

Dec. 24, 1963

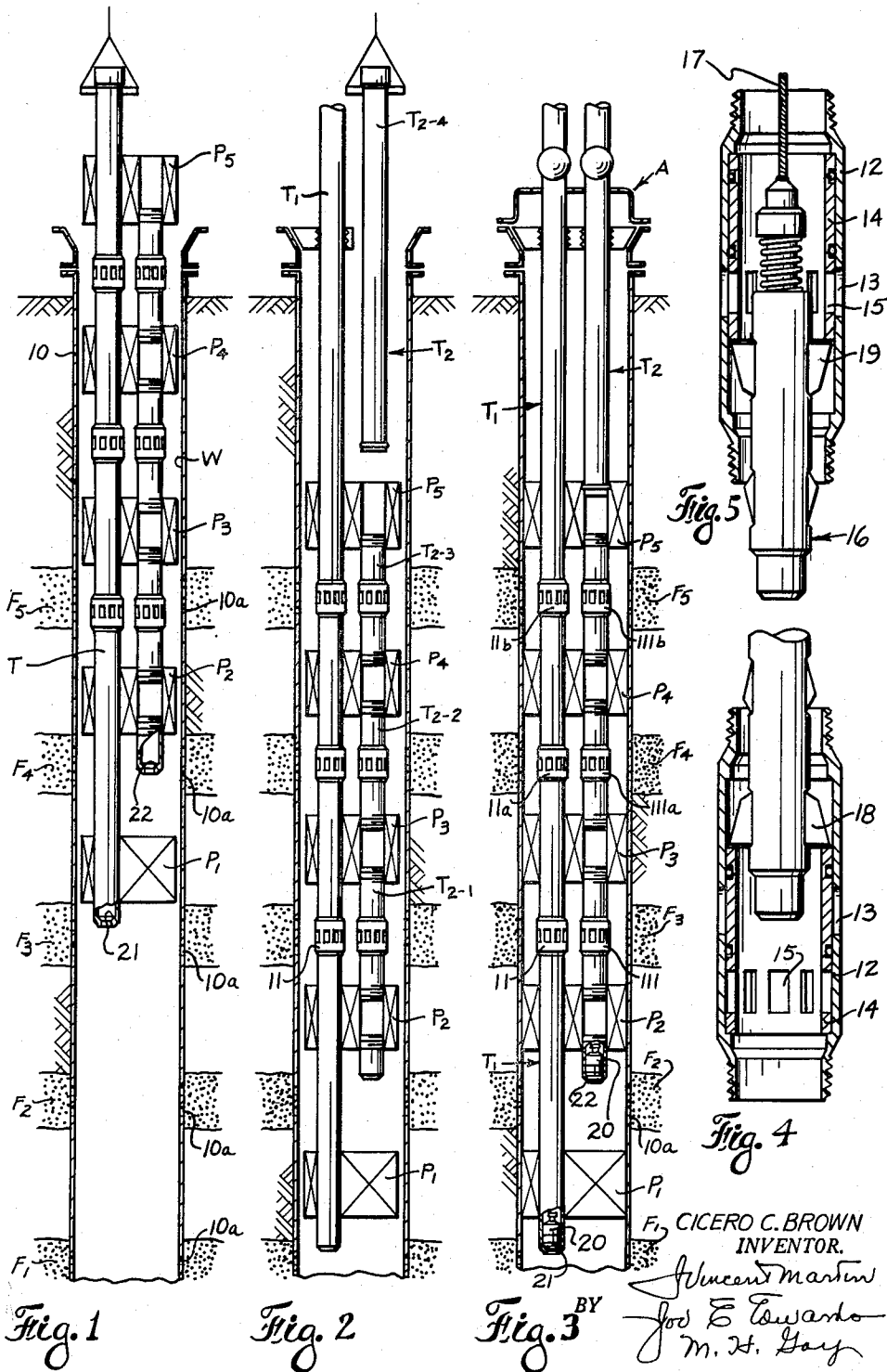
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3,115,187

METHODS OF AND APPARATUS FOR SELECTIVELY PRODUCING FLUIDS
FROM A PLURALITY OF SUBSURFACE FLUID ZONES

Filed April 27, 1959

2 Sheets-Sheet 1



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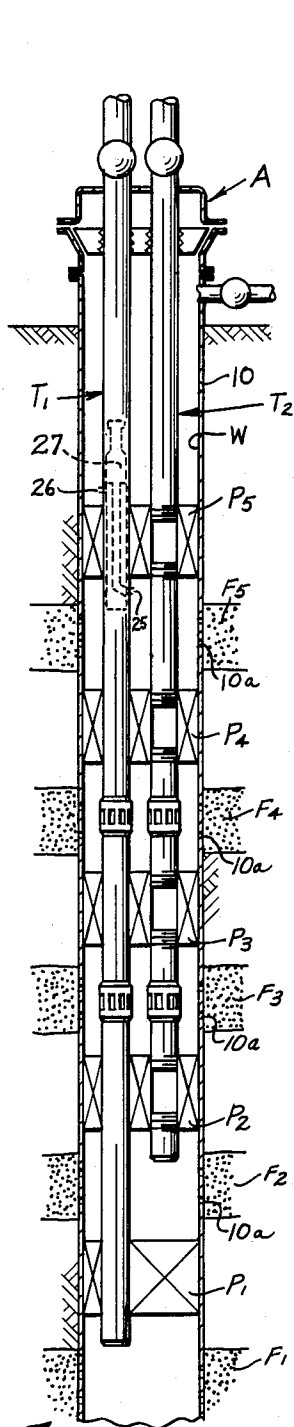


Fig. 6

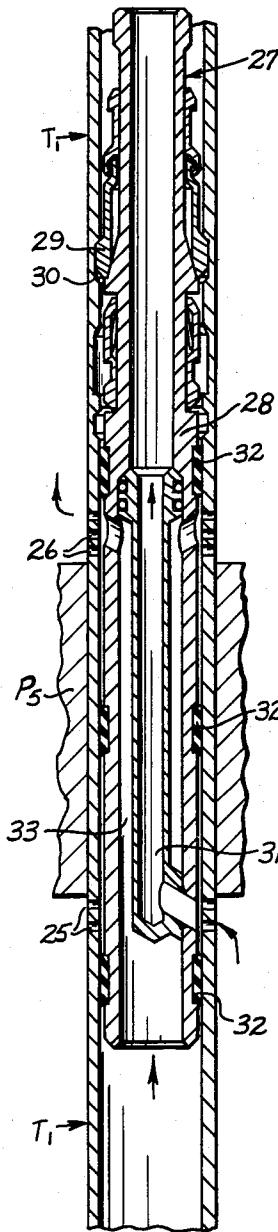


Fig. 7

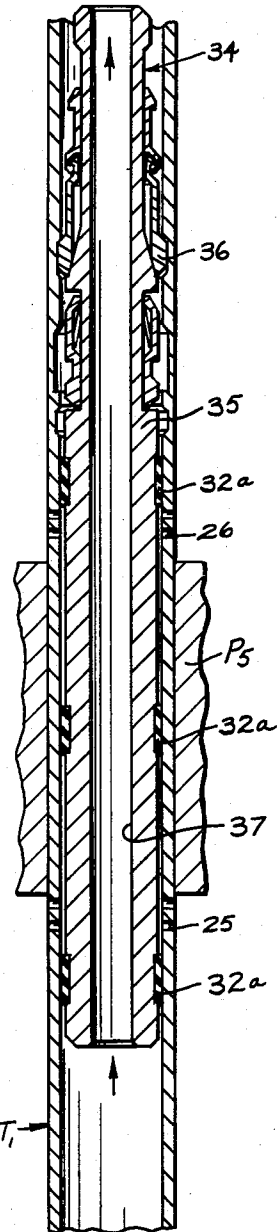


Fig. 8

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METHODS OF AND APPARATUS FOR SELECTIVELY PRODUCING FLUIDS FROM A PLURALITY OF SUBSURFACE FLUID ZONES

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This invention relates to new and useful improvements in methods of and apparatus for selectively producing fluids from a plurality of subsurface fluid zones.

It is not unusual for a well bore to traverse a plurality of well fluid producing formations or zones, and in recent years multiple zone production methods and apparatus have come into general use to permit the fluid production from each zone to be produced without commingling with the production from the other zones. The usual multiple zone production apparatus has ordinarily involved the use of spaced packers for separating the zones and an independent tubing string for conducting the flow from each zone. If the bore traverses two zones, two tubing strings have been provided and similarly three zones have required three strings, four zones have required four strings and so on. However, it is readily apparent that costs limit the number of independent strings which can be economically employed and further the physical size of the well bore is a restricting factor as to how many separate tubing strings can be actually disposed therein.

Furthermore, where a well bore traverses a plurality of zones, as for example, four, five or six in number, it is unlikely that all of the zones are equal in productivity; as a matter of fact, it is more usual that one, two or possibly more are relatively weak zones and would not of themselves justify the cost and expense of running a separate tubing string to communicate with such weaker zone. For this reason, it has been the practice to shut off, by cementing, the less productive zones and to complete the well without reference to said lesser productive zone or zones.

It is one object of this invention to provide an improved method and apparatus which will permit the selective production of well fluids from any number of producing formations traversed by a single well bore without the necessity of employing a separate or independent tubing string for each producing zone. This invention constitutes an improvement upon the invention disclosed in my co-pending application Serial No. 729,172, filed April 17, 1958, now Patent No. 3,059,699.

An important object is to provide an improved method which involves disposing at least dual tubing strings and the required number of packers for separating the producing zones, within the well bore, landing said strings and packers in final position before setting the packers, then subsequently setting said packers, and finally selectively establishing communication between each tubing string and one of the producing zones, whereby each tubing conducts fluids from one of the zones to the surface; the method permitting the initially selected zones to be produced and further permitting a change to be made at any time to shut off flow from the initially selected zones and allow flow from other zones into said strings.

Another object is to provide an improved well apparatus having at least a pair of tubing strings provided with the required number of well packers to separate a plurality of producing zones traversed by a well bore, together with valve means mounted in each string between each packer and manipulatable from the surface to selectively establish communication between each tubing string and one of the producing zones.

A further object is to provide an apparatus, of the character described, wherein the valve means which con-

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trols communication between each tubing string and the producing zones is operated by wire line or cable lowered within said tubing, whereby the selective opening and closing of said valve means does not disturb the well packers which are in set position.

Still another object is to provide an apparatus, of the character described, having a pair of tubing strings for separately producing from two of the zones traversed by the well bore but which lends itself to conversion to a triple production apparatus, in which event the well casing in which the apparatus is disposed functions as the third production string.

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

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

FIGURE 1 is a schematic view illustrating the first tubing string, the well packers and associate parts being lowered into the well bore;

FIGURE 2 is a similar view showing the packers and first string in position and illustrating the second tubing string being lowered;

FIGURE 3 is a similar view with both tubing strings and all well packers in final position with the packers set and showing the valves located in accordance with the present invention between the well packers;

FIGURE 4 is a vertical sectional view of one of the valves and also showing the sleeve shifting tool which shifts the valve in a downward direction;

FIGURE 5 is a view similar to FIGURE 4 but showing the sleeve shifting tool which shifts the valve in an upward direction;

FIGURE 6 is a view similar to FIGURE 3 and illustrating a cross-over unit which is shown in dotted lines, within the first tubing string, whereby the casing annulus may be employed as a flow conductor;

FIGURE 7 is a transverse sectional view showing the cross-over device in more detail, and

FIGURE 8 is a transverse sectional view of a closure unit which closes the bypass openings which co-act with a cross-over unit.

In the drawings the letter W designates a well bore which traverses a plurality of fluid producing zones. The usual well casing 10 extends throughout the length of the bore and is suitably perforated at 10a opposite each of the producing zones whereby fluid from said zones may flow into the casing. Five producing zones or formations F1, F2, F3, F4 and F5 are illustrated but, of course, the number of formations traversed by any particular well bore is dependent upon the particular subsurface conditions. The producing zones are spaced from each other and it is desirable that production from each zone be independent of the other zones. It is also desirable to selectively produce from the zones because one formation may be stronger than another or its production life may be longer or shorter than other zones. The present invention has to do with selectively producing from the various production zones through a minimum number of tubing strings.

In carrying out the present invention, a first tubing string T has a plurality of packers mounted thereon. The number of packers will, of course, depend upon the number of producing zones to be separated and in the present instance five such packers are shown. The packers are designated P1, P2, P3, P4 and P5 and are properly spaced on the first tubing string T whereby when in final position, said packers will be disposed between the producing formations or zones. The first tubing string, together with the

packers thereon, is lowered to the position shown in FIGURE 2 which properly locates the packers.

For the sake of convenience the lower portion of the second tubing string T2 is made in sections which connect the packers (FIGURES 1 and 2). The section T2-1 connects packers P2 and P3 while section T2-2 connects packers P3 and P4 and the additional section T2-3 connects packers P4 and P5. The upper section T2-4 of the second tubing string comprises the main part of the second tubing string T2 and is adapted to be independently handled and run separately which facilitates locating both tubing strings in position within the well bore.

The packers P1 to P5 are preferably hydraulically actuated packers of the type shown in my co-pending application Serial Number 525,585, filed August 1, 1955, now Patent No. 2,903,066. With this type of packer, both tubing strings and the packers may be located in final position with the well head equipment A in place prior to the time that the packers are set. This makes it possible to circulate through and around the packers and perform any other operation within the well bore prior to moving the packers into set position.

Following setting of the packers as shown in FIGURE 3, said packers function to separate the fluid production of the various formations F1 through F5 from each other. The lower end of the first tubing string T1 communicates with the area below the lowermost packer P1 and, therefore, communicates with the lowermost producing zone or formation F1. The lower end of the second tubing string T2 communicates with the producing zone or formation F2 which is between packers P1 and P2. Normally where dual strings are used, each string conducts the flow from one formation to the surface and thus where only two tubing strings are employed, it has heretofore been possible to produce only two zones. When one of said zones becomes depleted, then the dual installation, in effect, becomes a single producing well.

In order to make possible the production of several formations on a selective basis, a plurality of control valves are mounted in the tubing strings. Control valve 11 is connected in tubing string T1 in that portion of the tubing between packers P2 and P3. A similar valve 111 is connected in that section of the second string T2 between the same packers. Similarly, valves 11a and 111a are located between packers P3 and P4 and communicate with formation F4; additional valves 11b and 111b are disposed between packers P4 and P5 and communicate with formation F5. As will be explained, the valves are operable from the surface and may be selectively opened and closed to establish communication between each tubing string and the desired formation.

Although the structure of the valves 11 to 11b and 111 to 111b is subject to variation, one type of valve, which has been found particularly adaptable for the present purpose, is illustrated in FIGURES 4 and 5. This valve includes an outer body 12 having radial inlet openings 13. A sleeve member 14 having radial slots or openings 15 is slidable axially within the body or housing. When the valve member is in lowered position (FIGURE 4), the openings 13 and 15 are out of registration and the valve is closed. Shifting of the valve to a raised position (FIGURE 5) moves openings 13 and 15 into registration whereby the valve is open and a flow into the tubing string may occur.

Each valve is adapted to be actuated by a sleeve shifting tool 16 which is lowerable through the tubing string on a wire line or cable 17. The particular shifting tool forms no part of the present invention and may be one such as is available on the open market and manufactured by the Garrett Oil Tools Company of Longview, Texas. The shifting tool has downwardly facing dogs 18 which engage the upper end of the sleeve 14 so that a downward jar will shift the sleeve to a lowered position. The tool is also provided with upwardly facing dogs 19 which are adapted to engage the lower end of the sleeve to move the same up-

wardly. The particular valve shifting tool and its operation are illustrated in my prior co-pending application Serial No. 729,172, filed April 17, 1958.

The tubing strings T1 and T2 are lowered into the well bore in the manner heretofore described and as shown in FIGURES 1 to 3. The valves 11 to 11b and 111 to 111b are in a closed position. As has been noted, the lower ends of the strings T1 and T2 are normally open so that after the packers have been moved to set position (FIGURE 3), production from the zones or formations F1 and F2 may occur.

So long as zones F1 and F2 are producing, the various valves in the strings T1 and T2 remain in closed position. However, assuming that formation F1 becomes depleted and normal flow stops, then it is desirable to produce one of the other zones F3, F4 or F5 through the first string T1. In such event a suitable closure or plug 20 (FIGURE 3) is pumped downwardly through the string T1 and engages a seat 21 provided at the lower end of the string. This closes downward flow of fluid through the string T1.

Thereafter, the sleeve shifting tool 16 having the upwardly facing dogs 19 is lowered downwardly and, assuming that flow from formation F3 is to be directed into tubing T1, the shifting tool is engaged with the valve member 14 of valve 11. Upon an upward pull after the dogs 19 have engaged the lower end of the sleeve 14, said sleeve is shifted upwardly to move ports 13 and 15 into registration and thereby establish communication between formation F3 and tubing T1. The valve shifting tool 16 is so constructed that after the sleeve 14 has moved to its upper position, the dogs 19 are retracted to permit removal of the tool. Thereafter, production from zone F3 is through the first tubing string T1. It is, of course, obvious that if desired either valve 11a or 11b could be actuated to establish communication between formations F4 or F5 as the case may be, instead of producing from formation F3.

If the formation F2 with which the second tubing string T2 communicates is depleted first, then the plug 20 is pumped downwardly through tubing T2 and engages a seat 22 provided at the lower end of said tubing. Thereafter, the sleeve shifting tool 16 is utilized to open one of the valves 111, 111a or 111b to establish communication with the second tubing string T2. Thus the operator has a choice and may select the particular formation which is to be produced after the initial formation becomes depleted. The invention contemplates the selective opening and closing of the various valves and actually one formation may be produced for a length of time after which its valve may be closed and another valve opened. This renders the apparatus extremely versatile and allows selective production from a great many zones with only two tubing strings. Although it is desirable to use a minimum number of tubing strings, conditions may sometimes warrant the use of three strings of tubing with a plurality of packers. In such case, the valves would be located between the packers in all three strings so that selective production from any particular zone to any particular string may be accomplished.

The usual manner of producing from three zones or formations simultaneously involves the use of three tubing strings. However, under certain conditions it is possible to quickly convert the present apparatus from a dual production arrangement to triple production apparatus. This can be accomplished by utilizing the upper portion of the well casing 10, which is above the upper packer P5 as a flow conductor and such a modification is illustrated in FIGURES 6 to 8. In this modification a plurality of ports 25 are formed in the tubing string T1 at a point below the upper packer P5. Similar ports 26 are also formed in the string T1 and are located above said packer. The ports 25 establish communication with the area between packers P4 and P5 whereby flow from this area may enter the tubing T1; similarly ports 26 establish

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communication between the tubing string and the annulus which is, of course, the casing 10.

In order to utilize the upper portion of the casing as a third flow conductor, a removable cross-over assembly 27 is arranged to be lowered and removably latched within the tubing is illustrated in FIGURE 7. This assembly includes a main body 28 having well known latches 29 engageable within an annular recess 30 provided in the string T1. When the body is in position, an elongate passage 31 has its lower end communicating with the ports 25 in the tubing string while its upper end is in communication with the bore of the string above the body. Suitable packing elements 32 seal off between the body and the bore of the tubing so that flow from the area below packer P5 enters passage 31 and is directed upwardly through the tubing T1. A second passage 33 in the body conducts flow from the bore of the tubing T1 below the body and upwardly to the ports 26 whereby this fluid is conducted upwardly through the casing 10. Thus, by disposing the cross-over assembly 27 within the tubing T1 to coact with the ports 25 and 26, a third passage or conductor for well fluids to the surface is obtained.

If the cross-over arrangement is not desired, the assembly 27 is removed and a closure unit 34 shown in FIGURE 8 is substituted therefor. This unit includes a body 35 having latch members 36 engageable in the recess 30 to latch said unit in position. Suitable sealing rings 32a, which properly seal off the ports 25 and 26, are mounted on the exterior of the body. The body is formed with an axial bore 37 so that upward flow through the tubing T1 occurs through the unit 34 and then passes upwardly through said string. With the closure unit in place, ports 25 and 26 are closed and normal upward flow through the tubing may take place.

In both forms of the apparatus, selective production from a plurality of zones is possible. Any two zones may be produced through the two tubing strings merely by manipulating the proper valve or valves. At any time that a formation becomes depleted, it is only necessary to open one of the valves communicating with another formation and production can continue. Although it is ordinarily not desirable to commingle fluids from two different zones, conditions might occur which would allow such commingling and in such instance, by proper manipulation of the valves, the fluids from more than one zone can be conducted to the surface through a single tubing string.

By employing the packers, such as hydraulically-actuated packers, which may be set without any longitudinal movement of the tubing strings, the tubing strings may be landed in final position, the well head equipment A may be connected after which any washing or circulating operation may be carried out before the packers are moved into final set position. The use of the sleeve type valves, which are shiftable by means of a wire line tool, provides for selective control of the valves while maintaining the well under full control.

The foregoing disclosure and description of the invention is illustrative and 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 I claim is:

1. An apparatus for selectively producing fluids from a plurality of fluid producing zones including, a pair of parallel tubing strings extending downwardly within the well bore, a plurality of well packers on said strings and positioned between the producing zones when the tubing strings are in the well bore, whereby setting of the well packers separates said producing zones, non-removable valve means mounted in each tubing string located between the packers for controlling communication between each tubing string and each producing

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zone, and means controlled from the surface for actuating the valve means to selectively communicate each tubing string with a desired fluid producing zone.

2. An apparatus for selectively producing fluids from a plurality of fluid producing zones including, a pair of parallel tubing strings extending downwardly within the well bore, a plurality of well packers on said strings and positioned between the producing zones when the tubing strings are in the well bore, whereby setting of the well packers separates said producing zones, each tubing string having openings therein which are disposed between the well packers, each opening communicating with one of the producing zones which is sealed off by the packers above and below such opening, and non-removable valve means mounted within the tubing string associated with each opening whereby flow through said openings may be selectively controlled by the actuation of said valve means.

3. An apparatus as set forth in claim 2, together with an actuator for the valve means lowerable on a wire line within said tubing strings, whereby the operation of said valve means is controlled from the surface of the well.

4. A well apparatus including, a first tubing string, a second tubing string, a plurality of well packers mounted on said strings in spaced relationship and adapted to separate various producing zones traversed by a well bore, the first tubing string having its lower end communicating with the lowermost zone below the lowermost packer, said first string also having radial openings therein with each radial opening being located between the packers so that each opening is in communication with one of the producing zones, non-removable valve means mounted in said first tubing string and associated with each opening for controlling flow there-through, said second string having its lower end in communication with the zone immediately above the lowermost packer and also having radial openings therein with each radial opening being located between the packers so that each opening is in communication with one of the other producing zones, and valve means associated with each of said last-named openings for controlling flow therethrough.

5. An apparatus as set forth in claim 4, together with valve-actuating means lowerable through each tubing string on a wire line for selectively opening and closing the valve means whereby each tubing string may be selectively communicated with a desired producing zone.

6. An apparatus as set forth in claim 4, wherein one of the tubing strings is formed with by-pass openings above and below the uppermost well packer to establish communication between the tubing string and the annulus above and below the packer, a closure means removably mounted with the tubing string to close said by-pass openings to direct flow upwardly through the tubing, and a cross-over unit adapted to be substituted for said closure and having fluid passage means to cross-over flow from the tubing to the annulus above the uppermost packer while at the same time directing flow from the annulus below said packer upwardly through the tubing.

7. An apparatus as set forth in claim 4, wherein one of the tubing strings is formed with by-pass openings above and below the uppermost well packer to establish communication between the tubing string and the annulus above and below the packer, a closure means removably mounted with the tubing string to close said by-pass openings to direct flow upwardly through the tubing, and a cross-over unit adapted to be substituted for said closure and having fluid passage means to cross-over flow from the tubing to the annulus above the uppermost packer while at the same time directing flow from the annulus below said packer upwardly through the tubing, said closure unit comprising an elongate

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tubular body of a length sufficient to span the distance between the by-pass openings and having sealing means for sealing between the exterior of the body and the bore of the tubing.

8. An apparatus as set forth in claim 4, wherein one of the tubing strings is formed with by-pass openings above and below the uppermost well packer to establish communication between the tubing string and the annulus above and below the packer, a closure means removably mounted with the tubing string to close said by-pass openings to direct flow upwardly through the tubing, and a cross-over unit adapted to be substituted for said closure and having fluid passage means to cross-over flow from the tubing to the annulus above the

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uppermost packer while at the same time directing flow from the annulus below said packer upwardly through the tubing, said closure and cross-over units being run in and removed from the tubing string by means of a wire line.

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