

June 8, 1954

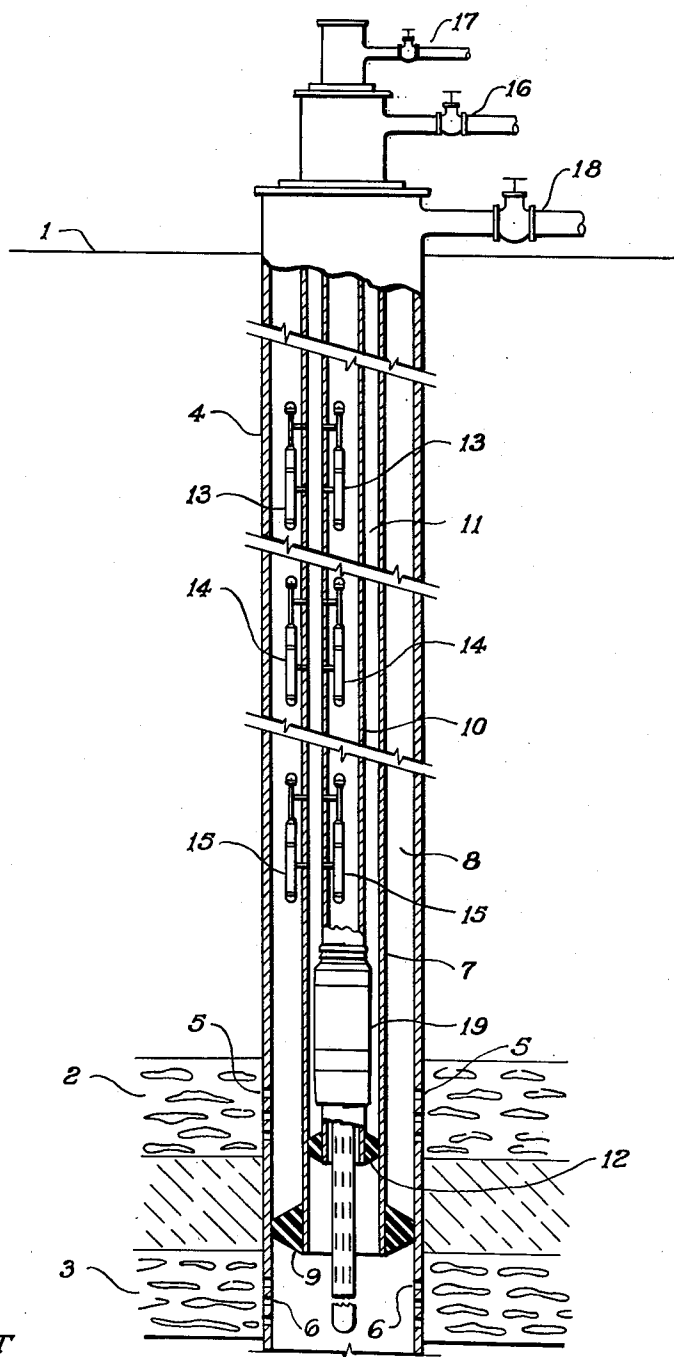
L. F. DAVIS

2,680,408

MEANS FOR DUALY COMPLETING OIL WELLS

Filed Feb. 16, 1949

5 Sheets-Sheet 1



ATTEST
Melvin C. Flint

Fig. 1

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June 8, 1954

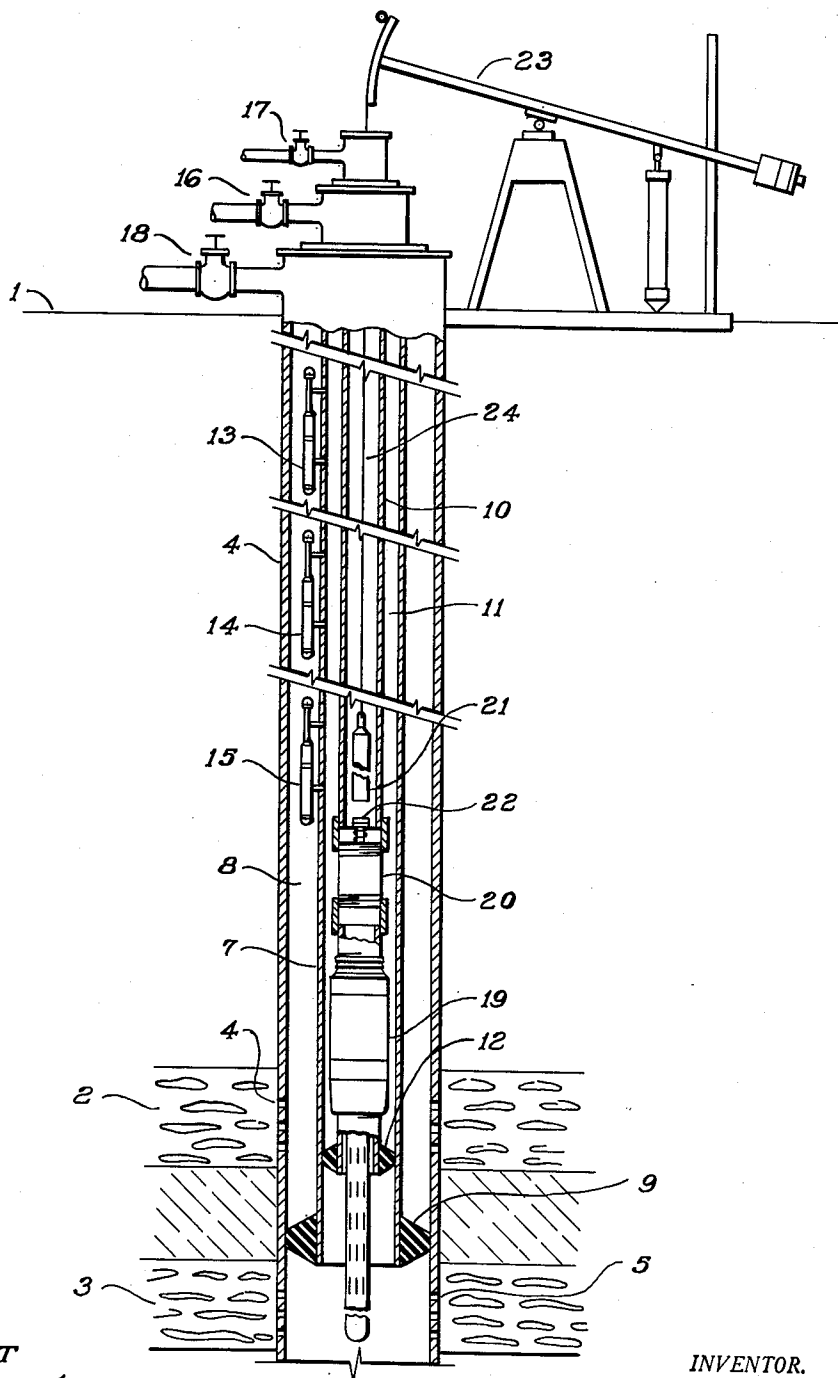
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MEANS FOR DUALY COMPLETING OIL WELLS

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ATTEST

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Fig. 2

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MEANS FOR DUALY COMPLETING OIL WELLS

Filed Feb. 16, 1949

5 Sheets-Sheet 3

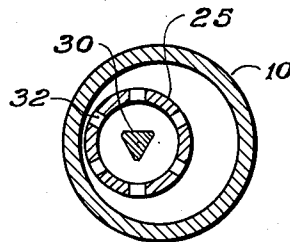
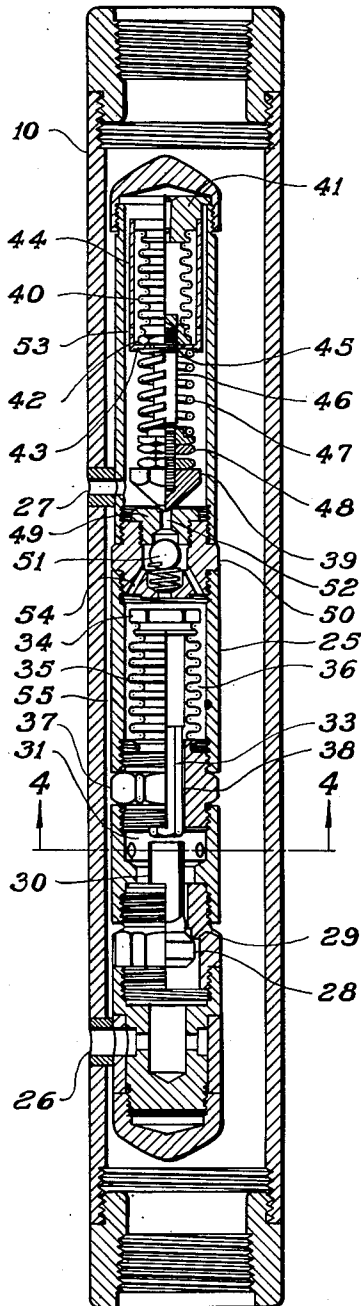


Fig. 4

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Fig. 3

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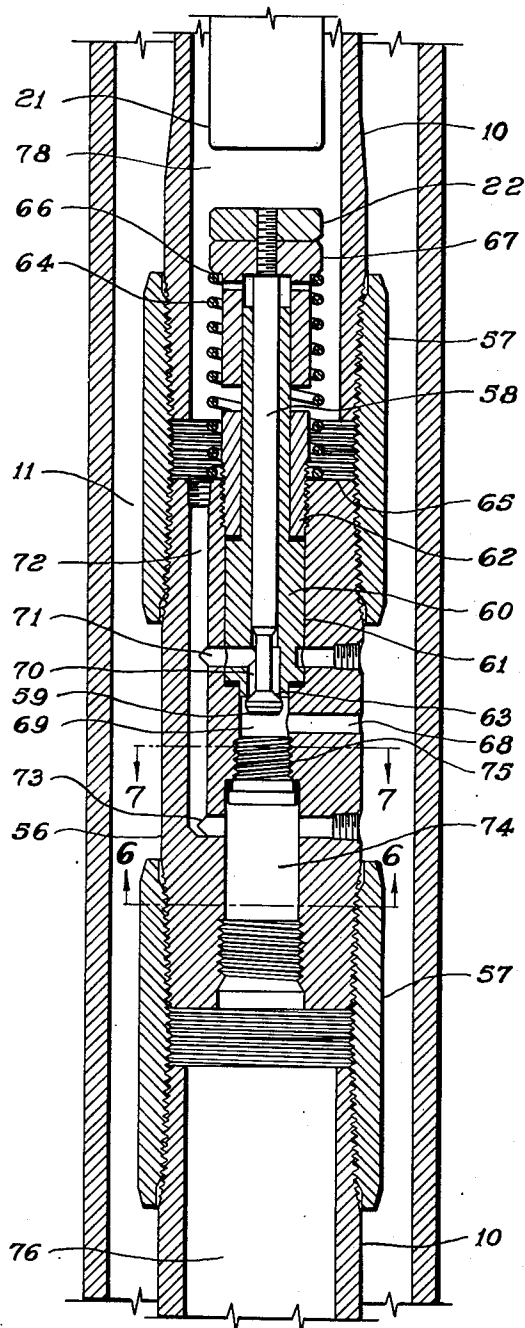
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2,680,408

MEANS FOR DUALY COMPLETING OIL WELLS

Filed Feb. 16, 1949

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ATTEST
Melvin C. Hunt Fig. 5

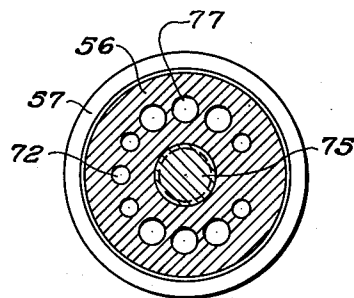


Fig. 7

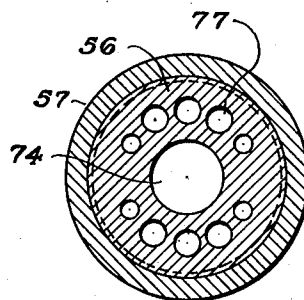


Fig. 6

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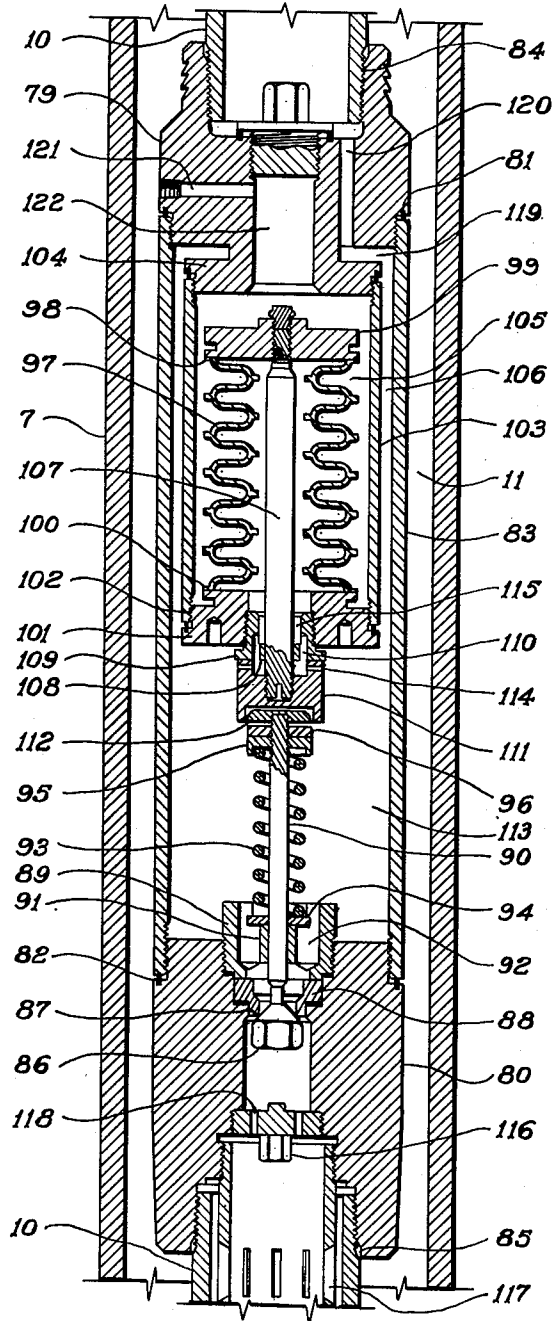
L. F. DAVIS

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MEANS FOR DUALY COMPLETING OIL WELLS

Filed Feb. 16, 1949

5 Sheets-Sheet 5



ATTEST
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Fig. 8

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UNITED STATES PATENT OFFICE

2,680,408

MEANS FOR DUALY COMPLETING OIL
WELLS

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Application February 16, 1949, Serial No. 76,750

9 Claims. (Cl. 103—4)

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This invention relates to an improved system for producing from a plurality of subterranean oil reservoirs. More particularly, the invention relates to a system including artificial lift means for producing from a plurality of oil reservoirs through a single bore hole without commingling of the fluids from the several reservoirs.

The search for oil has led to the discovery in certain oil fields of a number of producing zones. Generally, the characteristics of these producing zones are dissimilar and frequently both oil and gas reservoirs are encountered. In the case of oil reservoirs, to which the present invention is primarily directed, the pressure exerted on the oil contained therein may be attributable to a water drive, for example, or the presence of dissolved gaseous hydrocarbons. Further, there may be a considerable variance in the quantum of pressure exerted on the various reservoirs in the field.

Joint production of oil from two or more producing zones through a single casing, or tubing string is likely to result in irreparable damage of the reservoirs and wastage of the fluids contained therein due to drainage of fluid from one reservoir into a reservoir of lesser pressure and the attendant pressure drive reduction in the former. For the above reasons and the fact that in substantially all States in which oil is being produced from subterranean petroliferous zones laws have been enacted imposing restrictions on the production of oil and gas, or either, as the case may be, from two or more producing zones in an oil field, efforts have been directed to the development of a method and apparatus for independently producing oil from a plurality of overlying reservoirs.

Obviously, this could be accomplished by producing separately each of the reservoirs through a well or wells communicating solely therewith; however, relatively high drilling costs make desirable the production from the producing zones through a single bore hole. In this regard, little difficulty is experienced in the case of reservoirs having sufficient pressure exerted thereon by a water drive, for example, to produce the same without employment of artificial lift means. For this purpose a tubing string having a packer provided on the end thereof is run into a bore hole which traverses the reservoirs and is lined with a well casing having perforations therein communicating with each of the reservoirs. The well packer is set intermediate an upper and lower producing zone, whereby fluid from the upper producing zone will flow into the well cas-

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ing and thence to the well surface through the annular space between the casing and tubing string, and fluid from the lower producing zone will be directed into the tubing and will flow therethrough to the well surface. As the reservoirs are produced, the reservoir pressures will be reduced and this will continue until the pressure drives are insufficient to cause fluids contained therein to flow to the well surface. Natural flow having ceased, the reservoirs may then be put on artificial lift to recover an additional amount of reservoir fluid. The same situation obtains in the case of reservoirs in which the initial pressure is insufficient to permit natural flow of reservoir fluid.

A modification of the system described above, which has been proposed for producing separately from two or more reservoirs having pressures such as to require artificial lift means, utilizes gas lift valves operable upon the establishment of a preselected differential in pressure thereacross. In this system, an inner tubing string is run inside the outer tubing string in a manner to provide an annular space therebetween and a packer is set externally of the inner tubing string and adjacent the lower end thereof, in a manner sealing the annular space between it and the outer tubing string, whereby reservoir fluid from the lower reservoir instead of flowing upwardly in the outer tubing string, as in the previous system, will be directed upwardly into the interior of the inner tubing string. Pairs of oppositely disposed gas lift valves are provided at spaced intervals respectively in the walls of the inner and outer tubing strings for lifting independently reservoir fluid from the lower reservoir and the upper reservoir, respectively. The gas lift valves may be actuated by injection of gas under pressure into the annular space between the inner and outer tubing strings. The valves are adjusted so as to be actuated by decreasing pressure differentials from the uppermost down to the lowermost pair of valves. The gas is injected at a pressure sufficient to actuate the uppermost pair of valves whereby the gas will pass therethrough and lift to the well surface the reservoir fluids above the uppermost pair of valves. In a similar manner, succeeding pairs of gas lift valves are actuated until the reservoir fluids above the lowermost pair of gas lift valves have been raised to the well surface. In practice, this system is unsatisfactory because the gas pressure at which the gas lift valves are actuated is dependent upon the pressures of the reservoir fluids in the annular space between the

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outer tubing string and the casing, on the one hand, and within the inner tubing string, on the other hand, and, therefore, only partial control of this system from the well surface is possible.

The present invention is concerned with an improved system for producing from a plurality of subterranean oil wells and utilizes pressure responsive valve means of the intermitter type for lifting production to the well surface. The pressure responsive valve means are provided at vertically spaced intervals in the wall of the first and second tubing strings. It is necessary to maintain at all times the reservoir liquids in the annular space between the casing and first tubing string and within the second tubing string at substantially the same level. For this purpose there is connected in the second tubing string below the lowermost pressure responsive valve means a valve for controlling the level of the reservoir liquid normally standing in the second tubing string. By means of this improved system a plurality of producing zones may be produced through a single bore hole without commingling of the fluids from the several zones.

Other systems have been proposed for producing independently a plurality of producing zones through a single bore hole but none of them are entirely satisfactory for various reasons.

Accordingly, one object of the invention is to provide an improved system for producing from a plurality of subterranean reservoirs through a single bore hole, and a system that will obviate the difficulties above set forth.

Another object of the invention is to provide a system for producing from a plurality of producing zones through a single bore hole without commingling of the fluids from the several zones.

A further object is to provide a system for producing from a plurality of producing zones through a single bore hole, which system includes artificial lift means for lifting independently to the well surface production from the several zones.

A still further object is to provide such a system in which means are provided for controlling the level of production in the well from one of the producing zones.

Other objects and features of the invention will be apparent from the drawings and description which follow.

Figure 1 is an elevational view, partially in section, showing a system constructed in accordance with the invention and including pressure responsive valve means for lifting independently to the well surface fluid from a plurality of reservoirs.

Figure 2 is another embodiment of the invention in which pressure responsive valve means are employed for lifting to the well surface production from one of the producing zones and mechanically actuated valve means for lifting to the well surface production from another of the producing zones.

Figure 3 is an elevational view, partially in section, showing in detail a suitable gas lift valve for lifting reservoir liquid to the earth's surface.

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

Figure 5 is an elevational view, partially in section, showing in detail a suitable mechanically operated lift valve.

Figure 6 is a sectional view taken along the line 6—6 of Figure 5.

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Figure 7 is a sectional view taken along the line 7—7 of Figure 5.

Figure 8 is an elevational view, partially in section, showing a suitable liquid level control valve.

Referring to the drawings, and in particular at this time to Figure 1, the earth's surface is designated generally by the numeral 1. A well bore traversing an upper oil reservoir 2 and a lower oil reservoir 3 is lined with a well casing 4 which is provided with suitable perforations 5 and 6, adjacent reservoirs 2 and 3, respectively. A first tubing string 7 is disposed within casing 4 in a manner to provide a first annular space 8 therebetween. A conventional permanent type packer 9 is secured between casing 4 and tubing string 7, and intermediate of reservoirs 2 and 3. A second tubing string 10 is disposed within first tubing string 7 in a manner to provide a second annular space 11 therebetween, and a suitable anchor packer 12 is secured between tubing strings 7 and 10 and adjacent the lower ends thereof. By this arrangement reservoir liquids from reservoirs 2 and 3 are directed into first annular space 8 and the interior of second tubing string 10, respectively. It is obvious that conditions frequently may arise where it would be desirable to employ a removable type packer in place of permanent type packer 9 and also a hook wall packer in place of anchor packer 12 and it is to be understood that such arrangement is within the scope of this invention.

It is the purpose of this invention to provide artificial lift means of the intermitter type for lifting independently to the earth's surface 1 reservoir liquids from reservoirs 2 and 3 in the event that the pressure drive of the reservoirs, or either, as the case may be, is insufficient for this purpose. To this end pairs of pressure responsive valve means 13, 14, and 15 are provided at spaced intervals in the walls of tubing strings 7 and 10, the pairs of pressure responsive valve means being responsive to progressively decreasing pressures from the uppermost pair of pressure responsive valve means 13 to the lowermost pair of pressure responsive valve means 15. The pressure responsive valve means, which will be described more fully hereinafter, may be of the conventional type of intermitter gas lift valve operable upon application of a predetermined fluid pressure to the input side thereof to thereby permit the fluid to flow therethrough and lift to the earth's surface liquid standing thereabove in the well. Such a device is disclosed, for example, in U. S. Patent No. 2,385,316, issued to R. O. Walton on September 18, 1945, and entitled "Well Flow Device."

Any suitable means, not shown, may be employed for intermittently introducing into annular space 11 through valve controlled pipe 16 fluid under pressure sufficient to actuate the several pairs of pressure responsive valve means, whereby the fluid is permitted to flow therethrough and lift to the earth's surface 1 the reservoir liquids in first annular space 8 and in second tubing string 10 above the lowermost pair of pressure responsive valve means 15. The reservoir liquids from annular space 8 and tubing string 10 pass through valve controlled pipes 17 and 18, respectively, to suitable storage tanks, not shown.

For reasons which will be obvious from the description hereinafter, it is necessary to maintain the reservoir liquid in annular space 8 and second tubing string 10 at substantially the same

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level. Accordingly, there is connected in second tubing string 10 below the lowermost pressure responsive valve means 15 liquid level control valve means 19 for controlling the level of reservoir liquid normally standing in second tubing string 10. The liquid level control valve means, which will be described in detail hereinafter, may be of any conventional type, such as that disclosed in U. S. Patent No. 2,597,198, issued May 20, 1952, to Horace M. Staggs and Louis F. Davis.

In practice, due to the sizes of standard pipe which are employed usually in dual completion installations, the normal liquid level in second tubing string 10 is above that of the liquid in first annular space 8, regardless of the fact that reservoir 2 may be somewhat more productive than reservoir 3. Therefore, by suitably placing a liquid level control valve in second tubing string 10 the liquid standing in the tubing string may be maintained at the same level as that of the liquid in first annular space 8. In some instances, however, the rate of flow of liquid from upper producing reservoir 2 may be so much greater than that from lower reservoir 3, or the tubing employed in the well may be such that the liquid level in first annular space 8 is at a level higher than that of the liquid in second tubing string 10. In such instances, in order to maintain the liquid levels in the well equal, a suitable, conventional flow direction means or crossover packer may be employed and disposed in the well in a manner such that liquid from upper reservoir 2 is directed into second tubing string 10 and liquid from lower producing reservoir 3 is directed into first annular space 8. It is readily seen that liquid level control means 19 disposed in second tubing string 10 then may be adjusted in a manner to maintain the liquid level in tubing string 10 at the same height as the liquid level in first annular space 8.

Figure 2 shows another embodiment of the invention which differs from that of Figure 1 in that there is substituted for the pressure responsive valve means 13, 14, and 15 on second tubing string 10 a mechanically actuated lift device connected in tubing string 10 above liquid level control valve means 19 for periodically injecting fluid into the reservoir liquid standing in the tubing string to raise the liquid to the well surface. One such device, commonly termed an intermitter, is disclosed in U. S. Patent No. 1,633,930, issued to Horace M. Staggs on September 11, 1928, and entitled "Air-Lift Pump." The intermitter 20, which is described in detail below, is disposed, as shown, in second tubing string 10 and is actuated by means of a weight 21 periodically brought into contact with cap 22 of the intermitter, weight 21 being alternately raised and lowered by means of a suitable raising and lowering mechanism 23 located on the earth's surface 1 and to which the weight is operatively connected by means of wire line 24.

A suitable gas lift device, connected, for example, in the wall of second tubing string 10, is shown in Figures 3 and 4 and includes a housing, generally denoted by numeral 25, secured in the wall of tubing 10 by nipples 26 and 27 which provide communication between the interior of housing 25 and second annular space 11. Fluid under sufficient pressure to actuate the valve, which fluid has been introduced into second annular space 11 through valve controlled pipe 16, will enter the lower end of the housing through nipple 26 but will be prevented from passing upwardly by main valve 28 which is normally main-

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tained in a seated position on valve seat 29 by a pressure differential that exists thereacross, the pressure being greater from below, suitably provided about main valve stem 30 connected to valve 28. When valve 28 is opened, in a manner described hereinafter, the fluid in the lower end of housing 25 will flow upwardly past valve 28 into chamber 31 and thence will pass through a series of ports 32 formed in the wall of housing 25 into the interior of second tubing string 10. The fluid passing out of the valve will lift to the well surface reservoir liquid standing in tubing string 10 above the valve.

For opening valve 28 there is provided bellows stem 33, which is connected at one of its ends to floating head 34 and the free end of which is adapted to contact the end of valve stem 30 in a manner to cause valve 28 to be unseated. Floating head 34 is connected to one end of bellows 35, which is provided about bellows stem 33, and at its other end to fixed head 36 formed at the upper end of coupling 37. Coupling 37 connects successive sections of housing 25 and is provided with an axial opening 38 in which bellows stem 33 is mounted for slidable movement. When bellows 35 is contracted by the pressure of fluid on the exterior thereof, as described hereinafter, floating head 34 and, therefore, bellows stem 33, will be caused to move downwardly whereby bellows stem 33 will impinge upon valve stem 30 opening valve 28 and permitting fluid in the lower part of housing 25 to flow past the valve and into second tubing string 10 through ports 32, as described hereinbefore.

For controlling the pressure of fluid on the exterior of bellows 35 and thus the opening of valve 28, there is provided in the upper end of housing 25 secondary valve 39 which is actuated by pilot bellows 40. Bellows 40 is secured at one of its ends to fixed head 41 provided at the upper end of housing 25, and terminates at its lower end in floating head 42 which normally rests against plate 43 closing one end of bellows housing 44, which is connected at its other end to fixed head 41. Secured to floating head 42 and extending through a suitable aperture 45 in plate 43 of bellows housing 44 is secondary valve stem 46. Valve 39 is normally maintained in a closed position by means of helical spring 47 which is provided about valve stem 46 and which is distended between plate 43 of bellows housing 44 and adjustment nut 48 threaded on valve stem 46.

Valve 39 is adapted to be seated normally on valve seat 49 which is threaded or otherwise secured in coupling 50 connecting successive sections of housing 25 and carrying a conventional ball check valve 51 for closing passage 52 in valve seat 49 against fluid pressure from below. It is readily seen that fluid in second annular space 11, as well as entering into the lower part of housing 25 through nipple 26, will pass through nipple 27 into the upper end of the housing but normally will be prevented from passing downwardly through passage 52 by valve 39. The fluid, however, enters bellows housing 44 through radial ports 53 provided therein and impinges upon the exterior of pilot bellows 40 thereby causing the bellows to contract against the pressure of spring 47, thus opening valve 39. The fluid then passes through opening 52 in valve seat 49, past ball check valve 51, and through passages 54 provided in coupling 50 into that portion of housing 25 containing bellows 35; the pressure of the fluid, being initially sufficient to actuate the gas lift device, causes bellows 35 to contract,

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thereby opening valve 28, as described hereinbefore. When the pressure in second annular space 11 has decreased to a predetermined value by the passage of fluid through ports 32, the fluid pressure exerted on the exterior of pilot bellows 40 will be insufficient to maintain the bellows in a contracted position; therefore, the force of helical spring 47 will cause valve 39 to close. This is followed by the closing of main valve 28 which results when the fluid pressure exerted on the exterior of bellows 35 decreases below a value sufficient to maintain bellows 35 in a contracted position due to the escape of the fluid out of bleed ports 55 formed in housing 25. It is readily seen that by proper adjustment of nut 48, valve 28 may be caused to be seated or closed when the fluid pressure in second annular space 11 falls below a predetermined value.

The intermitter 20 of Figure 2, shown in detail in Figures 5, 6, and 7 of the drawings, comprises generally housing 56 secured at its opposite ends to successive sections of second tubing string 10 by threaded couplings 57. Valve stem 55 carrying valve 59 is mounted for slidable movement within sleeve 60 secured within axial bore 61 in housing 56 by threaded collar 62. Valve 59 is seated as at 63 and is normally maintained in a closed position by the action of helical spring 64 distended between shoulder 65 of housing 56 and shoulder 66 of cap 67 threaded to stem 58 of valve 59. Fluid under pressure in second annular space 11 is normally maintained against the pressure side of valve 59 through interconnecting port 68 and chamber 69. However, upon the opening of valve 59 the fluid will be permitted to pass through interconnecting ports 70, 71, 72, and 73 and axial bore 74 sealed against chamber 69 by threaded plug 75 and into the reservoir liquid in the space of second tubing string 10, generally denoted by the numeral 76, from which space it will rise through vertical bores or ports 77 (Figures 6 and 7) in housing 56 and into the body of liquid in the space above second tubing string 10, generally denoted by the numeral 78. Valve 59 is mechanically operated intermittently by the lowering of weight 21 against cap 22, the action of weight 21 being controlled through the medium of wire line 24 and lowering and raising mechanism 23 located at the earth's surface 1, as stated hereinbefore.

The liquid level control valve of Figures 1 and 2 is shown in detail in Figure 8 and comprises generally a housing formed of end sections 79 and 80 threaded as at 81 and 82, respectively, to central section 83, and as at 84 and 85, respectively, to successive sections of second tubing string 10. Valve 86 is seated as at 87 on seat member 88 rigidly secured within end section 80 by threaded collar 89, which collar also serves as a guide sleeve to valve stem 90 through axial bore 91 and to provide a series of vertical bores or ports 92 for the passage of fluid therethrough. Valve 86 is normally maintained in a closed position by helical spring 93 distended between flanged collar 94 and nut 95 threaded on the free end of stem 90 and rigidly secured thereon by lock nut 96. Bellows 97 is secured by welding, or in any other suitable manner, as at 98, to floating bellows head 99 and as at 100 to fixed bellows head 101, the fixed head being rigidly secured as by threading at 102, in one end of cylinder 103 which, in turn, is threaded at its opposite end to flanged member 104 of end section 79 and in a manner providing sealed bellows chamber 105 and annular space 106 therebetween and the inner

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wall of central section 83. Bellows stem 107 is threaded to bellows head 99 and adjacent its opposite end is mounted for slidable movement through axial bore 108 in cap 109 threaded into bellows head 101. A series of bores or ports 110 in cap 109 permit the flow of liquid into and from the interior of bellows 97. Cap 111 is threaded to the free end of bellows stem 107 and upon compression of bellows 97 will be caused to move downwardly with stem 107 against cap 112 and through the medium of stem 90 to open valve 86. It will be seen that when bellows 97 is in a distended position, cap 111 is brought to rest against cap 112 but that liquid within space 113 within central section member 83 is at all times free to flow into and from the interior of bellows 97 through openings 114 in cap 111, and ports 110 and annular groove 115 in cap 109. It furthermore will be seen that opening movement of valve 86, and, consequently, the compression of bellows 97, is limited by cap 116 threaded into end section 80.

Upon the opening of valve 86 liquid entering through strainer 117 will be caused to flow by reservoir pressure through openings 118 in cap 116, past valve 86, through ports 92 in space 113 in central member 83, and through annular space 106 from which it will flow through interconnecting ports 119 and 120 into tubing 10 to a predetermined level above the liquid level control means. Also, the reservoir liquid entering the liquid level control means will be caused to enter the interior of bellows 97 through ports 114 and 110, and annular groove 115, and thus to exert a pressure against the interior of bellows 97 dependent upon the level of the liquid in tubing 10 above the liquid level control means, as against the pressure of the fluid in annular space 11, which is applied against the exterior of bellows 97 through interconnecting ports 121 and 122 providing communication between annular space 11 and bellows chamber 105.

Upon removal of the reservoir liquid in tubing 10 by the artificial means associated therewith, a differential in pressure across bellows 97 in favor of the pressure of the fluid in annular space 11 will be brought about whereby bellows 97 will be compressed and cause bellows stem 107 to be moved in a downwardly direction against cap 112 and valve stem 90, thereby causing valve 86 to be opened and to admit additional liquid to tubing 10 to the predetermined level at which time the differential pressure across bellows 97 will be reversed in favor of the pressure of the liquid against the interior of the bellows and valve 86 closed.

Referring to Figure 1, a description of the operation of the invention when employing pressure responsive valve means on both tubing strings 7 and 10 will now be made. The several pairs of pressure responsive valve means provided at spaced intervals in the walls of the tubing strings are adjusted to respond progressively to decreasing pressures from the uppermost pair of pressure responsive valve means 13 to the lowermost pair of pressure responsive valve means 15. The apparatus is then assembled in the well, as shown in Figure 1, with the liquid level control means 19 connected in second tubing string 10 at a position such that the level of reservoir liquid therein is maintained substantially at the same level as that of the liquid contained in first annular space 8. When the apparatus is assembled initially liquid will be entrapped in second annular space 11. Fluid under pressure sufficient to

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actuate all of the pressure responsive valve means is introduced then into second annular space 11 through valve controlled pipe 16. At this point each of the pressure responsive valve means will open permitting reservoir liquids within second annular space 11 to pass therethrough into first annular space 8, and second tubing string 10. When the interface between the reservoir liquid and the fluid in second annular space 11 reaches the uppermost pair of pressure responsive valve means 13 fluid will pass therethrough into first annular space 8 and second tubing string 10 to thereby lift to the well surface reservoir fluids contained therein above the uppermost pair of pressure responsive valve means 13. The passage of gas through the uppermost pressure responsive valve means 13 will result in a decrease in the fluid pressure in second annular space 11, as described hereinbefore, to the pressure at which this pair of valve means has been adjusted to close. This reduced fluid pressure will be maintained until the interface between the reservoir liquid and the fluid reaches the next succeeding pair of pressure responsive valve means 14 which has been adjusted by means of adjustment nut 48, as described hereinbefore, to close at a pressure less than that at which the uppermost pair of pressure responsive valve means 13 closes. When the interface has reached this point, fluid will pass through the pair of valve means 14 into first annular space 8 and second tubing string 11, lifting the reservoir liquid therein above the pair of valve means 14 to the well surface and resulting in a decrease in the fluid pressure in second annular space 11 to the closing pressure of valve means 14. This action will be continued until the lowermost pair of pressure responsive valve means has been actuated and the reservoir liquids thereabove in first annular space 8 and second tubing string 10 have been raised to the well surface, at which time the introduction of fluid into second annular space 11 through valve controlled pipe 16 is interrupted. The introduction of fluid into second annular space 11 may be accomplished either manually or automatically by the time control mechanism, for example. The fluid is supplied to second annular space 11 until reservoir liquid in first annular space 8 and second tubing string 10 above the lowermost pressure responsive valve means 15 has been reached to the well surface, at which time the supply is interrupted. Sufficient time is allowed for the reservoir liquids to reach their normal standing level in the well before the fluid is again injected into second annular space 11 to once again actuate the liquid level control valves and lift to the well surface liquid standing in the well above the valves.

If the liquid in tubing string 10 and the liquid in first annular space 8 are not maintained at substantially the same level, only those pressure responsive valve means which are associated with the liquid at the lower level will operate to lift liquid to the well surface. Thus, for example, if the liquid in tubing string 10 normally stands at a level above the uppermost pressure responsive valve means 13, and the liquid in first annular space 8 stands normally at a level between valve means 14 and 15, when fluid under pressure sufficient to actuate all of the pressure responsive valve means is introduced into second annular space 11, the pressure of the fluid will decrease rapidly to a point below the closing pressure of pressure responsive valve means 14, which pressure is below the closing pressure of valve means

13, due to the passage of the fluid through the pressure responsive valve means 14 disposed in first tubing string 7 and into the first annular space 8. Although, obviously, valve means 13 and 14 will close almost immediately, the fluid pressure in second annular space 11 will be sufficient to maintain the lowermost pair of valve means 15 open, and, therefore, the fluid will pass through the one of the pair of valve means 15 which is disposed in first tubing string 7 to lift the liquid standing in first annular space 8 above the valve means to the well surface. However, due to the hydrostatic head of the liquid in second tubing string 10 above the lowermost valve means 15, the fluid pressure will be insufficient to lift such liquid to the well surface.

In view of the above, it is necessary to maintain at all times the reservoir liquids in first annular space 8 and second tubing string 10 at substantially the same level. This is accomplished, as pointed out hereinbefore, by suitably disposing liquid level control valve means 19 in second tubing string 10.

Operation of the embodiment of the invention shown in Figure 2 is similar to that of the system shown in Figure 1, with the exception that intermitter 20 is not actuated by the fluid pressure, but instead by the periodic lowering of weight 21 against cap 22 of the intermitter, as described above. The raising and lowering mechanism 23 located at the earth's surface 1 is adjusted in a manner so that intermitter 20 is caused to operate after each unloading of liquid in first annular space 8 by operation of the associated pressure responsive valve means. In this embodiment liquid level control valve means 19 functions to maintain the liquid in second tubing string 10 at a level such that the pressure of the fluid in second annular space 11 is sufficient to cause the liquid in tubing string 10 above intermitter 20 to be lifted to the earth's surface. If the liquid entering tubing string 10 is permitted to rise without control the hydrostatic head of the liquid above the intermitter in many instances would be so great as to prevent the unloading of the liquid by fluid passing through the intermitter from second annular space 11.

The fluid introduced periodically into second annular space 11 for lifting the reservoir liquid to the earth's surface may be any suitable, available gaseous medium; however, it is preferable to employ normally gaseous hydrocarbon mixtures obtained, for example, from nearby gas wells.

I claim:

1. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of intermitter control valves operatively secured to each of the tubing strings for controlling admission of lifting fluid under pressure into the first annular space and the second tubing string, and liquid level control valve means connected in one of said tubing strings for controlling the normal level of production therein.

2. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of pairs of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals respectively in the walls of the first and the second tubing strings for controlling admission of lifting fluid under pressure into the first annular space and second tubing string, and liquid level control valve means connected in said second tubing string for controlling the normal level of production therein.

3. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of pairs of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals respectively in the walls of the first and the second tubing strings for controlling admission of lifting fluid under pressure into the first annular space and second tubing string, means for periodically admitting lifting fluid into the second annular space at a pressure sufficient to actuate the intermitter control valves, and liquid level control valve means connected in said second tubing string for controlling the normal level of production therein.

4. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of pairs of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals respectively in the walls of the first and the second tubing strings for controlling admission of lifting fluid under pressure into the first annular space and second tubing string, means for periodically admitting lifting fluid into the second annular space at a pressure sufficient to actuate the intermitter control valves, and liquid level control valve means connected in the second tubing string for maintaining normally well liquid in the second tubing

string at the same level as well liquid in the first annular space.

5. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of pairs of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals respectively in the walls of the first and the second tubing strings for controlling admission of lifting fluid under pressure into the first annular space and second tubing string, means for periodically admitting lifting fluid into the second annular space at a pressure sufficient to actuate the intermitter control valves, and liquid level control valve means connected in the second tubing string for maintaining normally well liquid in the second tubing string at the same level as well liquid in the first annular space, the pairs of intermitter control valves being responsive to progressively decreasing pressures from the uppermost pair of intermitter control valves to the lowermost pair of intermitter control valves whereby fluid from the second annular space will be admitted substantially simultaneously through the uppermost pair of intermitter control valves into the first annular space and second tubing string and will lift the well liquid therein above the levels of the respective uppermost pair of intermitter control valves to the earth's surface and progressively will be admitted through succeeding pairs of intermitter control valves to lift the well liquid thereabove to the earth's surface until the well liquids in the first annular space and the second tubing string above the lowermost pair of intermitter control valves have been lifted to the earth's surface.

6. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals in the wall of the first tubing string for controlling admission of lifting fluid under pressure into the first annular space, a mechanically operated intermitter control valve positioned within the second tubing string for controlling admission of lifting fluid under pressure into the second tubing string, and liquid level control valve means connected in the second tubing string for controlling the normal level of well liquid therein.

7. In a well producing from a plurality of oil

reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular spaces whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals in the wall of the first tubing string for controlling admission of lifting fluid under pressure into the first annular space, a mechanically operated intermitter control valve positioned within the second tubing string for controlling admission of lifting fluid under pressure into the second tubing string, means operable from the earth's surface to periodically actuate the mechanically operated intermitter control valve, and liquid level control valve means connected in the second tubing string for controlling the normal level of well liquid therein.

8. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular space whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals in the wall of the first tubing string for controlling admission of lifting fluid under pressure into the first annular space, means for periodically admitting fluid into the second annular space at a pressure sufficient to actuate the intermitter control valves, a mechanically operated intermitter control valve positioned within the second tubing string for controlling admission of lifting fluid under pressure into the second tubing string, means operable from the earth's surface to periodically actuate the mechanically operated intermitter control valve, and liquid level control valve means connected in the second tubing string

for controlling the normal level of well liquid therein.

9. In a well producing from a plurality of oil reservoirs including a well casing communicating with each of the reservoirs, a first tubing string disposed in the casing in a manner to provide a first annular space therebetween, a second tubing string disposed in the first tubing string in a manner to provide a second annular space therebetween, and packing means provided in the first and the second annular space whereby production from one of the reservoirs is directed into the first annular space and production from another of the reservoirs is directed into the interior of the second tubing string, the combination therewith of intermitter control valves responsive to lifting fluid pressure within the second annular space and provided at vertically spaced intervals in the wall of the first tubing string for controlling admission of lifting fluid under pressure into the first annular space, means for periodically admitting fluid into the second annular space at a pressure sufficient to actuate the intermitter control valves, a mechanically operated intermitter control valve positioned within the second tubing string for controlling admission of lifting fluid under pressure into the second tubing string, means operable from the earth's surface to periodically actuate the mechanically operated intermitter control valve, and liquid level control valve means connected in the second tubing string for controlling the normal level of well liquid therein, the intermitter control valves being responsive to progressively decreasing pressures from the uppermost intermitter control valve to the lowermost intermitter control valve whereby the fluid will be admitted through the uppermost intermitter control valve to the first annular space and will lift the well liquid therein above the level of the intermitter control valve to the earth's surface and progressively will be admitted through succeeding intermitter control valves to the first annular space and will lift the well liquid thereabove to the earth's surface until the well liquid in the first annular space above the lowermost intermitter control valve has been lifted to the earth's surface.

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