form, the well fluids are lifted to the surface, the oil is separated from the water and the water is returned to the formation below the producing area.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made, within the scope of the appended claims, without departing from the spirit of the invention.

What we claim and desire to secure by Letters Patent, is:

1. An apparatus for producing well fluids from a well bore including, a well packer adapted to be set in a well bore below the producing strata to seal off said strata from the formation therebelow, a water and oil separator above the packer for separating the water from the well fluids which rise upwardly in the well bore, means communicating with the separator for conducting the separated water downwardly through the well packer and to the formation therebelow, a well pump in said means for pumping the water under pressure into the formation, and a well pump above the separator and communicating therewith for lifting the well fluids which have been separated from the water to the surface.

2. An apparatus for producing well fluids from a well bore including, a well packer adapted to be set in a well bore below the producing strata to seal off said strata from the formation therebelow, a water and oil separator above the packer for separating the water from the well fluids which rise upwardly in the well bore, a conductor communicating with the separator for conducting the separated water downwardly through the well packer and to the formation therebelow, a well pump in said conductor for pumping the water under pressure into the formation, means connected in said conductor below the pump for maintaining a substantially constant pressure on the water being pumped to prevent surging, and means above the separator and communicating therewith for lifting the well fluids which have been separated from the water to the surface of the well.

3. An apparatus for producing well fluids from a well bore including, a well packer adapted to be set in a well bore below the producing strata to seal off said strata from the formation therebelow, a water and oil separator above the packer for separating the water from the well fluids which rise upwardly in the well bore, a conductor communicating with the separator for conducting the separated water downwardly through the well packer and to the formation therebelow, a well pump in said conductor for pumping the water under pressure into the formation, an air chamber connected in the conductor below the pump and communicating with the bore of said conductor for maintaining a substantially constant pressure on the water being pumped to prevent surging, and means above the separator and communicating therewith for lifting the well fluids which have been separated from the water to the surface of the well.

4. As a sub-combination in a well pumping apparatus, a separator adapted to be connected to the pump barrel and composed of a plurality of superposed annular elements, each element having a transverse partition provided with upstanding conductors, each conductor having an oil inlet

in its upper end to allow oil to enter said conductor, the water which is separated from the oil settling onto the partition around the base of the upstanding conductors.

5. An apparatus for producing well fluids from a well bore and for disposing of the water produced therewith including, a flow line, means within said flow line for lifting the well fluids to the surface, means within the well bore for separating the water from the remaining well fluids, and means for returning the water through the same well bore to the formation below the producing strata simultaneously with the production of additional well fluids.

6. An apparatus for producing well fluids from a well bore and for disposing of the water produced therewith including, a flow line, means within said flow line for lifting the well fluids to the surface, means for separating the water from the remaining well fluids, and pumping means connected in the flow line for returning the water to the formation below the producing strata simultaneously with the production of additional well fluids.

7. An apparatus for producing well fluids and for disposing of water produced therewith including, a well packer adapted to be set in a well bore below the producing strata to seal off said strata from the formation therebelow, a flow line leading upwardly from the producing strata, a second flow line leading from the formation below the producing strata, a well pump within the first flow line for lifting well fluids therethrough, a second well pump in the second flow line for pumping water downwardly therethrough, and means for simultaneously actuating said pumps from the surface.

8. An apparatus for producing well fluids and for disposing of water produced therewith including, a well packer adapted to be set in a well bore below the producing strata to seal off said strata from the formation therebelow, a flow line leading upwardly from the producing strata, a second flow line leading from the formation below the producing strata, means within the well bore for separating the water from the well fluids, means for conducting the separated well fluids to the first flow line and for conducting the separated water to the second flow line, and well pumps within the flow lines for lifting the well fluids to the surface and for returning the water to the formation below the producing strata through said lines.

9. An apparatus for producing well fluids and for disposing of water produced therewith including, a well packer adapted to be set in a well bore below the producing strata to seal off said strata from the formation therebelow, a flow line leading upwardly from the producing strata, a second flow line leading from the formation below the producing strata, means within the well bore for separating the water from the well fluids, means for conducting the separated well fluids to the first flow line and for conducting the separated water to the second flow line, well pumps within the flow lines for lifting the well fluids to the surface and for returning the water to the formation below the producing strata through said lines, and means for simultaneously actuating said pumps.

10. The method of producing well fluids from a well bore, which consists in conducting into the bore the cognate fluids from the producing strata, separating within and below the top of the well bore the water from said fluids, returning

the separated water through the same bore to the formation below the producing strata and lifting the water-freed well fluids to the surface.

11. The method of producing well fluids from a well bore, which consists in packing off in the bore the producing strata from the formation therebelow, conducting the cognate fluids from the producing strata upwardly in the bore, separating within and below the top of the well bore the water from said fluids, returning the separated water through the same bore directly to the formation below the producing strata and lifting the water-freed well fluids to the surface.

12. The method of producing well fluids from a well bore, which consists in packing off in the bore the producing strata from the formation therebelow, conducting the cognate fluids from the producing strata upwardly in the bore, separating within and below the top of the well bore the water from said fluids, returning the separated water under pressure through the same bore directly to the formation below the producing strata and simultaneously lifting to the surface the remaining fluids which have been freed of the water in the well bore.

13. The method of producing well fluids from a well bore, which consists in conducting the cognate fluids from the producing strata upwardly in the bore, separating within and below the top of the well bore the water from said fluids, forcing the separated water under substantially constant pressure and even flow downwardly through the same bore directly to the formation below the producing strata and simultaneously lifting to the surface the remaining fluids which have been freed of the water in the well bore.

14. A method of producing oil from a sub-surface formation containing both oil and water

which comprises producing oil and water into a well, separating said oil and water within said well, injecting said separated water directly into a sub-surface formation and conveying said separated oil to the surface.

15. A method of producing oil from a sub-surface formation containing both oil and water which comprises separating said oil and said water near the bottom of said well, injecting the separated water directly into a sub-surface formation at a level below the level from which said oil and water entered said well and conveying said separated oil to the surface.

16. Apparatus for producing oil from a formation containing both oil and water which comprises a well, a packer in said well, said well being in fluid communication with a porous formation above said packer and in fluid communication with a porous formation below said packer, a separator, means for conveying oil and water entering said well above said packer to said separator and means associated with said separator for conveying the separated water through said packer and into said porous formation below said packer.

17. Apparatus for producing oil from a formation containing both oil and water comprising a well, a packer in said well, said well being perforate both above and below said packer opposite at least one porous formation, a pump located above said packer, a separator connected with said pump, a second pump for conveying oil from said separator to the surface and means for conveying water separated in said separator through said packer and thence to the porous formation located below said packer.

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