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TWO ZONE PUMPING

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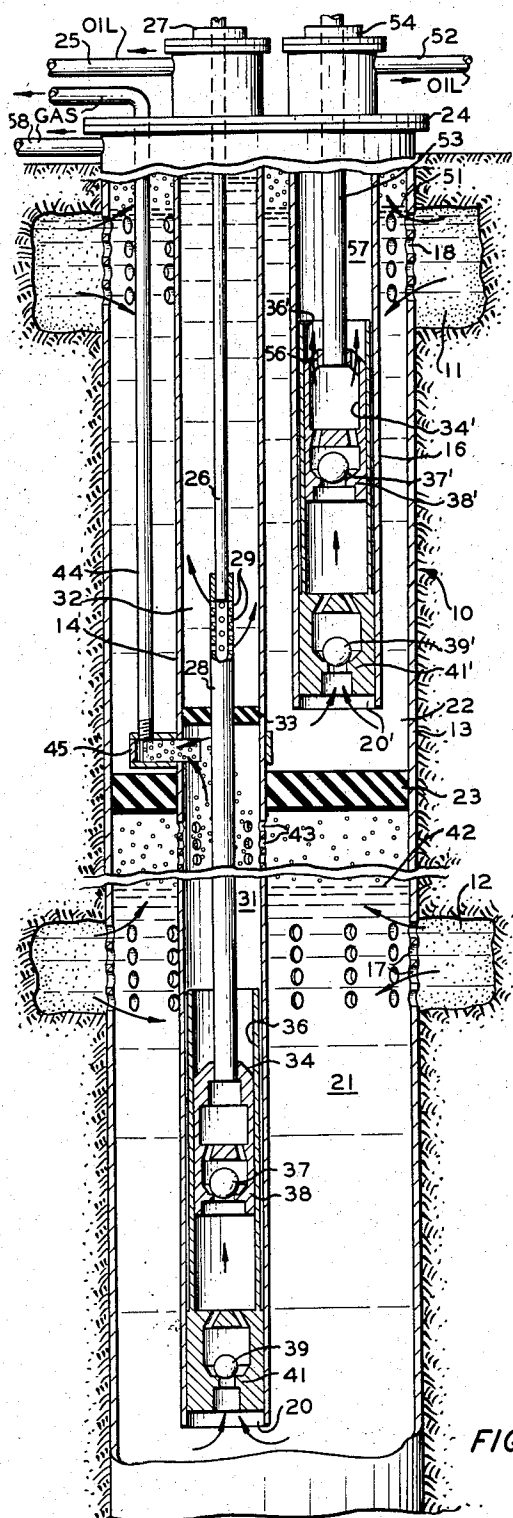


FIG. 1

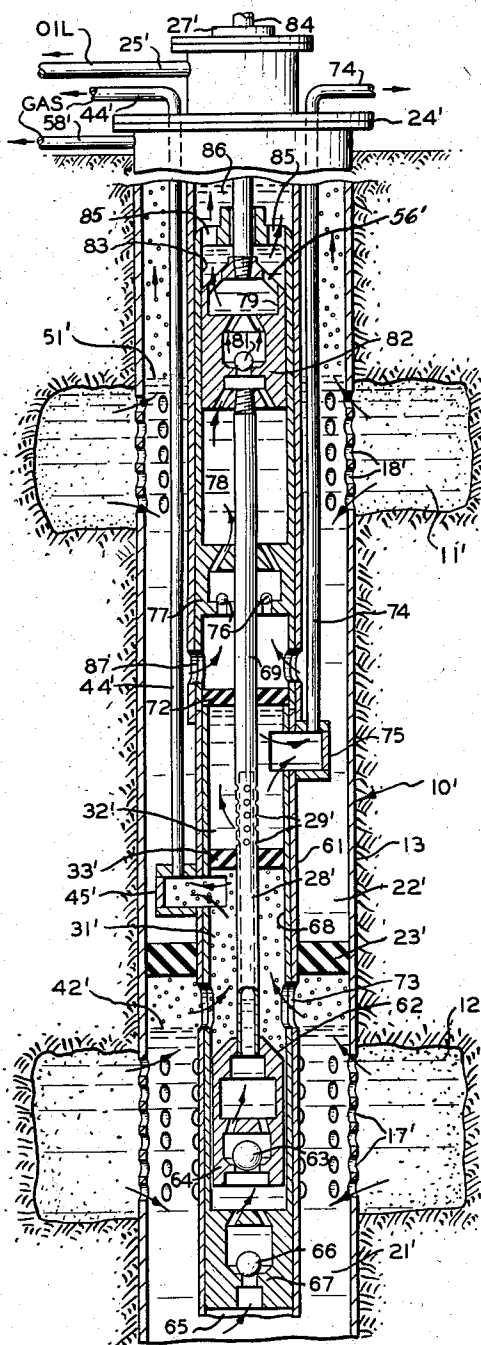


FIG. 2

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TWO ZONE PUMPING

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5 Claims. (Cl. 103—4)

This invention relates to dual-zone pumping apparatus. More particularly, this invention relates to a dual-zone pumping apparatus, of the sucker rod type, for simultaneously producing oil and gas from two formations or zones within a single well bore without commingling the oil and gas from either formation.

Wells often intersect several independent strata or formations from which oil and gas may be produced. In pumping wells of this nature after the reservoir pressure has decreased to a point where the wells do not effectively flow by themselves, it is often desirable or necessary that the oil and gas produced from the separate zones be removed as independent streams and without commingling the same. This can be accomplished either by employing a plurality of pumps in different well bores in the same field or by separating the inlets of the plurality of pumps in a single well bore in such a manner that the oil and gas in the two zones are removed through separate conduits. Various types of dual-zone deep well pump assemblies are known in the art for pumping such wells, such as hydraulic pumping systems or pumping systems of the sucker rod type; the present invention is concerned with the latter type of pumping system. Dual-zone pumping systems have not been too popular, however, because they lack satisfactory means for efficiently pumping the two zones without commingling the oil and gas from either zone. The pump efficiencies of these prior art pumping assemblies are often low due to insufficient or no separation of gas ahead of the pumps, thus forcing the pumps to handle large quantities of gas. Low pump efficiencies are also due to insufficient submergence of the pump, thus resulting in gas separating in the pump suction with consequent gas locking.

Accordingly, an object of this invention is to provide an improved dual-zone pumping apparatus.

Another object is to provide a dual-zone pumping apparatus, of the sucker rod type, for simultaneously producing oil and gas from two formations or zones within a single well bore without commingling the oil and gas from either formation.

A further object is to provide a novel dual-zone pumping apparatus characterized by its desirable pumping efficiency and the absence of gas locking.

Further objects and advantages of this invention will become apparent, to those skilled in the art, from the following discussion, appended claims and accompanying drawing in which:

Figure 1 is a schematic elevation view, shown partly in section, of a dual-zone producing well having one embodiment of the pumping apparatus of this invention inserted therein; and

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Figure 2 is a schematic elevation view, shown partly in section, of a dual-zone producing well having another embodiment of the pumping apparatus of this invention inserted therein.

Referring to the drawing, and particularly to the well production apparatus illustrated in Figure 1, reference number 10 generally designates a well bore which extends downwardly through upper producing formation or zone 11 and lower producing formation or zone 12. The well bore 10 is provided with a string of casing 13 and two strings of oil flow tubing 14, 16. Casing 13 is perforated at 17, 18 or may have other suitable means for permitting communication of the producing zones 11, 12 with the interior of the casing 13. The annular space between the casing 13 and tubing 14 is divided into separate lower and upper annular fluid accumulating regions or spaces 21, 22, respectively, by a conventional well packer 23 at a point between the two producing zones 11, 12 so as to seal off the two zones from each other.

The lower end of oil flow tubing 14 passes through an opening in packer 23 and extends therebelow a sufficient distance so that inlet 20 is completely submerged in the oil accumulating in lower region 21. The upper end of flow tubing 14 passes through the casing head 24 and is connected to a pipe 25 which conducts the oil produced from the lower zone 12 to storage. A solid sucker rod 26 passes downwardly through a stuffing box 27 into the interior of flow tubing 14 and is mounted for reciprocation therein. Sucker rod 26 can be mounted for reciprocation at the surface of the well bore by a suitable conventional pumping apparatus, for example, a walking beam pumping unit. Solid sucker rod 26 carries at its lower end a hollow sucker rod 28, the upper end of which is provided with perforations 29. The interior of flow tubing 14 is divided by a fluid seal 33 (made of rubber, asbestos, metal, flax, "Teflon," or the like) into separate lower and upper annular spaces 31, 32 respectively; fluid seal 33 is positioned at a point above well packer 23 and below perforations 29.

The hollow sucker rod 28, which passes upwardly through an opening in fluid seal 33, communicates at its lower end with lower producing zone 12 through a reciprocal pumping unit disposed in the lower portion of flow tubing 14, which pumping unit is adapted to induce flow from lower producing zone 12. The lower end of hollow sucker rod 28 carries a plunger member 34 which has an enlarged diameter so as to closely fit a tubing section 36 which functions as a pumping cylinder. The plunger member 34 is equipped with a traveling valve which may comprise a ball 37 operable with seat 28. The lower end of the flow tubing 14 is equipped with a standing valve which similarly may comprise a ball 39 operable with seat 41. These two valves are adapted to permit upward flow only via the flow passage defined by hollow sucker rod 28 and upper annular space 32. The lower end of flow tubing 14 is substantially below the oil-gas interface 42 and is completely submerged in substantially gas-free oil.

That portion of flow tubing 14 immediately below packer 23 is provided with an inlet or perforation 43 to permit communication of the lower annular space 31 of flow tubing 14 with the gas produced from lower zone 12 and present within the annular casing space 21 below packer 23. That portion of flow tubing 14 above packer

23 and below fluid seal 33 communicates with gas auxiliary flow tubing 44 (through cross-over 45) which is disposed within the annular casing space 22; the upper end of auxiliary flow tubing 44 extends through the casing head 24 and provides a flow passage to conduct the gas produced from the lower zone 12 to storage.

The foregoing described apparatus is employed to independently and simultaneously produce the oil and gas from the lower producing zone 12 without commingling the two streams. The following will describe the apparatus employed to independently and simultaneously produce the oil and gas from the upper producing zone 11 without commingling the two, reference being made again to Figure 1.

Oil flow tubing 16 extends downwardly within the interior of casing 13 to a point below the oil-gas interface 51 and above packer 23. The upper end of flow tubing 16 passes through casing head 24 and is connected to a pipe 52 for conducting the oil produced from the upper producing zone 11 to storage. A solid sucker rod 53 passes through a suitable stuffing box 54 into the interior of flow tubing 16. The lower end of solid sucker rod 53 communicates with the oil in the casing 13 above packer 23 through a reciprocal pumping unit disposed in the lower portion of flow tubing 16, which pumping unit induces flow from the upper producing zone 11; the structural elements of this pumping unit are similar to that provided at the lower end of flow tubing 14 and have been designated with primed corresponding reference numerals. The upper end of plunger member 34' is provided with suitable passages 56, permitting communication between the lower end of flow tubing 16 through the inlet 20' and the annular space 57 above the plunger member 34', space 57 serving as a flow passage. The upper end of casing 13 is connected to pipe 58 to conduct the gas produced from the upper zone 11 to storage, the upper portion of casing 13 serving as a flow passage for this gas.

The embodiment of my invention thus far described is particularly applicable where the size of the casing is relatively large, e.g., 7 inches O.D., so as to accommodate the two separate oil flow tubings 14, 16 and the auxiliary flow tubing 44.

Another embodiment of my invention particularly applicable where the casing is relatively small, e.g., 4-5 1/2 inches O.D., will now be described, reference being made to Figure 2 in which structural elements similar to those of Figure 1 have been designated with primed corresponding reference numerals.

Oil flow tubing 61 extends downwardly within casing 13 to a point below packer 23', the distance being such that the inlet 65 is completely submerged in substantially gas-free oil. Disposed within the lower portion of flow tubing 61 is a reciprocal pumping unit similar to that disposed in the lower portion of the flow tubing 14 of Figure 1, plunger member 62 being provided with a traveling valve having ball 63 operable with seat 64, and the standing valve at the end of the flow tubing 61 being provided with ball 66 operable with seat 67. Plunger member 62 is closely fitted within pumping cylinder 68 which may extend upwardly within flow tubing 61, as shown, to a point above packer 23'. Plunger member 62 is mounted for reciprocation within pumping cylinder 68, reciprocating motion being transmitted to the plunger member 62 by hollow sucker rod 28', the latter passing upwardly through fluid seal 33' into upper annular space 32'. The hollow sucker rod 28' communicates at its lower end with lower producing zone 12' through inlet 65, and communicates at its upper end through perforations 29' with upper annular space 32'. The hollow sucker rod 28' is carried by solid sucker rod extension 69, the lower end of which is connected to hollow sucker rod 28' at a point within upper annular space 32'; solid sucker extension 69 passes upwardly through a fluid seal 72.

That portion of flow tubing 61 immediately below packer 23', and the adjacent portion of pumping cylinder 68, is provided with perforations 73 to permit communication of the lower annular space 31' of flow tubing 61 with the gas produced from the lower producing zone 12' and accumulating in the annular space 21' below packer 23'. The portion of the lower annular space 31' above packer 23' communicates with gas auxiliary flow tubing 44' (through cross-over 45'). The upper annular space 32' of flow tubing 61 communicates with oil flow tubing 74 (through cross-over 75) which extends upwardly through the annular casing space 22' to the surface to conduct oil produced from the lower producing zone 12' to storage.

The reciprocal pumping unit adapted to induce the flow of upper producing zone 11' of Figure 2 will now be described. Solid sucker rod extension 69 extends upwardly through fluid seal 72 and through a standing valve, comprising balls 76 operable with seat 77, into lower annular space 78. The upper end of solid sucker rod extension 69 is connected to plunger member 79 and is reciprocally carried thereby. Plunger member 79 is associated with a traveling valve, comprising ball 81 operable with seat 82, which is reciprocally moved within the upper portion of pumping cylinder 83 by reason of solid sucker rod 84 which is connected to and carries plunger member 79. Solid sucker rod 84 extends upwardly through upper annular space 86 to the surface where it is mounted for reciprocation by the usual surface pumping apparatus, for example, a walking beam pumping unit.

That portion of the flow tubing 61 which carries the reciprocal pumping unit that is adapted to induce the flow of the upper producing zone 11' is provided with perforations 87 which are positioned at a point below the oil-gas interface 51' and above fluid seal 72. As such, communication of the lower annular space 78 with the oil in the annular casing space 22' above packer 23' is permitted.

The gas produced from the upper producing zone 11' rises upwardly in an annular casing space 22' to the surface where it is conducted by pipe 58' to storage.

The operation of that embodiment of my novel dual-zone pumping apparatus illustrated in Figure 1 will now be described. After the reservoir pressure is sufficient to sustain natural flow from producing formations 11, 12, the apparatus of Figure 1 is lowered into the well bore 10. The surface pumping apparatus, for example, a walking beam pumping unit, is started and causes the reciprocation of the solid sucker rods 26, 53. The production of the lower producing zone 12 will be the initially described. The reciprocating motion of solid sucker rod 26 is transmitted to hollow sucker rod 23 which in turn actuates the plunger member 34 and its associated traveling valve. On the downstroke of the plunger member 34, ball 37 is lifted off its seat 38 and any oil present therebelow within the pumping unit is caused to flow upwardly through hollow sucker rod 23 into the upper annular space 32 above fluid seal 33. Upon the upstroke of plunger member 34 the ball 39 of the standing valve is lifted off its seat 41 and the resulting suction causes oil to flow from the lower accumulating region 21 into the pumping unit from which it is produced upon the next downstroke of the plunger member 34. The oil produced from the lower producing zone 12 flows to the surface through the flow tubing 14 and is separate from the gas produced from the same zone and separate from the gas and oil produced from the upper zone 11. The gas from the lower producing zone 12 accumulates above the oil-gas interface 42 and flows under its own pressure through perforations 43 into the lower annular space 31 in flow tubing 14 from which it is produced via cross-over 45 and gas auxiliary flow tubing 44. As such, the gas produced from the lower producing formation 12 is not commingled with oil from either the lower or upper producing zones 11, 12.

The reciprocation of solid sucker rod 53 actuates the reciprocal pumping unit in the lower portion of flow tubing 16 whereby the oil accumulating in the upper casing space 22 is produced in a manner similar to the production of the oil in the lower annular casing space 21. Upon the downstroke of plunger member 34', ball 37' is lifted off its seat 38' and oil within the pumping cylinder 36' is caused to flow upwardly through the openings 56 in the plunger member 34' into the flow tubing 16 thereabove. The gas from the upper producing zone 11 accumulates above the oil-gas interface 51 and flows under its own pressure upwardly within the annular casing space 22 to the surface.

The operation of the dual-zone pumping apparatus illustrated in Figure 2 will now be described. After the natural flow of producing zones 11, 12 ceases, the apparatus of Figure 2 is lowered in the well bore 10'. Upon the starting of suitable surface pumping apparatus, the solid sucker rod 84 is caused to reciprocate, reciprocating motion being transmitted from the latter to the plunger member 79 and its associated traveling valve. The reciprocation of the plunger member 79 on its downstroke causes ball 81 to be lifted from its seat 82 whereby any oil accumulating in this reciprocal pump unit is caused to flow upwardly through the openings 56' in the plunger member 79 and thence through the openings 85 in the top of the pumping cylinder 83 into the upper annular space 86 of flow tubing 61. Upon the upstroke of plunger member 79 the resulting suction causes balls 76 to be lifted from their seat 77 causing any oil accumulating in the upper annular casing space 22' to flow through inlet 87 into the reciprocal pump unit from which it is subsequently produced upon the next downstroke of plunger member 79. Like the apparatus in Figure 1, any gas from the upper producing zone 11 which accumulates above the oil-gas interface 51' will flow under its own pressure upwardly through the casing to the surface.

Since plunger member 79 is connected to and carries solid sucker rod extension 69, reciprocation of the former is transmitted to the latter. Consequently, the plunger member 62 is actuated so as to cause the lower reciprocal pump means to induce the flow from the lower producing zone 12' in a manner similar to that described in regard to the operation of the apparatus of Figure 1. That is, the oil from the lower producing zone 12' is produced independently of the gas from the lower producing zone 12' and independently and separately from the oil and gas produced from the upper producing zone 11'.

The efficient operation of the pumping apparatus of either Figure 1 or Figure 2 is not dependent upon the presence of an oil-gas interface in the casing below the well packer. The drawing illustrates an ideal situation where there is a phase separation of oil and gas below the well packer. Although such an ideal situation is preferred, it is readily apparent that the absence of an oil-gas interface beneath the well packer will not prevent the gas from the lower producing zone from being separately produced because such an oil-gas interface will be present in the auxiliary gas flow tubing due to the pressure differential. Moreover, the pumping apparatus can be inserted in the well in such a manner that the oil inlets of the respective upper and lower reciprocal pump units are submerged in the oil accumulating above and below the well packer. Although the drawing also illustrates the ideal and preferred situation where the upper and lower reciprocal pump units are positioned below the corresponding producing zones, the efficiencies of the reciprocal pump units will not be unduly hampered if the reciprocal pump units are positioned above or adjacent their respective producing zones, as long as their respective oil inlets are submerged in the accumulated oil.

Various modifications and alterations of my invention will become apparent, to those skilled in the art, from the foregoing discussion and accompanying drawing which

merely represents the preferred embodiments of my invention, and it is to be understood that my invention is not to be unduly limited thereto.

Having described my invention, I claim:

1. In a well bore communicating with lower and upper oil and gas producing zones, a mechanism for simultaneously and separately producing the oil and gas from each of said zones, comprising, in combination, a casing, flow tubing depending within said casing and annularly spaced therefrom, a well packer within said casing between said zones and surrounding said flow tubing for sealing said zones from each other and providing lower and upper fluid accumulating regions within said casing, said lower and upper regions communicating with said lower and upper zones respectively, a first inlet in said flow tubing immediately below said well packer, first reciprocal pump means in that portion of said flow tubing depending in said lower region beneath said well packer, said first pump means having a second inlet, said first pump means having a first standing valve and a first traveling valve controlling flow through said second inlet, said first traveling valve operatively carried by a hollow rod section which slidably extends through sealing means in said flow tubing above said first inlet, the interior of said hollow rod section communicating at one end with said second inlet through said first standing valve and at the other end with a passage for separately conducting the oil from said lower zone, a separate flow passage communicating with said first inlet for separately conducting the gas from said lower zone, said last-mentioned separate flow passage defined by an auxiliary flow tubing which depends within said upper region and communicates with said first inlet through a cross-over at its lower end, said cross-over being connected to said first tubing and communicating therewith at a point beneath said sealing means, the upper end of said auxiliary flow tubing extending to the surface of said well bore, second reciprocal pump means disposed in said upper region, said second pump means having a third inlet, a second standing valve, and a second traveling valve controlling flow through said third inlet, said second traveling valve operatively carried by a solid rod section, a separate flow passage communicating with said third inlet through said second standing valve for separately conducting the oil from said upper zone, the annular space above the accumulated oil in said upper region functioning as a separate flow passage for conducting the gas from said upper zone, and reciprocating means associated with said hollow and solid rod sections so as to transmit reciprocating motions to said first and second reciprocal pump means whereby flow is induced from said lower and upper producing zones respectively.

2. In a well bore communicating with lower and upper oil and gas producing zones, a mechanism for simultaneously and separately producing the oil and gas from each of said zones, comprising, in combination, a casing, a first flow tubing depending within said casing and annularly spaced therefrom, a well packer within said casing between said zones and surrounding said first flow tubing for sealing said zones from each other and providing lower and upper fluid accumulating regions within said casing, said lower and upper regions communicating with said lower and upper zones respectively, first reciprocal pump means carried by that portion of said first flow tubing depending in said lower region beneath said well packer, a first inlet in said first flow tubing immediately below said packer, said first pump means having a second inlet, said first pump means having a first standing valve and a first traveling valve operatively carried by a hollow rod section which slidably extends through a fluid seal in said first flow tubing positioned above said first inlet, the interior of said hollow rod section communicating at one end with said second inlet through said first standing valve and at the other end with the interior of said first flow tubing above said fluid seal, a separate flow passage communicating with said first inlet for con-

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ducting gas from said lower region, said last-mentioned separate flow passage defined by an auxiliary flow tubing which depends within said upper region and communicates with said first inlet through a cross-over at its lower end, said cross-over being connected to said first tubing and communicating therewith at a point beneath said sealing means, the upper end of said auxiliary flow tubing extending to the surface of said well bore, a second flow tubing depending within said casing above said packer in said upper region, second reciprocal pump means carried by the lower portion of said second flow tubing, said second pump means having a third inlet, a second standing valve, and a second traveling valve controlling flow through said third inlet, said second traveling valve operatively carried by a solid rod section, a flow passage communicating with said third inlet through said second standing valve for separately conducting the oil from said upper producing zone, and reciprocating means for actuating said first and second pump means.

3. In a well bore communicating with lower and upper oil and gas producing zones, a mechanism for simultaneously and separately producing the oil and gas from each of said zones, comprising, in combination, a casing, a first flow tubing depending within said casing and annularly spaced therefrom, a well packer within said casing between said zones and surrounding said first flow tubing for sealing off said zones from each other and providing lower and upper fluid accumulating regions within said casing, said lower and upper regions communicating through ports in said casing with said lower and upper zones respectively, a first inlet in said first flow tubing immediately below said packer, first reciprocal pump means carried by that portion of said first flow tubing depending in said lower region beneath said well packer, said first pump means having a second inlet, said first pump means having a first standing valve and a second traveling valve controlling flow through said second inlet, said first traveling valve operatively carried by a hollow rod section which slidably extends upwardly through a fluid seal positioned in said first flow tubing above said first inlet, the interior of said hollow rod section communicating at one end through said first standing valve with said second inlet and at the other end with the interior of said first flow tubing above said fluid seal, said hollow sucker rod section carried at its upper end by a solid sucker rod section, an auxiliary flow tubing depending within said upper region of said casing and communicating through a cross-over with said first inlet through an outlet in said flow tubing positioned below said fluid seal, the upper end of said auxiliary flow tubing extending to the surface of said well bore, a second flow tubing depending within said casing above said packer, second reciprocal pump means carried by the lower portion of said second flow tubing, said second pump means having a third inlet, said second pump means having a second standing valve and a second traveling valve for controlling the flow through said third inlet, said third inlet communicating through said second traveling and standing valves with a flow passage in said second flow tubing above said second pump means, said second traveling valve carried by a solid sucker rod section, the upper annulus of said casing functioning as a flow passage for the gas produced from said upper zone.

4. In a well bore communicating with lower and upper oil and gas producing zones, a mechanism for simultaneously and separately producing the oil and gas from each of said zones, comprising, in combination, a casing, a flow tubing depending within said casing and annularly spaced therefrom, a well packer within said casing between said zones and surrounding said flow tubing for sealing said zones from each other and providing lower and upper fluid accumulating regions within said casing, said lower and upper regions communicating with said lower and upper zones respectively, first reciprocal pump means carried by that portion of said flow tubing depend-

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ing in said lower region beneath said well packer, a first inlet in said flow tubing immediately below said packer, said first pump means having a second inlet, said first pump means having a first standing valve and a first traveling valve for controlling flow through said second inlet, said first traveling valve operatively carried by a hollow rod section which slidably extends through a first fluid seal in said flow tubing positioned above said first inlet, the interior of said hollow rod section communicating at one end with said second inlet through said first standing valve and at the other end with the interior region of said flow tubing above said first fluid seal, a separate flow passage communicating with said interior region for conducting oil from said lower region, a separate flow passage communicating with said first inlet for conducting gas from said lower region, said last-mentioned separate flow passage defined by an auxiliary flow tubing which depends within said upper region and communicates with said first inlet through a cross-over at its lower end, said cross-over being connected to said first tubing and communicating therewith at a point beneath said sealing means, the upper end of said auxiliary flow tubing extending to the surface of said well bore, a solid rod extension connected to and carrying said hollow rod section which slidably extends through a second fluid seal in said flow tubing which defines the upper end of said interior region, second reciprocal pump means carried by that portion of said flow tubing above said second fluid seal, said second pump means having a third inlet positioned above said second fluid seal, said second pump means having a second standing valve and a second traveling valve controlling flow through said third inlet, said standing valve connected to and carrying said solid rod extension, said second traveling valve connected to and carried by a solid sucker rod which extends upwardly in said flow tubing, and a flow passage communicating with said third inlet through said second standing valve for separately conducting the oil from said upper producing zone.

5. In a well bore communicating with lower and upper oil and gas producing zones, a mechanism for simultaneously and separately producing the oil and gas from each of said zones, comprising, in combination, a casing, a flow tubing depending within said casing and annularly spaced therefrom, a well packer within said casing between said zones and surrounding said flow tubing for sealing said zones from each other and providing lower and upper fluid accumulating regions within said casing, said lower and upper regions communicating through ports in said casing with said lower and upper zones respectively, first reciprocal pump means carried by that portion of said flow tubing depending in said lower region beneath said well packer, a first inlet in said flow tubing immediately below said packer, said first pump means having a second inlet, said first pump means having a first standing valve and a first traveling valve for controlling flow through said second inlet, said first traveling valve operatively carried by a hollow rod section which slidably extends through a first fluid seal in said flow tubing positioned above said first inlet, the interior of said hollow rod section communicating at one end with said second inlet through said first standing valve and at the other end with the interior region of said flow tubing above said first fluid seal, an auxiliary flow tubing depending within said upper region of said casing and communicating at a point above said first fluid seal with said interior region of said flow tubing, an auxiliary flow tubing depending within said upper region of said casing and communicating through a cross-over in the said first inlet through an outlet in said flow tubing positioned below said first fluid seal, the upper end of said auxiliary flow tubing extending to the surface of said well bore, a solid rod extension connected to and carrying said hollow rod section which slidably extends through a second fluid seal in said flow tubing which defines the upper end of said interior region, second reciprocal pump means carried by that portion of said flow tubing above said

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second fluid seal, said second pump means having a third inlet positioned above said second fluid seal, said second pump means having a second standing valve and a second traveling valve controlling flow through said third inlet, said standing valve connected to and carrying said solid rod extension, said second traveling valve connected to and carried by a solid sucker rod which extends upwardly in said flow tubing, said third inlet communicating

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through said second traveling and standing valves with a flow passage in said flow tubing above said second pump means, the upper annulus of said casing functioning as a flow passage for the gas produced from said upper zone.

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