

[54] DUAL ZONE COMPLETION SYSTEM

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[58] Field of Search.....166/.5, .6, 313, 315, 153,
166/154, 155, 156

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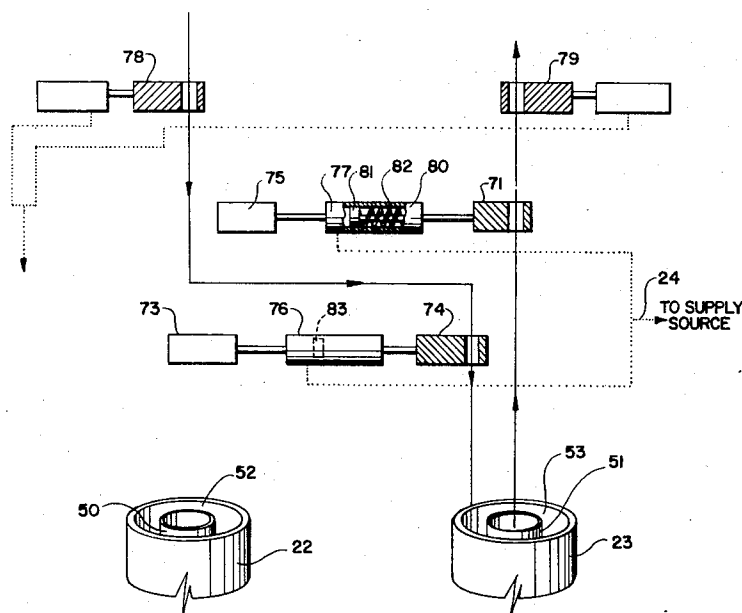
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[57] ABSTRACT

An arrangement is disclosed which makes it possible to (1) produce both zones of a dual completion well simultaneously or (2) permit either one of the two flowlines used in such production operation to be used as a service line for the other of said flowlines. In the disclosed arrangement, a tubing string is concentrically disposed within each of the production strings extending into the well. Valves selectively operable by means of a single control line are associated with the strings to alter the fluid flow path with respect to the strings and the flowlines to permit through-the-flowline operations to be carried out separately with respect to each zone or, alternatively, to allow production from both zones without commingling of the production fluid.

8 Claims, 6 Drawing Figures



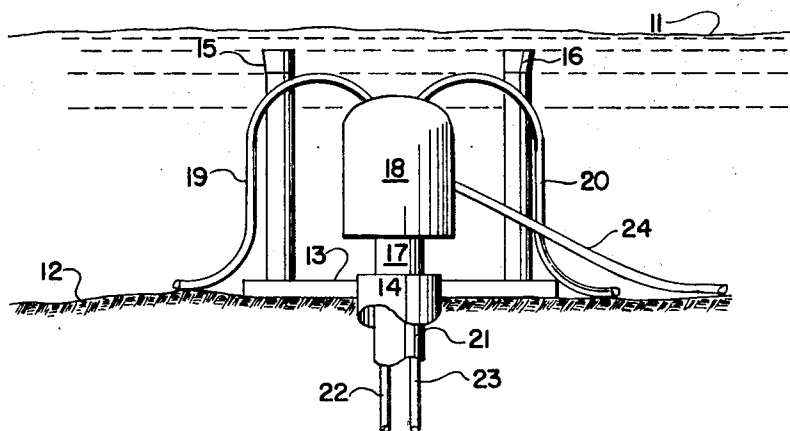


FIG. 1

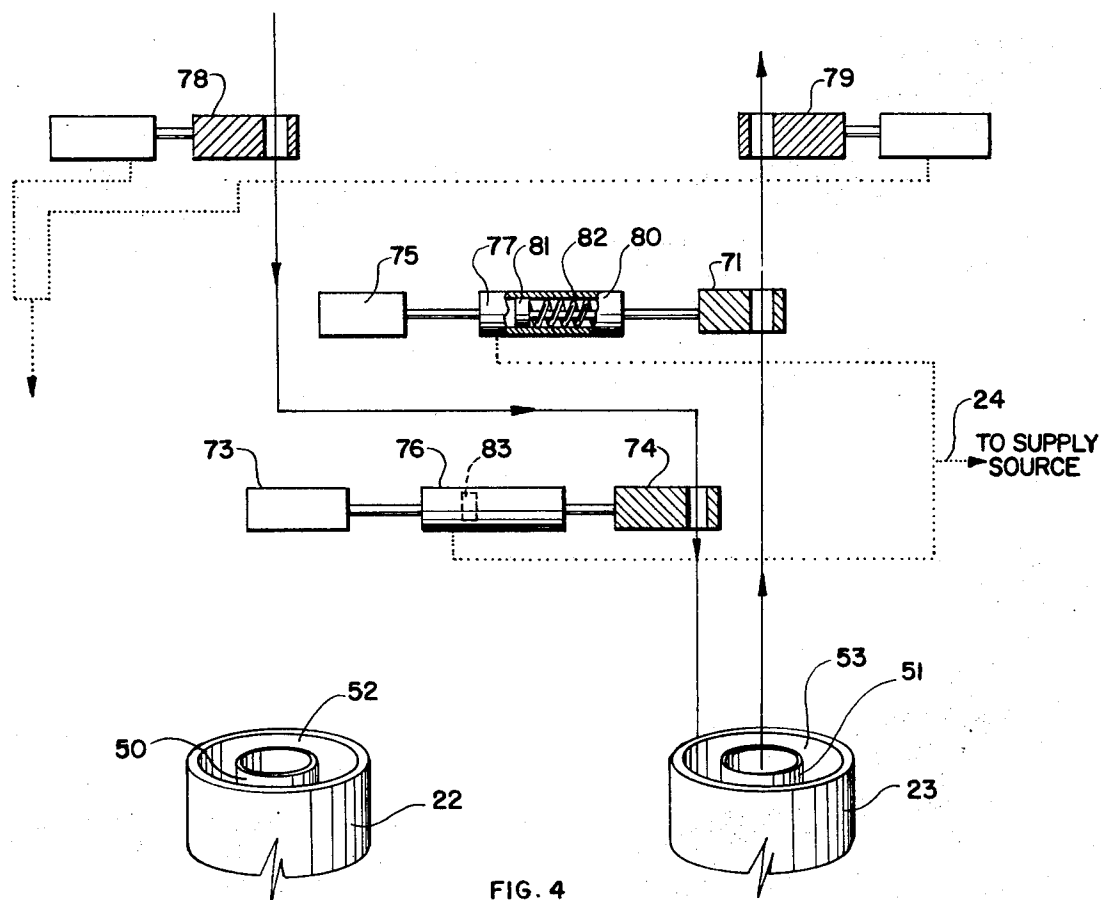


FIG. 4

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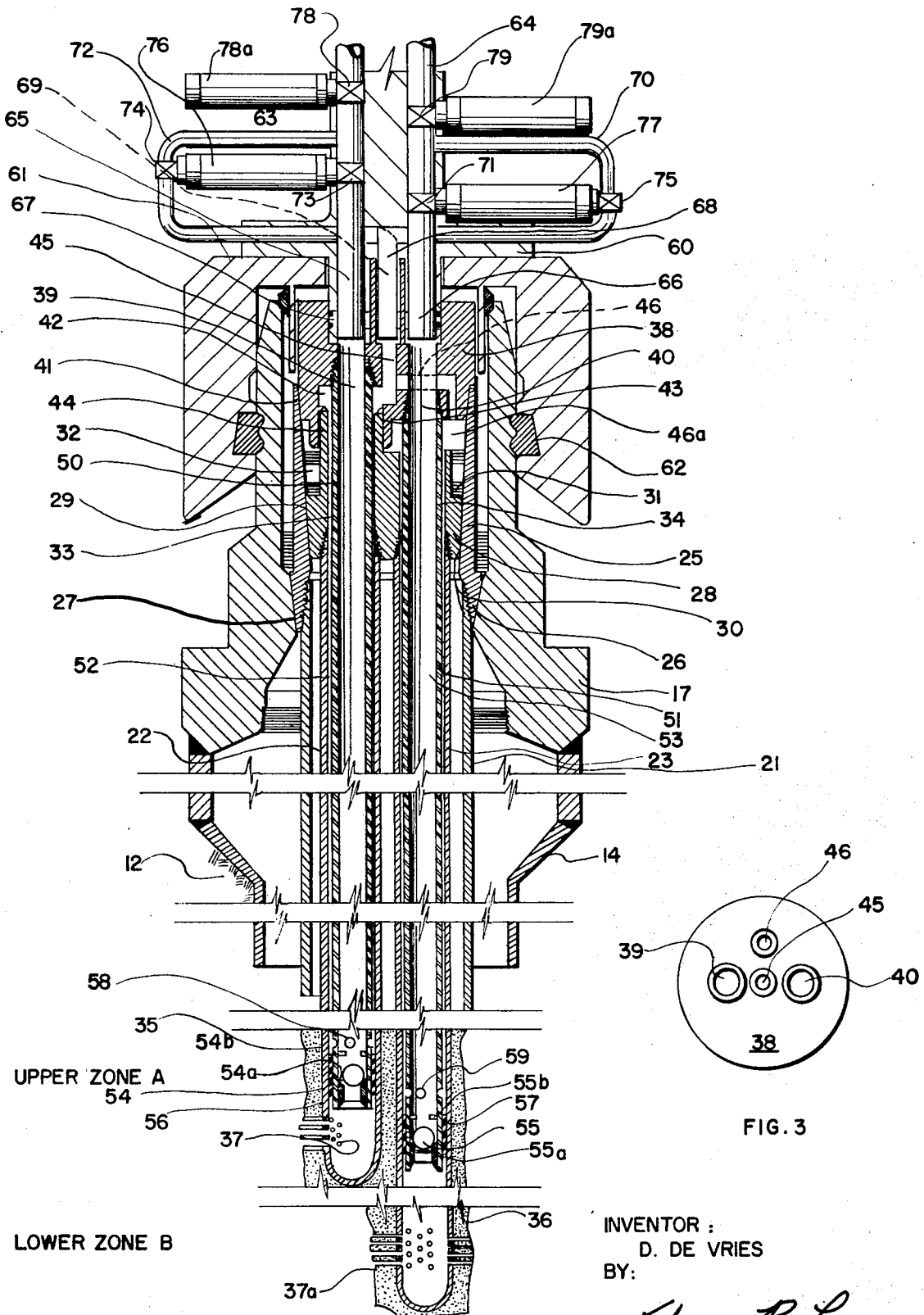


FIG. 2

FIG. 3

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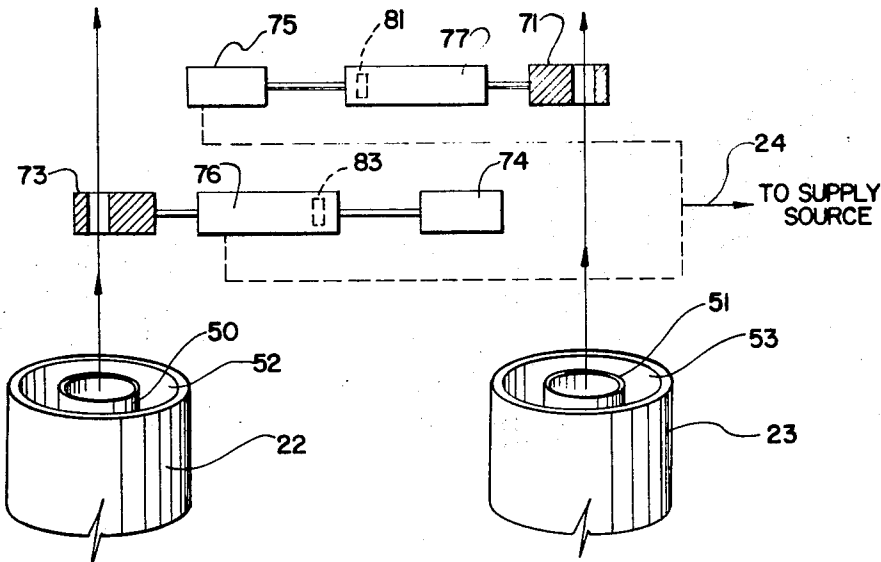


FIG. 5

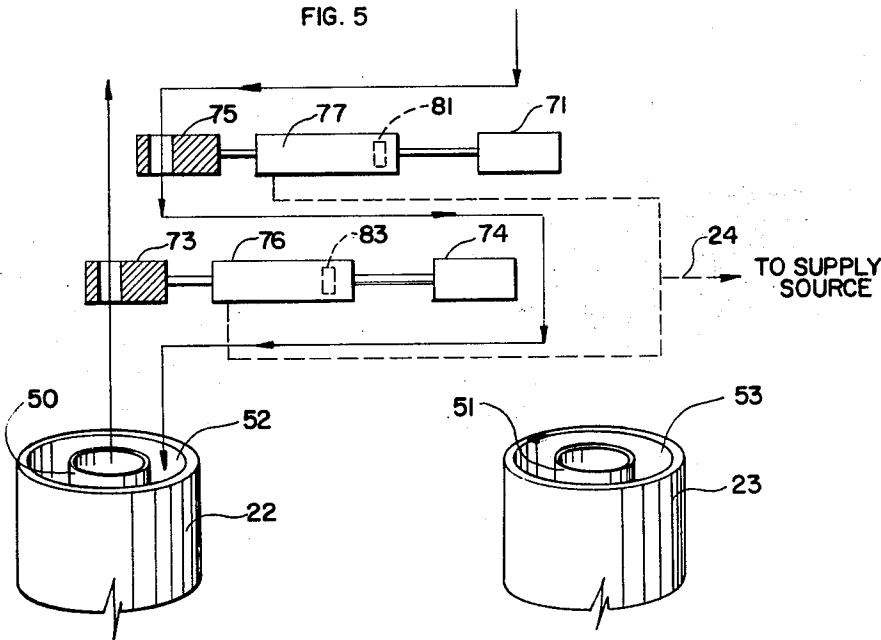


FIG. 6

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DUAL ZONE COMPLETION SYSTEM

This invention relates to the completion of wells having two spaced-apart distinct producing zones or formations and pertains more particularly to an arrangement making it possible to (1) produce both zones simultaneously without commingling the production and (2) permit either one of two flowlines provided in such production operation to be used as a service line for the other of said flowlines.

This invention is especially adapted for use in carrying out through-the-flowline operations with respect to underwater wells. Through-the-flowline operations refer to techniques wherein various well activities, such as workover and maintenance operations, are carried out by tools which pass through a flowline extending between some remote location, such as an onshore storage facility, and the underwater well installation. Such tools are normally moved within the flowline by pumping a driving fluid through the line. Operations representative of those which may be carried out through the use of such specially designed through-the-flowline tools are the opening of a packer, the removal or insertion of a choke or valve, the cleaning of paraffin from a tubing string, etc. After being pumped through the flowline from the remote location, which is often a mile or more from the well, the tool enters the well and passes down the production tubing string, therein to be subsequently positioned to perform the desired operation. After completing the operation, the tool is subsequently removed from the well and returned to the remote location, generally by reverse circulation of driving fluid through the flowline.

Through-the-flowline operations become more difficult in those situations wherein the tubing strings, through which the flowline tools must pass, extend into two fluid-producing zones rather than a single producing zone. Since the quality of the fluid produced in one zone may differ greatly from that produced in the other, it is desirable to keep the fluids from the two zones separate. In addition, some states have regulations which forbid the commingling of fluids from separate producing zones.

While dual completion systems permitting through-the-flowline work without commingling of fluids from the two zones have been devised in the past, such systems are characterized by the fact that they are often complex and expensive. In addition, such prior art systems routinely require lengthy well "down times" to actuate the required control arrangements associated therewith.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved dual completion system wherein two production zones may be produced simultaneously without commingling the production fluids therefrom, and wherein either one of two flowlines utilized in such production may be selectively used as a service line for through-the-flowline operations with respect to the other of said flowlines upon actuation of a suitable valving arrangement.

This and other objects have been attained in the present invention by providing a dual zone completion system including a production string extending into each zone. A tubing string is concentrically disposed within each production string to define an annular

space therebetween. A valve arrangement comprising a plurality of valves, all of which are selectively operable by means of a single control line, allow a fluid flow path to be established between the production flowline associated with one zone and the annular space and production string associated with the other zone whereby through-the-flowline operations may be carried out with respect to said other zone. Alternatively, the valves may be positioned to permit production from both zones.

Other objects, purposes, and characteristic features of the present invention will be obvious from the accompanying drawings and from the following description of the invention.

DESCRIPTION OF THE DRAWING

In describing the invention in detail, reference will be made to the accompanying drawings in which like reference characters designate corresponding parts throughout the several views, and in which:

FIG. 1 is a schematic view in partial longitudinal section illustrating a wellhead assembly positioned on the ocean floor;

FIG. 2 is a diagrammatic view taken in longitudinal cross-section illustrating elements of the dual completion system according to the present invention in operative association with a production casing string and wellhead assembly;

FIG. 3 is a plan view in reduced scale of one element of the dual completion system shown in FIG. 2; and

FIGS. 4, 5 and 6 are schematic presentations illustrating fluid flow directions in response to the setting or placement of the valve structures associated with the present invention.

Referring to FIG. 1 of the drawings, a wellhead assembly is shown as positioned below the surface 11 of a body of water and preferably on the earth 12 underlying said body of water. The wellhead apparatus comprises a platform 13 secured to the top of a conductor pipe or surface casing 14 which in turn extends into the earth 12 and is preferably cemented therein in a conventional manner. The wellhead assembly may also be provided with two or more vertically-positioned guide columns 15 and 16 which are fixedly secured at their lower ends to the platform 13. A well casing head 17 is mounted on the top of conductor pipe 14 with a control equipment housing 18 closing the top of the casinghead and/or any casing and tubing suspension equipment employed on the wellhead assembly, as well as the various control valves and other equipment normally used on the top of a well of this type.

Emerging from the housing 18 are two flowlines 19 and 20 which preferably bend in long sweeping curves from a vertical position down to a substantially horizontal position so that they can run along the ocean floor 12 to a remote location where fluid from the well, and normally from other wells, is collected and metered and treated. Such a collection station may be several miles away from the various wells associated therewith. The well may be provided with one or more strings of well casing 21 suspended within the conductor pipe 14. The flowlines 19 and 20, respectively, are in fluid communication with two production strings 22 and 23 which depend within the well in the manner illustrated. Also emerging from housing 18 and extend-

ing to a suitable power source (not shown) is a hydraulic line 24, the purpose of which will be more fully brought out below.

Referring now to FIG. 2, a cylindrical casing head member or casing hanger 25 having a bevelled lower portion or landing surface 26 is seated within well casing head 17. In such position, the bevelled lower portion 26 of member 25 is in seating engagement with a cooperating inwardly-extending shoulder member or landing surface 27 of casing head 17 thereby preventing member 25 from moving downwardly with respect to casing head 17. Casing string 21 is threadedly engaged or otherwise secured to member 25 and extends into the well in the usual manner. Surface casing or conductor pipe 14 is welded or otherwise fixedly secured to casing head 17, as shown. As previously stated, surface casing 14 is preferably cemented in the earth 12 below body of water 11 (FIG. 1).

A dual tubing hanger or manifold means 28 is seated within cylindrical casing head member 25, as shown in FIG. 2, with sloping wall 29 of hanger 28 cooperating with inwardly projecting shoulder 30 of casing head member 25 to maintain these elements in position. Preferably, dual tubing hanger 28 is provided with an upwardly facing annular cavity 31 into which seal 32 is seated, thereby providing a fluid-tight fit between said hanger 28 and said casing head member 25.

Dual tubing hanger 28 is provided with two spaced-apart vertical throughbores 33 and 34. The lower walls of hanger 28 defining said through-bores are threaded to receive and matingly engage cooperating threads on production strings 22 and 23. Production strings 22 and 23 are thus supported by hanger 28 so that the inner walls thereof are in alignment with the walls of hanger 28 which define throughbores 33 and 34. Production strings 22 and 23 depend within the well and terminate at their lower ends within an upper producing zone A and a lower producing zone B, respectively, within the well. At their lowermost ends, production strings 22 and 23 are shown as being cemented as at 35 and 36 and provided with a series of perforations 37 and 37a through the tubing string walls and the cement. These perforations permit fluid from the production zones A and B to enter into the interior of the production strings. It should be noted at this juncture that the fluid zones A and B are segregated one from the other to avoid any commingling of the production fluid. Although not illustrated, one or more packers may be utilized to accomplish this result in the well known manner.

Positioned above dual tubing hanger 28 is a second tubing hanger or manifold means 38 which includes two full-bore tubing runs 39 and 40. As with dual tubing hanger 28, hanger 38 includes a sloping wall 41 which seats upon inwardly projecting shoulder 30 of casing head member 25 to support the hanger in position. Tubing run 39 is bored out, as at 42, to form a full-opening production seal sub in the form of a downwardly extending nipple 43. Nipple 43 is fitted telescopically over and in fluid-tight engagement with an upstanding nipple 44 which is formed at the top of dual tubing hanger 28. Suitable seals (not shown), which may be in the form of O-ring seals, are provided between adjacent surfaces of nipples 43 and 44 to ensure fluid-tight engagement therebetween. In addition,

suitable seal means may be utilized to make certain that sloping wall 41 of hanger 28 is in fluid-tight engagement with shoulder 30 as it is supported thereupon.

In addition to the two full-bore tubing runs 39 and 40, tubing hanger 38 includes circulating ports 45 and 46 having a somewhat smaller diameter than the diameter of the tubing runs. FIG. 3 is a plan view in reduced scale of the top of hanger 38 as viewed in FIG. 2. As may be seen clearly with reference to FIGS. 2 and 3, port 45 exists from the top of hanger 38 with the center line thereof in alignment with the center lines of tubing runs 39 and 40 while port 46 emerges from the top of the hanger 38 in offset relation thereto. With particular reference to FIG. 2, it may be seen that circulating port 45 passes through hanger 38 and connects with bore 42 within nipple or seal sub 43 while circulating port 46 is bored within hanger 38 to exit from the space 46a below the tubing hanger 38 outside seal sub 43.

Threadedly connected to hanger 38 and depending therefrom into the well are tubing strings 50 and 51 each having an outer diameter somewhat smaller than the distance between the inner wall surfaces of production strings 22 and 23. Tubing strings 50 and 51 extend into production strings 22 and 23, respectively, as shown, with annular space 52 being formed between the inner wall of production string 22 and the outer wall of tubing string 50 and a similar annular space 53 being formed between the inner wall of production string 23 and the outer wall of tubing string 51.

Tubing strings 50 and 51 extend downwardly along substantially the full lengths of their associated production strings and terminate at their depending ends just above perforations 37 formed in the production strings. The tubing strings are open at the bottom and house conventional standing valves within their terminal portions. In this instance the valves include ball valve members 54 and 55 which cooperate with peripheral sloping shoulders 54a and 55a at the ends of the tubing strings to allow upward passage of fluid into the tubing strings through the apertures defined by the sloping shoulders but prevent downward passage of fluid therethrough. Inwardly projecting pins 54b and 55b determine the limits of the upward path of movement of the ball valve members. Packers 56 and 57 are provided to close off annular spaces 52 and 53 in the vicinity of the standing valve members and circulation ports 58 and 59 are formed in the tubing strings above the packers. In this way, free fluid communication may be established between the annular spaces 52 and 53 and the respective interiors of tubing strings 50 and 51.

Although production strings 22 and 23 terminate at their uppermost ends by being threadedly engaged to dual tubing hanger 28, annular spaces 52 and 53 continue upwardly through that hanger and are defined at this point by the outer walls of tubing strings 50 and 51 and the walls of hanger 28 defining throughbores 33 and 34. Above dual tubing hanger 28, annular spaces 52 and 53 communicate, respectively, with bore 42 and space 46a.

A production tree 60, illustrated in schematic fashion, is positioned above well casing head 17 and attached thereto by means of tree connector 61, also illustrated somewhat schematically, as by means of lock ring 62 of any suitable construction. The body of the

production wellhead assembly of tree 60 is provided with a pair of vertical conduits 63 and 64 which terminate in two downwardly-extending seal nipples or subs 65 and 66. It may be assumed that conduits 63 and 64 communicate respectively with production flowlines 19 and 20 (FIG. 1). Seal nipples 65 and 66 extend into cooperating recesses in the upper portion of tubing hanger 38 as shown in FIG. 2 so that the throughbore of conduit 63 is in communication with the interior of tubing string 50 and the throughbore of conduit 64 is in communication with the interior of tubing string 51. Preferably seals, such as O-ring seal 67, are provided to ensure fluid-tight engagement between the subs or nipples 65 and 66 and the cooperating recesses of hanger 38.

The lower end of the production tree also carries two circulating port seal subs 68 and 69 which fit into additional cooperating recesses at the top of hanger 38 and communicate, respectively, with circulating ports 45 and 46 which pass through the hanger as previously described. At its upper end seal sub 68 branches out into a bypass conduit 70 which passes through the tree body and thence in looping fashion into communication with the throughbore of conduit 64 above a gate valve 71 which is disposed in said throughbore. Similarly, seal sub 69 cooperates with a bypass conduit 72 which is in fluid communication with the throughbore of conduit 63 above a gate valve 73 which is disposed in that throughbore.

Each bypass conduit is also provided with a valve of any desired type such as schematically illustrated gate valves 74 and 75. Valves 71, 73, 74 and 75 are preferably hydraulically actuated with one hydraulic actuator unit being operatively associated with both a throughbore gate valve and the valve disposed in the bypass conduit cooperating with that throughbore. Accordingly, hydraulic actuator unit 76 is operatively associated with valves 73 and 74 and hydraulic actuator unit 77 is operatively associated with valves 71 and 75. In addition to the aforementioned valves, hydraulically actuated master valves 78 and 79 having actuators 78a and 79a, respectively, may also be disposed in the christmas tree throughbore.

The operation of the previously described arrangement will now be described in detail. With particular reference to both FIGS. 2 and 4, the operation of the present invention will be set forth for the situation in which upper zone A is shut in and the flowline associated therewith is used as a service line for through-the-flowline (TFL) work with respect to zone B. FIG. 4 shows the position assumed by the various valve members associated with the present invention for this operation. It should be noted at this point that one hydraulic control line may be used with the present system to provide for all operating conditions. In the first operating condition, i.e. that permitting TFL work with respect to zone B, both master valves 78 and 79 are open to permit free fluid flow through their respective vertical throughbores of conduits 63 and 64. Gate valve 73 in the lower portion of the throughbore of conduit 63 is, however, closed under control of the hydraulic actuation unit 76 while gate valve 74 in bypass conduit 72 is open, also under the influence of actuator unit 76. Hydraulic actuator unit 77, on the other hand, maintains gate valve 71 disposed within the

throughbore of conduit 64 in an open condition, thus permitting free fluid flow through the entire length of that throughbore. Valve 75 within bypass conduit 70 is maintained in a closed position by actuator 77.

With the valves in the above-described first operating condition, a fluid circuit is established whereby fluid may be pumped through production flowline 19 (FIG. 1) into conduit 63. Since gate valve 73 is closed, the flow of production fluid from upper zone A is halted and the fluid pumped down conduit 63 passes through bypass conduit 72, through seal sub 69 and thence into circulating port 46 within hanger 38. The pumped fluid exits from hanger 38 into space 46a and flows downwardly into annular space 53 formed between the inner wall of production string 23 and the outer wall of tubing string 51. After passing through circulation ports 59, the pumped fluid passes up tubing string 51 since it is prevented from exiting from the bottom thereof by ball valve member 55. Finally, the fluid passes up and through conduit 64 (through open valve 71) and out production flowline 20.

The just-described fluid flow circuit is illustrated in schematic fashion in FIG. 4. It is obvious that the path of fluid flow through the valves positioned as illustrated in that Figure may be reversed simply by introducing the pumped fluid into flowline 20 rather than through flowline 19. In this manner through-the-flowline tools may be introduced into tubing string 51 and removed therefrom as desired without lengthy well "down times" caused by complicated operations with respect to the often complex prior art systems.

The construction of the hydraulic actuator units employed for valve placement may be seen with particular reference to actuator unit 77 in FIG. 4. In essence, the unit includes a cylindrical housing 80 in which a piston 81 is positioned for relative movement with respect thereto. In the form shown, the piston is continuously urged to the left by a compression spring 82. Valves 75 and 71 are both connected by suitable armature members to piston 81 and are thus maintained in the position illustrated in FIG. 4 under the influence of spring 82. In like manner, hydraulic actuator unit 76 functions to normally maintain valves 73 and 74 in the respective positions illustrated in FIG. 4. The corresponding location of piston 83 within the housing of actuator unit 76 is illustrated by means of hidden lines. Hydraulic actuator units 76 and 77 are connected by means of suitable conduit means to hydraulic line 24 as shown so that the interiors of the actuator housings are in fluid communication therewith on the sides of pistons 81 and 83 opposed to the respective compression springs.

By introducing pressurized hydraulic fluid of sufficient value from hydraulic line 24 into the interiors of the actuator housings, pistons 81 and 83 will be caused to move against their respective compression springs in an obvious manner. The springs are of differing strengths so that, for example, piston 83 (and consequently valves 73 and 74) will move to the right at a hydraulic pressure of 500 psi while piston 81 and its associated valves will move against the applied spring load at a hydraulic pressure of somewhat greater value, e.g., 1,500 psi. When the above-described first operating condition exists, however, no hydraulic pressure is introduced through line 24 and both sets of valves are urged to the left (as viewed in FIG. 4) by the compression springs.

By introducing 500 psi of pressurized hydraulic fluid into the system through line 24, piston 83 moves to the right against its associated compression spring as shown in FIG. 5, which illustrates in schematic fashion the positions assumed by the various valves in the second operating condition assumed by the elements of the present invention. In this condition, valve 71 remains open and valve 75 remains closed since the pressure of the hydraulic fluid introduced through line 24 is insufficient to urge piston 81 to the right against the urging of its associated spring. However, since piston 83 has moved to the right, valve 73 is opened and valve 74 is closed. With the valves in this second operating condition, bypass conduits 70 and 72 are closed and a fluid circuit is established whereby full fluid communication exists between the full lengths of the throughbores of conduits 63 and 64 and the interiors of tubing strings 50 and 51, respectively. Production fluid thus flows from both upper zone A and lower zone B through production flowlines 19 and 20, respectively, to the storage facility (not shown). This fluid is illustrated schematically in FIG. 5 by the arrows.

By increasing the hydraulic operating pressure through line 24 to 1,500 psi or above, piston 81 and the associated valves 71 and 75 move to the positions shown in FIG. 6. The system is now in the third, and final, operating condition. With the valves 71, 73, 74 and 75 in the condition illustrated, lower zone B is shut in with the production from that zone temporarily terminated. A fluid circuit is established whereby flowline 20 may be used to pump fluid into annulus 52 and out flowline 19 in much the same manner as that previously described with respect to TFL work in zone B (the first operating condition).

While this invention has been described with particular reference to a preferred embodiment thereof, it should be understood that the particular form disclosed has been selected to facilitate explanation of the invention rather than to limit the number of forms which it may assume. Further, it should be understood that various modifications, alterations, and adaptations may be applied to the specific forms described to meet the requirements of practice without in any manner departing from the spirit of the invention or the scope of the subjoined claims.

I claim as my invention:

1. Apparatus for use with a well having an upper producing zone and a lower producing zone, said apparatus comprising:

a first tubing string extending downwardly from the top of the well into said upper zone, at least a portion of said first tubing string being disposed within the interior of a first production string which extends into said upper producing zone;

a second tubing string extending downwardly from the top of the well into said lower zone, at least a portion of said second tubing string being disposed within the interior of a second production string which extends into said lower producing zone;

means including hanger means for supporting said production strings and said tubing strings in substantially fixed relationship to one another whereby a first annular space is formed between said first production string and said first tubing string and a second annular space is formed between said second production string and said second tubing string,

flowline means including a first production flowline and a second production flowline extending outwardly from said well;

valve means operatively associated with said tubing strings and said flowline means to selectively establish fluid communication therebetween;

actuating means associated with said valve means whereby operation of said actuating means causes said valve means to selectively assume three distinct operating conditions;

said valve means in its first operating condition establishing a fluid flow circuit between said first production flowline, said second tubing string, said second annular space and said second production flowline whereby through-the-flowline operations may be carried out with respect to said lower producing zone;

said valve means in its second operating condition establishing a fluid flow circuit between said first production flowline and said first tubing string and between said second production flowline and said second tubing string whereby production fluid may be produced from both said upper zone and said lower zone without commingling of said production fluid; and

said valve means in its third operating condition establishing a fluid flow circuit between said first production flowline, said first tubing string, said first annular space and said second production flowline whereby through-the-flowline operations may be carried out with respect to said upper producing zone.

2. The apparatus according to claim 1 wherein said actuating means is operatively associated with a single hydraulic control line with the operating condition assumed by said valve means being responsive to the degree of pressure of the fluid in said line.

3. The apparatus according to claim 1 wherein a production well-head assembly is disposed above said hanger means, said wellhead assembly including conduit means disposed between said flowline means and said tubing strings and in operative association therewith;

bypass means branching off from said conduit means and in fluid communication with said first and second annular spaces; and

said valve means being operatively associated with said conduit means and with said bypass means to interrupt fluid communication between said first production flowline and said first tubing string when said valve means is in said first operating condition and to interrupt fluid communication between said second production flowline and said second tubing string when said valve means is in said third operating condition.

4. The apparatus according to claim 3 wherein said wellhead assembly conduit means includes a first throughbore and a second throughbore passing through said wellhead assembly in spaced relationship to one another;

said bypass means comprising a first bypass conduit and a second bypass conduit, said first bypass conduit branching off from said first throughbore and said second bypass conduit branching off from said second throughbore, said first bypass conduit being in fluid communication with said second an-

nular space and said second bypass conduit being in fluid communication with said first annular space; and

said valve means when in said second and third operating conditions interrupting fluid flow within said first bypass conduit and said valve means when in said first and second operating conditions interrupting fluid flow within said second bypass conduit.

5. The apparatus according to claim 2 wherein said hanger means includes circulating port means through which fluid flow communication is established between said bypass means and said annular spaces.

6. In combination:

first and second tubing strings extending into a well; first and second production strings extending into said well and respectively disposed in concentric spaced relationship with respect to said first and second tubing strings;

first valve means and second valve means, said valve means being operatively associated with said tubing strings and with said production strings to modify the path of fluid flow therethrough; and

actuating means associated with said valve means whereby operation of said actuating means causes said valve means to move to one of a plurality of selected positions to condition said tubing strings and said production strings for either production of fluid from said well or through-the-flowline operations.

7. The combination according to claim 6 wherein

said actuating means comprises a plurality of actuator units operatively associated with and controlled by a single control line.

8. In combination:

first and second tubing strings extending into a well; first and second production strings extending into said well and respectively concentrically disposed in spaced relationship with respect to said first and second tubing strings;

manifold means positioned at the upper ends of said tubing strings and said production strings, said manifold means defining fluid flow passage means in communication with respective interiors of said tubing strings and said production strings;

flowline means extending from said manifold means and in fluid communication with said fluid flow passage means;

bypass means operatively associated with and in fluid communication with said flowline means and said manifold fluid flow passage means;

valve means associated with said flowline means and said bypass means, said valve means being selectively movable to one of a plurality of preselected positions to permit through-the-flowline operations to be carried out with respect to the well through said flowline means or the passage of production fluid from said well through said flowline means; and

actuator means to position said valve means.

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