

[54] **WELL APPARATUS AND METHOD OF OPERATING SAME FOR PERFORMING WELL OPERATIONS**

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 [51] Int. Cl. **E21b 43/12**
 [58] Field of Search 166/224, 315, 313;
 137/625.28

[56] **References Cited**
UNITED STATES PATENTS

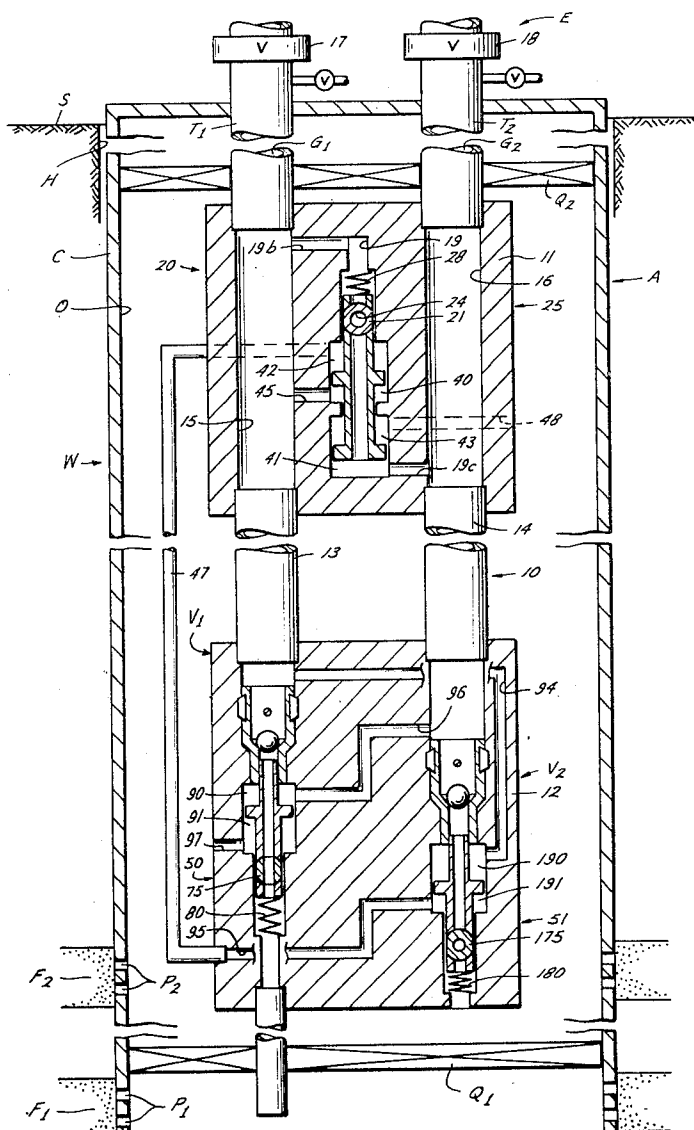
3,381,753	5/1968	Fredd.....	166/224
3,441,084	4/1969	Fredd.....	166/224
3,448,803	6/1969	Sizer.....	166/224
3,552,491	1/1971	Thompson	166/224
3,666,012	5/1972	Sizer et al.	166/224
3,680,637	8/1972	Raylins	166/224

Primary Examiner—James A. Leppink

[57] **ABSTRACT**

A well apparatus and method for communicating a plurality of flow conductor passages extending through a housing to enable controlled circulation between passages when desired while blocking flow through portions of the passages to assure a desired circulating flow path for performing various well operations. Increasing fluid pressure in either or both flow conductor passages establishes communication therebetween by operating a valve means while blocking flow in the other passage to obtain a desired flow circulation path. In the preferred embodiment the valve means for blocking the other flow conductor is located below the valve means to enable replacement of a standing valve by the use of fluid pressure movable tool trains without subjecting the producing formation to the fluid pressure circulating the tool train.

43 Claims, 7 Drawing Figures



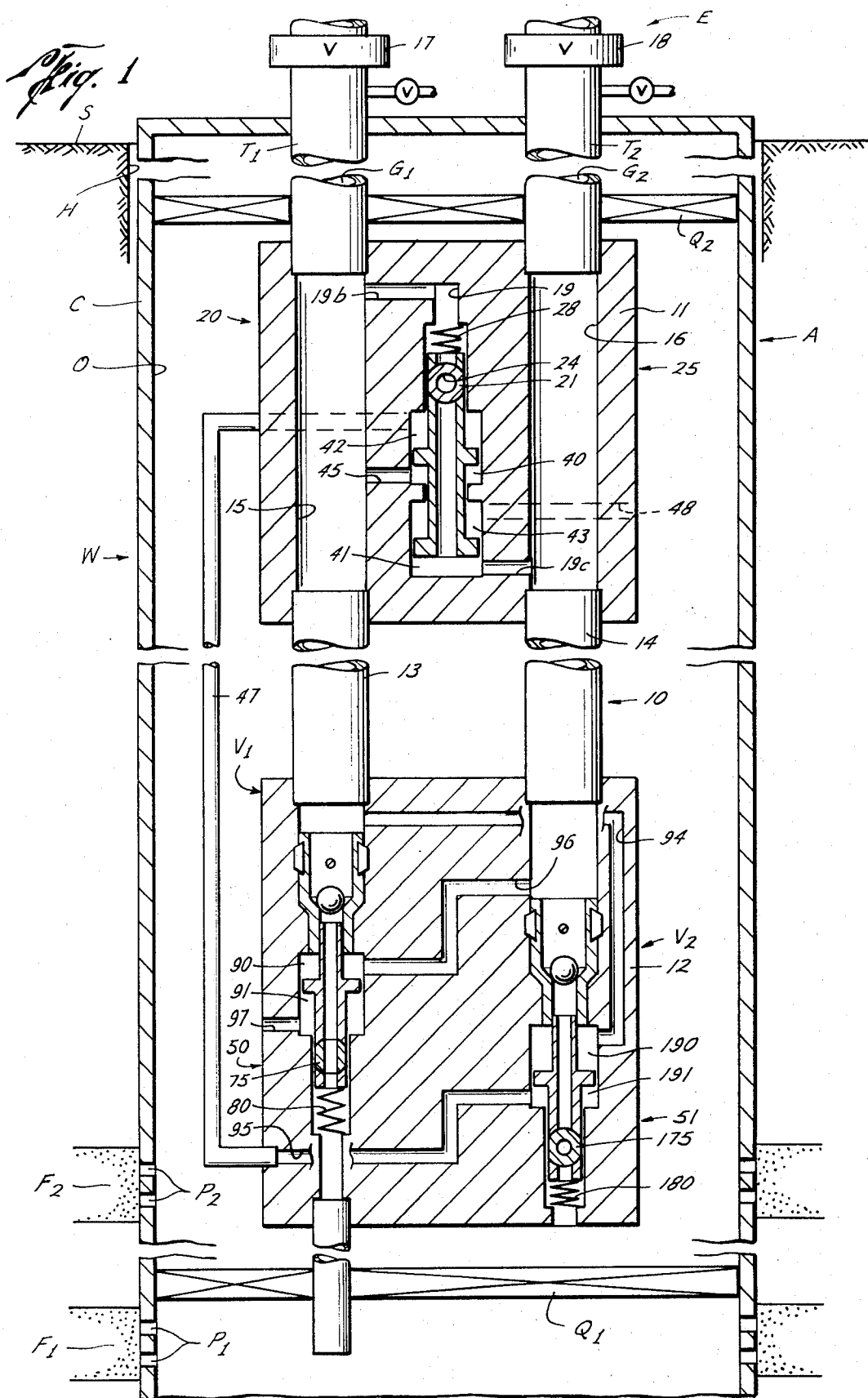
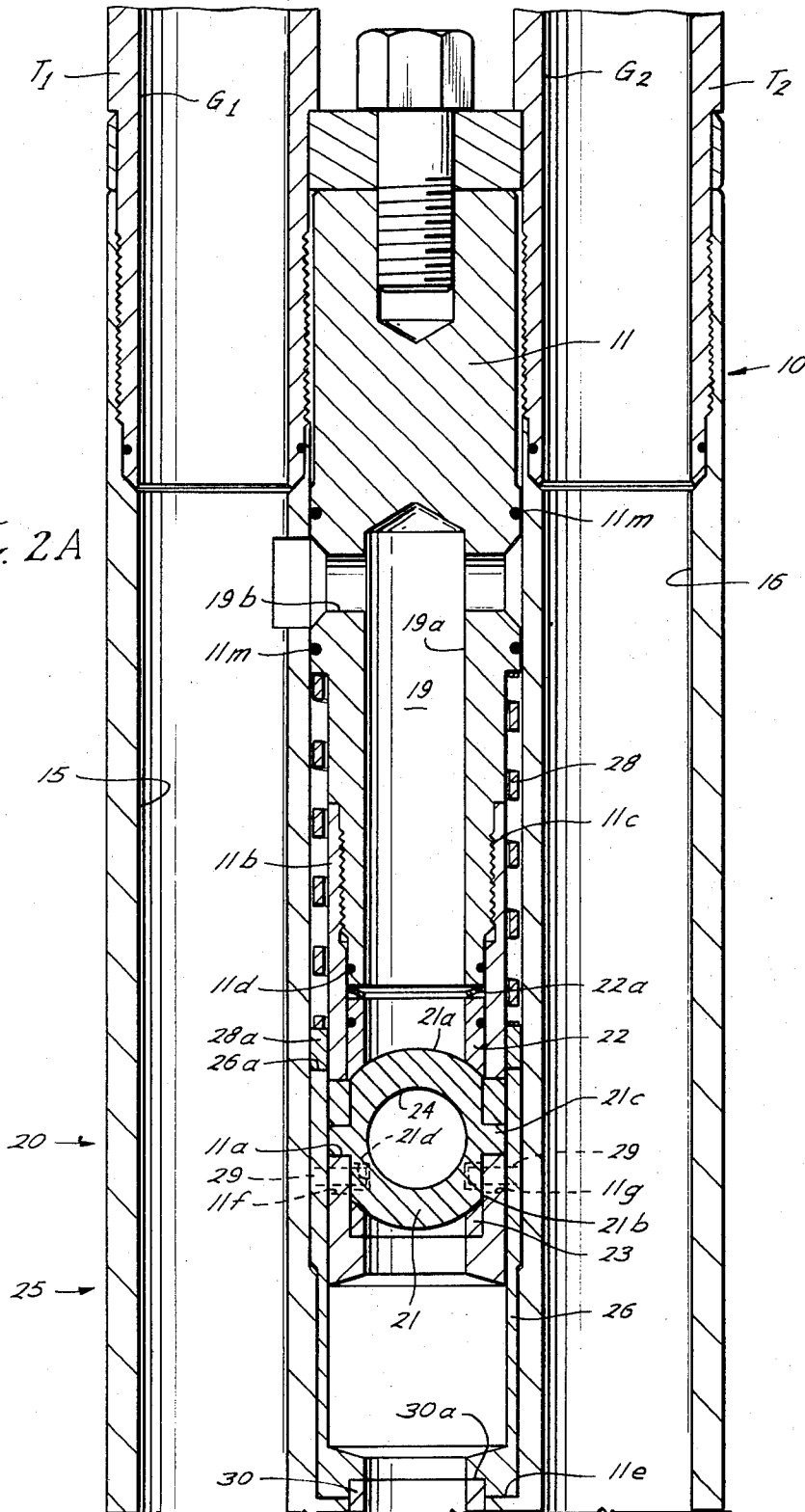
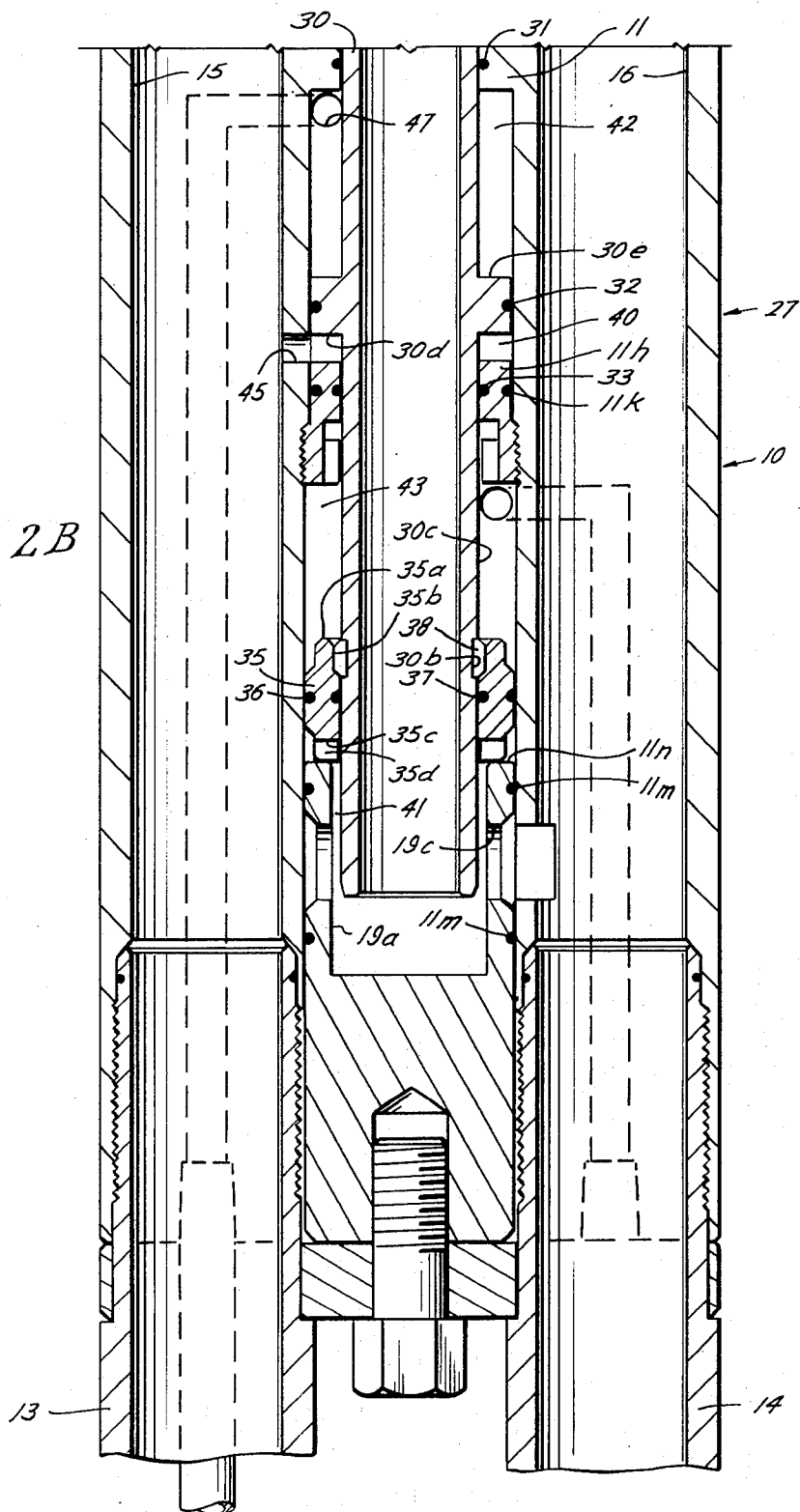
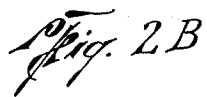
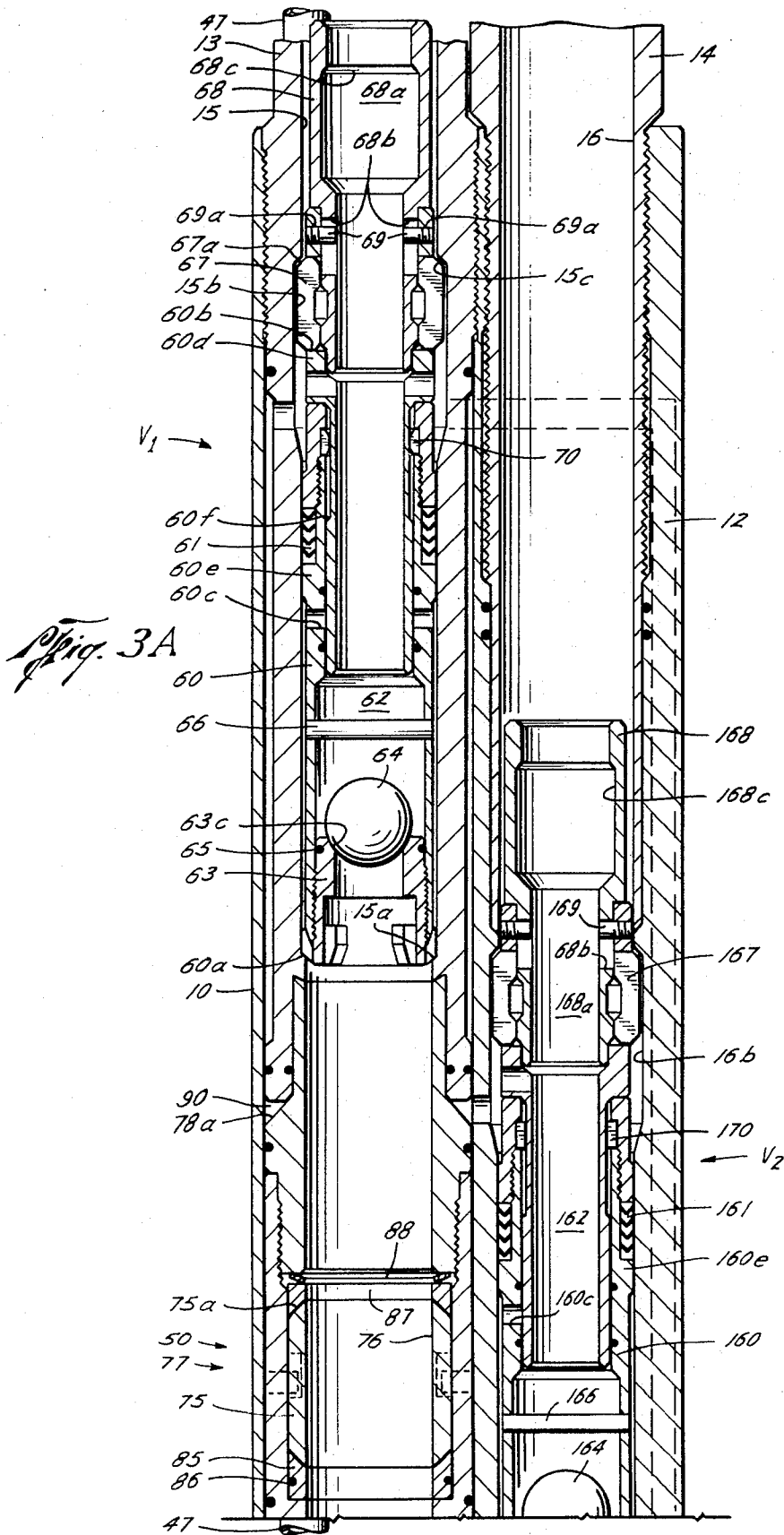
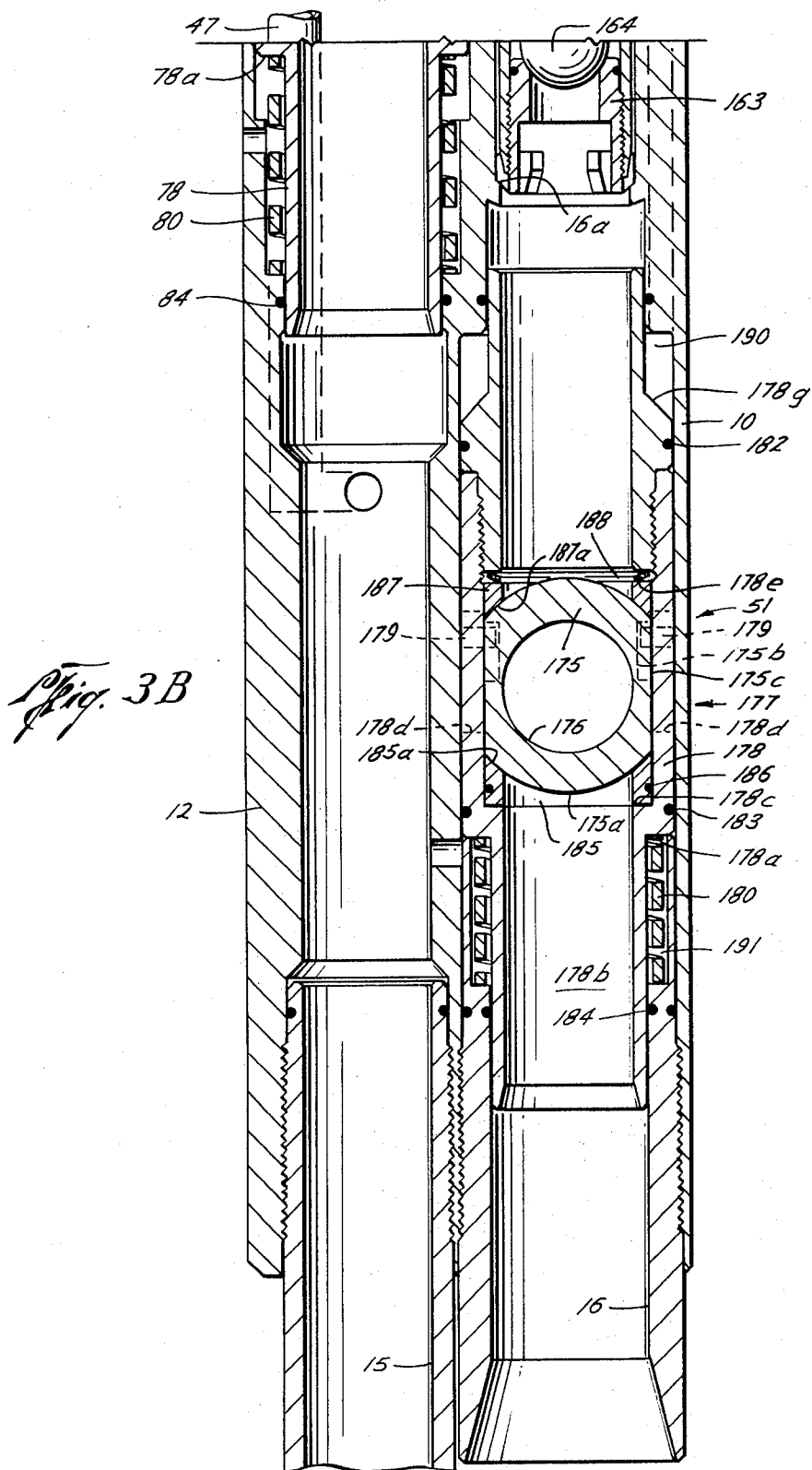


Fig. 2A









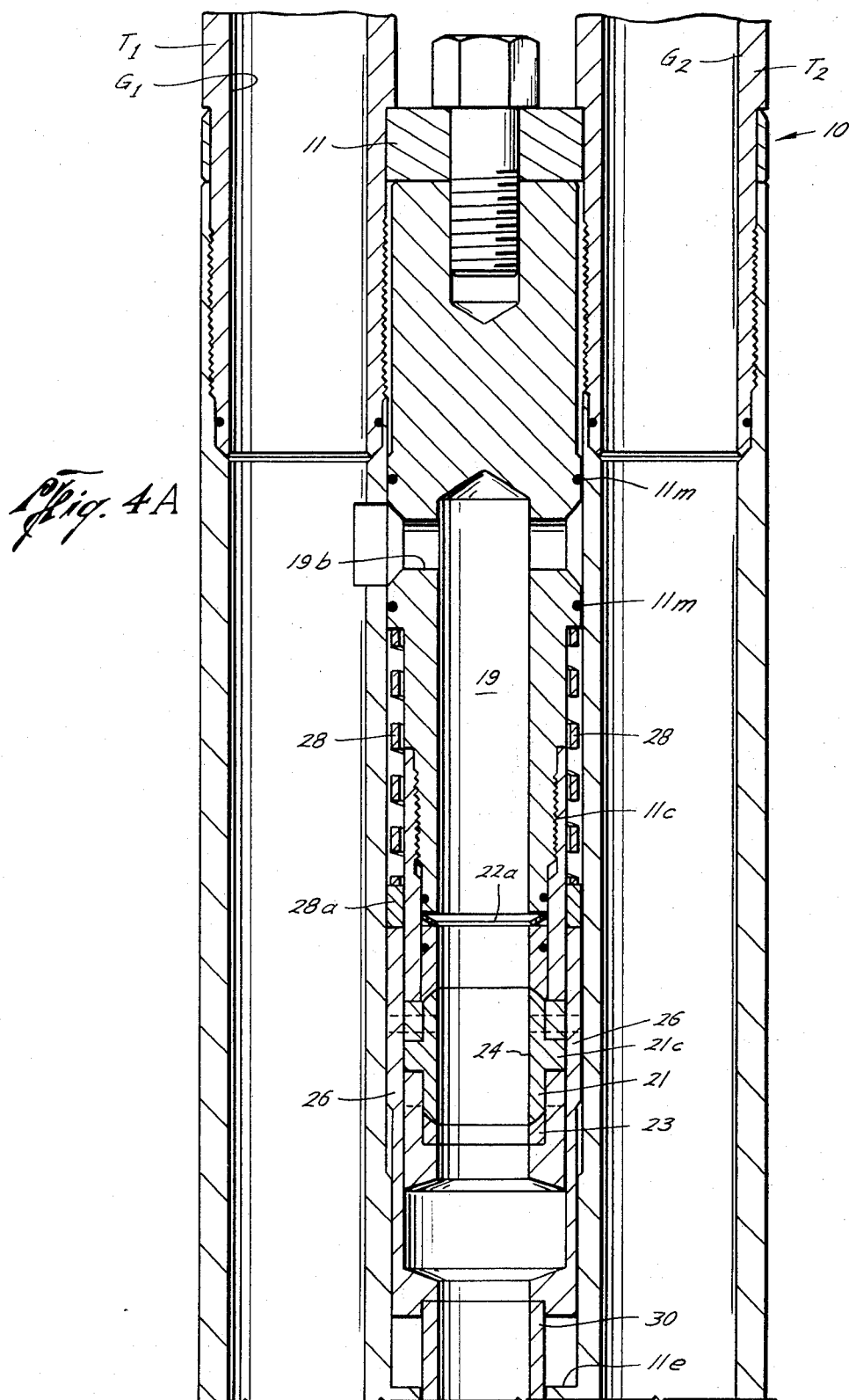
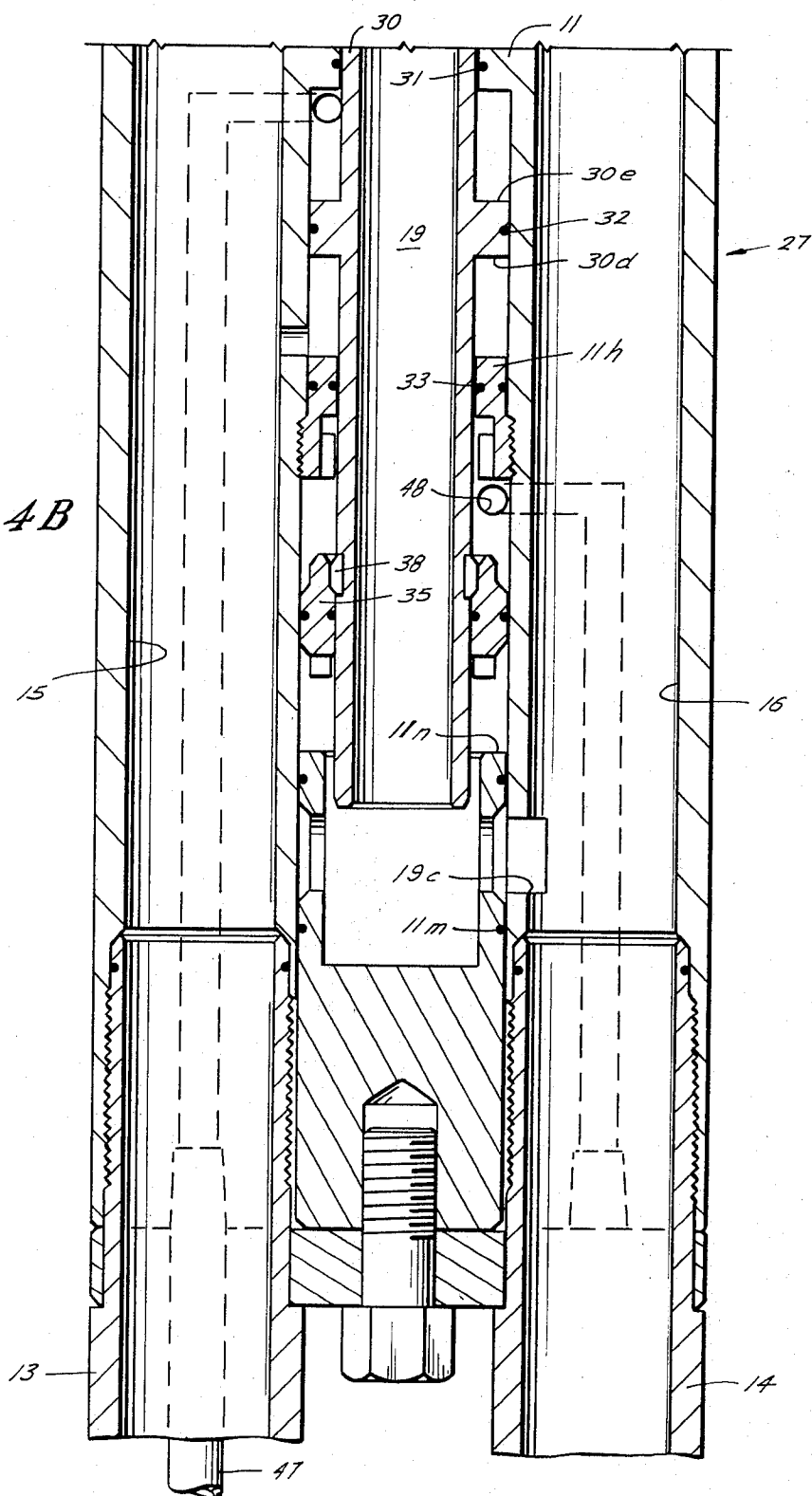


Fig. 4B



WELL APPARATUS AND METHOD OF OPERATING SAME FOR PERFORMING WELL OPERATIONS

BACKGROUND OF THE INVENTION

This invention relates generally to the field of well apparatus and methods and more particularly to the field of well apparatus and methods of operating same for performing well operations by circulating fluids in a desired manner through a pair of well flow conductors placed in a communication by operation of the well apparatus.

Communicating valve assemblies, such as disclosed in U.S. Pat. Nos. 3,448,803 and 3,494,420 adapted for installation at a subsurface location in a well for enabling desired circulation patterns in a well for performing well operations have been known and used. Some communicating valve assemblies, such as U.S. Pat. No. 3,381,753, have required the running of an additional control tubing string to control operations of the cross over valve assembly. Other communicating valve assemblies have operated when pressure was increased in either pipe string to effect communication therebetween, but as disclosed in U.S. Pat. No. 3,552,491, have required two independent valve systems and flow passages for effecting such operation. Also, the prior art devices have required that a standing or check valve be located in the production tubing below the communicating flow port to protect the well producing formation from damage during circulation through and in some prior art embodiments, a leaking or defective standing valve rendered the communicating valve assembly inoperative. Replacing the standing valve, if possible in the prior art, has required subjecting the producing formation to the circulation pressure which could substantially and permanently reduce the producing capability of the formation.

Additional examples of relevant prior art methods and apparatus have been disclosed in U.S. Pat. Nos. 3,666,012 and 3,680,637.

SUMMARY OF THE INVENTION

This invention relates to a new and improved well apparatus and method of operating same for performing well operations.

The apparatus of the present invention includes a housing adapted for connection in a well tubing at a subsurface location and having a circulation channel formed therein for providing a flow passage for circulation of well fluid to perform various well operations. Valve means responsive to predetermined pressure conditions controls flow through the circulation channel while plug means operably responsive to the same predetermined pressure condition protect the well producing formation from fluid pressure conditions present while performing the well operations. The methods of using the apparatus for performing various well operations protects producing formations from damage during such operations.

An object of the present invention is to provide a new and improved well apparatus.

A further object of the present invention is to provide a new and improved methods for performing well operations.

Yet still a further object of the present invention is to provide a new and improved method of operating a well apparatus for performing well operations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a cross-section of a well having the apparatus of the present invention located therein at a subsurface location;

FIGS. 2A and 2B are side views, in section, of the upper portion of the housing of the present invention, arranged in alphabetical sequence from top to bottom, illustrating the circulation channel closed by valve means;

FIGS. 3A and 3B are side views, in section, of the lower portion of the housing of the present invention, arranged in alphabetical sequence from top to bottom, illustrating the plug means in the open position; and

FIGS. 4A and 4B are similar to FIGS. 2A and 2B, respectively, with the valve means opened to enable flow through the circulation channel.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The well apparatus A of the present invention is schematically illustrated in the well W of FIG. 1 located below the earth's surface S in a well bore hole H which extends downwardly through one or more producing formations F₁ and F₂. The well W is preferably provided with a plurality of flow conduits including casing C and well production tubings T₁ and T₂ which extend downwardly in the bore hole H from the well head or Christmas tree equipment E located on the surface S to the producing formations F₁ and F₂. In the arrangement of the well W illustrated, the production tubing T₁ and T₂ are located within the longitudinal bore or opening O of the casing C which is provided with perforations P₁ and P₂ to enable passage of hydrocarbons and other fluids from the producing formations F₁ and F₂, respectively, into the opening O of the casing C. Suitable packers Q₁ and Q₂ are other means to seal between the casing C and the production tubings T₁ and T₂ to direct the flow of fluid from the formation F₁ and F₂ to the well head E through the bores G₁ and G₂ of the production tubings T₁ and T₂, respectively may be provided. The above-described well completion arrangement should merely be considered as typical of the many well known arrangements for single and multiple completion wells and the method and apparatus of the present invention should not be considered limited to any particular well arrangement.

The well apparatus A includes a body or housing 10 having an upper portion 11 and a lower portion 12 secured in a spaced arrangement by parallel connector pipes 13 and 14 of any desired length. Extending longitudinally through the housing 10 is a pair of space flow conductor passages 15 and 16 enabling flow through the housing 10. The housing 10 is adapted for mounting with the well tubings T₁ and T₂ at a subsurface location with the flow conductor passages 15 and 16 in communication with the bores G₁ and G₂, respectively, of the production tubings for directing flow to the surface S from the formations F₁ and F₂. In the illustrated arrangement, the first flow conductor passage 15 is in communication with the bore G₁ of the production tubing T₁ above and below the housing 10 for flowing fluids from the formation F₁ through the well head valve indicated at 17 while flow conductor passage 16 is in communication with the bore G₂ of the production tubing T₂ for flowing fluids from the formation F₂ through the well head valve indicated at 18.

Formed in the upper portion 11 of the housing 10 is a circulation channel 19 for communicating between the flow conductor passages 15 and 16. By pumping fluids down one of the production tubings to the communicating flow conductor passage and through the circulation channel 19 into the other flow conductor passage and then back to the surface S through the other production tubing numerous well operations may be performed. As examples of such operations, the well may be completed or killed, acidizing or washing operations may be performed and well tools moved through the bores G_1 and G_2 of the production tubings T_1 and T_2 respectively, to and from subsurface operating locations. Many other useful well operations may be performed with the well apparatus A and the scope of the present invention should not be considered limited in any manner by the type of well operation performed.

The well apparatus A includes a valve means 20 mounted with the housing 10 and disposed in the circulation channel 19 from movement to and from open and closed positions for controlling communication between the flow conductor passage 15 and 16 through the circulation channel 19. Normally the valve means 20 is maintained in the closed position for blocking communication through the circulation channel 19 and directing the flow of well fluids from the formations F_1 and F_2 to the surface S through separate flow passages. This arrangement enables the surface valves 17 and 18 to control the flow from the formations F_1 and F_2 respectively.

As illustrated in greater detail in FIGS. 2A and 2B, the circulation channel 19 includes longitudinally extending portion 19a in parallel spaced arrangement with the flow conductor passages 15 and 16. The upper end of the central portion 19a communicates with the first flow conductor passage 15 through the horizontal port 19b (FIG. 2A) while the lower end of the central portion 19a communicates with the second flow conductor passage 16 through the port 19c (FIG. 2B).

The valve means 20 is disclosed in the central portion 19a of the circulation channel 19 and includes the ball member 21 and a seat ring 22. The ball 21 includes a spherical outer sealing surface 21a and having two portions removed to form parallel flat surfaces 21b having pivot or journal pins 21 concentrically extending from each of the flats 21b providing an axis about which the ball 21 is rotated. The pivot pins 21c fit within openings 11a of the fixed sleeve 11b which is secured to the upper portion 11 of the housing 10 by threaded engagement at 11c with an O-ring 11d blocking leakage of fluid along the threaded engagement. The valve means 20 further includes a lower seat ring 23 mounted with the sleeve 11b below the ball 21. The seat ring 23 and the upper seat ring 22 engage spherical surface 21a of the ball 21 for providing annular seals therebetween to block passage of fluid therebetween. A spring 22a urges the upper seat ring 22 downwardly for engaging the ball 21 while O-ring 22a affects an annular seal between the upper seat ring 22 and the sleeve 11b to block leakage of fluid therebetween.

The ball member 21 includes a flow port 24 formed therethrough which is located in a position substantially transverse to the portion 19a of the circulation channel 19 when the ball 21 is in the closed position and which is positioned in substantial alignment with the passage 19a when the ball 21 is rotated to the open

position for enabling flow through the circulation channel 19 to pass through the flow port 24.

The well apparatus A includes an actuator means 25 operably connected with the ball 21 for affecting movement thereof to the open or aligned position in response to the urging on the actuator means 25 of a predetermined pressure differential resulting from increasing the fluid pressure and either of the flow conductor passages 15 or 16 above the normal well pressure. The actuator means includes an operator sleeve member 26 for rotating the ball 21, a piston means 27 arranged to move the operator sleeve 26 for rotating the ball 21 open and spring means 28 for urging the operator sleeve 26 to rotate the ball 21 to the closed position and maintaining the ball 21 in the closed position until the predetermined pressure differential urges on the piston means 27.

The operator sleeve member 25 is disposed in the portion 19a of the circulation channel 19 adjacent the ball 21. The sleeve 28 surrounds the sleeve 11b in a concentric manner and is telescopically movable relative thereto. The operator sleeve 26 is movable between a first or lower position (FIG. 2A) and a second or upper position (FIG. 4A). The upper portion 11 of the housing 10 forms an upwardly facing annular shoulder 11e for limiting downwardly movement of the operator sleeve while the downwardly urging of the spring means 28 transmitted through the spring keeper 28a engaging the upwardly facing annular shoulder 26a provides a cushion for limiting upward movement of the operator sleeve 26. The operator sleeve 26 eccentrically mounts a pair of aligned inwardly extending pins 29 which extend through longitudinal slots 11f and 11g in the sleeve 11b into radially extending recesses 21d formed in the ball 21 for cranking the ball to the closed position when the sleeve 26 is in the lower position and rotating the ball 90° to the open position when the operator sleeve 26 moves to the upper position. The longitudinal slots 11f and 11g through the sleeve 11b provide movement enabling clearance to the pins 29 as the operator sleeve 26 moves longitudinally.

As illustrated in FIG. 2B, the piston means 27 includes a piston sleeve member 30 operably positioned in the portion 19a of the circulation channel 19 to move the operator sleeve 26 upwardly for rotating the ball 21 to the open position in response to the urging on the piston means 27 of a predetermined pressure differential resulting from increasing the fluid pressure in either of the flow conductor passages 15 and 16 to a value greater than normal well fluid pressure. Without the presence of the predetermined pressure differential urging on the piston means 27, the spring means 28 urging the operator sleeve 26 to the lower position will move the piston sleeve 30 to a lower position by engagement with an upwardly facing annular shoulder 30a of the piston sleeve (FIG. 2A).

The piston sleeve 30 is concentrically positioned in the circulation channel portion 19a and is slidably sealed to the upper portion 11 of the housing 10 at O-rings 31, 32 and 33 to block leakage of fluid therebetween. The O-ring 33 is mounted on a ring 11h secured to the upper portion 11 by threaded engagement at 11j while O-ring 11k blocks leakage of fluid along the threaded engagement at 11j. Other O-rings, generally designated 11m, are carried by the housing for affecting seals to prevent leakage of fluid from the circulation channel 19 in an undesired manner.

The piston means 27 includes a piston ring 35 concentrically mounted about the piston sleeve 30 below the stationary ring 11*h*. The piston ring 35 mounts an O-ring 36 for effecting a sliding annular seal with the upper portion 11 of the housing 10 while an O-ring 37 affects a sliding annular seal between the piston ring 35 and the piston sleeve 30. The piston ring 35 includes an upwardly facing shoulder 35*a* having a surface formed at 35*b* for holding a gapped expansible detent ring 38 in an annular recess 30*b* formed in the outer surface 30*c* of the piston sleeve 30. As will become more apparent hereinafter, the piston sleeve and detent 37 may move upwardly while the piston ring 35 remains stationary and therefor the upwardly facing shoulder 35*a* is formed in the manner illustrated to insure the movement of the detent 38 back into the recess 30*b* when the piston sleeve 30 returns to the lower position. The piston ring 35 forms a downwardly facing annular shoulder surface 35*c* having a plurality of spaced downwardly projecting flukes 35*d* formed thereon for engaging an upwardly facing annular shoulder 11*n* to provide a lower movement limit stop for the piston ring 35.

The piston sleeve 30 and the housing 11 form a first annular expansible chamber 40 with the piston sleeve 30 having a first downwardly facing pressure responsive surface 30*d* exposed to the fluid pressure in the chamber 40 for urging upwardly on the piston sleeve 30 to effect upward movement thereof along with the operator sleeve 25 to rotate the ball 21 open. The seals affected by the O-rings 36 and 37 on the piston ring 35 with the piston sleeve 30 and the housing 11 form a second annular expansible chamber 41 in the lower portion of the circulation channel 19*a* for urging upwardly on the downwardly facing pressure responsive surface 35*c* of the piston ring 35 for moving the operator sleeve 26 along with the piston sleeve 30 upwardly to rotate the ball 21 open. Thus fluid pressure urging on the surface 30*d* of the piston sleeve 30 or the surface 35*c* of the piston ring 35 will effect opening rotation of the ball 21.

The piston sleeve 30 and the housing 11 form a third annular expansible chamber 42 between the sliding seals affected by the O-rings 31 and 32 with a third upwardly facing pressure responsive surface 30*e* exposed to fluid pressure in the chamber 42 for urging on said piston sleeve 30 to effect downward movement thereof to enable closing rotation of the ball 21 by the spring 28. The seals affected by the O-rings 36 and 37 of the piston ring 35 again in conjunction with the piston sleeve 30 and the housing 11 form a fourth annular expansible chamber 43 above the piston ring 35 with fluid pressure in the chamber 35 exposed to the upwardly facing annular pressure responsive shoulder 35*a* of the piston 35 for urging downwardly movement thereof. As the piston ring 35 utilizes the detent 38 to transmit the upwardly urging on the piston ring 35 to the piston sleeve 30 downwardly urging on the piston ring 35 will merely slide the piston ring 35 into engagement with the shoulder 11*n* unless other downwardly urging on the piston sleeve 30 is sufficient to move the sleeve 30 downwardly along with the piston ring 35.

The first expansible chamber 40 communicates with the first flow conductor passage 15 through a first conductor means provided by the port 45 for urging the ball 21 open in response to the fluid pressure present in the passage 15. The second expansible chamber 41 communicates with the second flow conductor passage

16 through a second conductor means provided by the port 19*b* of the circulation channel 19 for urging the ball 21 open in response to the fluid pressure present in the passage 16. With this arrangement increased fluid pressure in either of the passages 15 and 16 urges the ball 21 to rotate open to establish communication between the passages 15 and 16 through the circulation channel 19.

As best illustrated in FIG. 1, the third expansible chamber 42 communicates through a conduit or third conductor means 47 with the first flow conductor passage 15 in the lower portion 12 of the housing 10. The fourth expansible chamber 43 communicates through a fourth conductor means provided by the port 48 (illustrated in phantom) with the same fluid pressure present in the second flow conductor passage 16 of the lower portion 12 of the housing 10 with the arrangement of the packers Q_1 and Q_2 of FIG. 1. The port 48 is sufficient in this well arrangement as the pressure within the bore O of the casing C at the port 48 is essentially the same as the present in the passage 16 at the lower portion 12 of the housing 10. With other well arrangements it may be necessary to run a conduit, similarly to the third conductor means 47, to communicate desired fluid pressure to the fourth expansible chamber 43.

Referring now to the lower portion 12 of the housing 10 schematically illustrated in FIG. 1, a first plug means 50 is located in the first flow conductor passage 15 below a retrievable standing valve means V_1 . A similar arrangement of a second plug means 51 and a second standing valve means V_2 is found in the second flow conductor passage 16.

A first plug means 50 and the first standing valve means V_1 are located in the first flow conductor passage 15 at a location below and spaced from the circulation channel 19 while the second plug means 51 and the second standing valve means V_2 are located in a similar manner in the second flow conductor passage 16. Thus, well fluids may be circulated down either one of the production tubings through the circulation channel 19 when the ball 21 is rotated open and up the other production tubing back to the surface for performing well operations. Both standing valve means V_1 and V_2 serve as check type valves for enabling upwardly flow in the passages 15 and 16 while blocking downwardly flow therethrough which could potentially damage the ability of the formations F_1 and F_2 to produce the sought after well fluids. The use of a standing valve means in the lower portion of a well tubing is known including the use in a communicating valve assembly as disclosed, for example in the previously mentioned U.S. Pat. No. 3,552,491. The kind of standing valve employed is not critical and any commercially available valve may be utilized with this invention, but it is preferable to use retrievable valves such as illustrated in detail in FIGS. 3A and 3B. As the standing valves V_1 and V_2 are duplicates, only one will be described and the same reference characters will be used to designate identical parts but those of V_2 shall be increased by 100.

The standing valve means V_1 includes a body 60 mounting an annular packing 61 thereon for sealing with the walls of the flow conductor passage 15 to block leakage of fluid by the body 60. The body includes a longitudinal bore 62 formed therethrough in which is secured a seat ring 63 for providing an up-

wardly facing arcuate annular shoulder 63c upon which the ball element 64 seats to block downwardly flow through the bore 62 and which is moved upwardly to a space location from the seat 63c to enable the desired upwardly flow through the bore 62. An O-ring 65 provides an annular seal between the seat ring 62 and the body 60 to block leakage of fluid therebetween. A ball retainer pin 66 is secured to the body 60 above the ball 64 in a position transversely across the bore 62 to maintain the ball 64 in proximity to the seating surface 63a. The tubular body 60 is dimensioned to pass downwardly through the production tubings and flow conductor passages until a lower annular shoulder 60a engages an upwardly facing annular shoulder 15a or 16a for operably locating the safety valve means in the lower portion 12 of the housing 10.

When positioned in the operating location, the standing valve means V_1 is releasably secured with the housing 10 by a plurality of radially expandable latch dogs 67 located in a corresponding plurality of radially spaced openings or windows 60b formed in the body 60 adjacent an annular recess 15b of the flow conductor passage 15. With the latch dogs 67 expanded, the tapered upwardly facing shoulders 67a will engage a correspondingly tapered downwardly facing annular shoulder 15c formed by the recess 15b to block upward movement of the tubular body 60 in the passage 15. The latch dogs 67 are moved to and held in the radially expanded position by downward movement of a latch sleeve 68. The latch sleeve 68 includes a longitudinally extending bore 68a formed therethrough which is aligned and in communication with the bore 62 of the body 60 for enabling flow of fluid through the standing valve means and a pair of longitudinally extending window recesses 68b for receiving therein a pair of inwardly projecting pins 69 which are secured to the body 60 by a suitable means, such as threaded engagement therewith at 69a. The arrangement of pin 69 in the windows 68b enables limited relative telescopic movement of the latch sleeve 68 between an upper position (not illustrated) and a lower position holding the latch dogs 67 in the radially expanded position (FIG. 3A). Thus the standing valve means moves through the flow conductor passage 15 with the latch sleeve 68 in the extended or upper position and the latch dogs 67 within the windows 60b. When the shoulder 60a engages the shoulder 15a the latch sleeve 60a is moved down relative to the tubular body 20 for forcing the latch dogs 67 outwardly into the recess 15b for operably securing the standing valve means V_1 with the housing 10. When it is desired to retrieve the standing valve means V_1 from the housing 10 a retrievable tool is run down the bore of the tubing T_1 and the flow conductor passage 15 to engage an annular fishing tool recess 68c formed in the bore 68a of the latch sleeve 68. Upward movement of the retrievable tool with the latch sleeve 68 will release the latch dogs 67 and urge the body 60 to move upwardly when the lower edge of the windows 68b engage the connecting pin 69. With the latch dogs 67 released by the movement of the latch sleeve 68 to the extended position the tapered surface 15c of the recess 15b will force the latch dogs 67 to move radially inwardly to enable passage of the standing valve means V_1 through the production tubing T_1 back to the surface S. For a more detailed description of the operation of the latch dogs 67 for securing the standing valve means V_1 in the flow conductor passage 15, reference

may be had to my co-pending application Ser. No. 131,628, filed Apr. 6, 1971 and now U.S. Pat. No. 3,744,564 in which a detailed description of the operation including the running and retrievable tools is set forth.

To enable retrieval of the standing valve means V_1 without lifting the entire column of fluid above the standing valve means V_1 when using a wireline retrievable operation, the standing valve body 60 is provided with an equalizing or by-pass port 60c to enable the well fluids to flow around the ball 64 seated on the seating surface 63c. The body 60 includes an upper sleeve portion 60d which is enabled to move upwardly relative to the remainder of the body 60 to uncover the equalizing port 60c when the standing valve means V_1 commences to move upwardly. A detent ring 70 mounted with the lower portion 60e of the body 60 engages an upwardly facing shoulder 60f formed on the upper portion 60d for moving the body upwardly as a unit.

The illustrated standing valve means V_1 and V_2 are typical of the many types that may be used with the present invention and other types of retrievable valves may be used without any adverse affects.

Position in the first flow conductor passage 15 below the standing valve means V_1 is the first plug means 50 which is illustrated in the open position in FIG. 3A for enabling production of hydrocarbons and other well fluids from the formation F_1 through the passage 15. The purpose of the first plug means 50 and the second plug means 51, which is positioned below the second standing valve means V_2 is for blocking flow through the passage 15 and 16, respectively, below the standing valve means V_1 and V_2 to enable replacement of either standing valve means or for performing well operations using the circulation channel 19 with a defective standing valve without exposing the formations F_1 and F_2 to potentially damaging circulation pressure. The first plug means 50 is structurally identical to the second means 51 and the reference characters of the latter will be increased by 100 for like structure in both plug means. To simplify understanding of the present invention, the second plug means 51 will be considered in detail as it is fully illustrated in the closed position in FIG. 3B.

Plug means 51 includes a closure element means for movement to and from a first or open position for enabling flow of fluids through the second flow conductor passage 16 and a second or closed position for blocking flow of fluid through the passage 16. The preferred and illustrated embodiment of the closure element means is a rotatable ball 75 having a full opening bore 176 formed therethrough with the ball 175 rotating 90° from the open position aligning the bore 176 with the passage 16 to the closed position with the bore 176 located transverse to the passage 16.

The plug means 51 further includes mover means 77 for affecting movement of the closure element means to and from the open and closed position comprising a mover sleeve member 178 which is concentrically located in the passage 16 between the lower portion 12 of the housing 10 and the ball 175. The sleeve 178 is longitudinally movable between a first or upper position and a second or lower position for rotating the ball 175 about a pivot means provided by a pair of aligned and eccentrically located pins 179 secured with the housing 10. The mover means 177 further includes a spring or urging means 80 for urging the mover sleeve

78 to the upper position for maintaining the ball 75 in the open position.

The sleeve 78 is slidably sealed by O-rings 81 and 82 to the housing 10 to block leakage of fluid at both locations above the ball 75 while O-rings 83 and 84 affect similar seals between the sleeves 78 and the housing 10 below the ball 75. The springs 80 engages a downwardly facing annular shoulder surface 78a for urging the sleeve 78 to move upwardly.

The sleeve 78 includes a longitudinally extending bore 178b for enabling flow of fluid therethrough and which forms an upwardly facing annular shoulder 178c for mounting a seat ring 185 in sealing engagement with the ball 175. The seat ring 185 is sealed by an O-ring 186 to the sleeve 170a and includes an upwardly facing arcuate annular surface 185a in sealing contact with the outer spherical surface 175a of the ball 175 for blocking leakage of fluid around the seat ring 185. A pair of longitudinally extending openings or windows 178d are formed through the sleeve 178 adjacent the ball 175 through which pivot pins 179 extend within radially extending recesses 175b formed in the flats 175c of the ball 175. The windows 178d are dimensioned to enable the longitudinal movement of the sleeve 170a to move the ball 175 longitudinally for effecting rotation about the pivot pins 179. Mounted with the sleeve 178 above the ball 175 is an upper seat ring 187 having a downwardly facing arcuate surface 187a for engaging the spherical surface 175a of the ball 175. Mounted between the upper seat ring 187 and a downwardly facing annular shoulder 178e is an annular leaf spring 188 for urging the upper seat ring 187 to move the ball 175 into sealing engagement with the lower seat ring 185. For purposes of assembly the sleeve 187 is formed of two portions which are secured together by any suitable means such as threaded engagement at 178f between the O-rings 181 and 182. The sleeve 178 forms an upwardly facing tapered annular shoulder 178g which is exposed to the fluid pressure in an expansible operating chamber 190 formed by the housing 10 and the sleeve 178. A lower or exhaust expansible chamber 191 is formed by the housing 10 and the sleeve 178 between the seals on the O-rings 183 and 184 with fluid pressure in the chamber 191 exposed to the downwardly facing annular shoulder 178a of the sleeve 178. Thus, fluid pressure in the upper expansible chamber 190 urges on the upwardly facing pressure responsive surface area 178g of the sleeve 178 for urging the sleeve to move downwardly while the fluid pressure in the lower chamber 192 and the spring 180 urge upwardly on the pressure responsive surface 178a for urging the sleeve 178 to move upwardly. Thus, it is apparent that when the pressure in the upper chamber 190 is increased sufficiently to overcome the combined upwardly urging of the spring 180 and the fluid pressure in the chamber 191 the sleeve 178 will be moved downwardly for rotating the ball 175 closed to block flow through the passage 16. Increasing the fluid pressure in the chamber 190 of the first plug means 50 will affect blocking of fluid flow through the passage 15, but to fully explain reference must be again be made to the schematic drawing of FIG. 1.

As illustrated in FIG. 1, the operating chamber 190 of the second plug means 51 communicates through flow passage 94 with the first flow conductor passage 15 at a location between the first standing valve means V_1 and the circulation channel 19. The lower or ex-

haust chamber 191 of the second plug means 51 communicates through the passageway 95 with the first flow conductor passage 15 at a location below the first plug means 50. Thus, by increasing the pressure in the bore G_1 of the production tubing T_1 at the surface S by a suitable fluid pressure supply means, such as a pump, the pressure in the first flow conductor passage 15 will be increased above well pressure which desirably operates the first standing valve means V_1 to close to protect the formation F_1 . When this occurs a pressure differential will exist across the standing valve V_1 with the greater pressure in the passage 15 above the standing valve V_1 which is communicated through the conductor 94 to the operating chamber 190 of the second plug means 51 for blocking in the second flow conductor passage 16 below the second standing valve means V_2 . The fluid exhausted from the lower annular chamber 191 of the second plug means 51 is communicated through the passage 95 to the lower pressure area of the first conductor passage 15 below the first standing valve means V_1 . The increased pressure in the first passage 15 above the first standing valve means V_1 will also be communicated through the port 45 for urging the piston sleeve 30 to move upwardly to rotate the ball 21 to the open position for enabling circulation through the circulation channel 19 as the chamber 42 communicates with the first passage 15 below the first standing valve means V_1 . The differential pressure urging on the piston sleeve 30 is sufficient to effect opening rotation of the ball 21 substantially simultaneously with the blocking of the second flow conductor 16 by the second plug means 51. In this manner the well apparatus A of the present invention provides a desired circulating path down the bore G_1 of the production tubing T_1 through the circulation channel 19 and upwardly through the bore G_2 of the second production tubing T_2 for enabling circulation flow while isolating both formation F_1 and F_2 from the circulation pressure and circulating fluid. It will also be apparent that this circulation path may be established when the first standing valve means is leaking or otherwise malfunctioning if the valve V_1 effects a sufficient pressure differential to operate the second plug means 51 and the ball valve 21.

The operating chamber 90 of the first plug means communicates with the bore of the second passage 16 above the second standing valve means through the passage 96. The exhaust chamber 91 of the first plug means 50 is illustrated in FIG. 1 communicating with the area adjacent the exterior of the housing 10 through the conductor passage or port 97. It will be immediately apparent to those skilled in the art that such arrangement is sufficient in the illustrated well as the fluid pressure in the second passage 16 below the plug means 51 is the same as that present adjacent the exterior of the housing 10. Should a different well arrangement be employed it would be necessary to communicate with the second passage 16 below the ball 175 in a manner similar to that of the conductor passage 95. With the conductor passages 96 and 97 arranged in this manner, increasing the fluid pressure in the bore G_2 of the production tubing T_2 will affect a pressure differential in the passage 16 across the second standing valve means V_2 to operate the first plug means 50 closed for blocking flow through the first passage 15. Again the increased pressure will effect opening of the ball 21 to enable flow through the circulation channel 19 to es-

establish the desired circulation pattern down the bore G_2 of the production T_2 and up the bore G_1 of the production tubing T_1 for performing well operations. The increased pressure in bore G_2 will urge the piston ring 35 to move upwardly while the chamber 43 will be exhausted through the passage 48 to the area adjacent the housing 10. As mentioned previously, with a different well arrangement the fourth conductor means 48 should be in communication with the second passage 16 below the second plug means 51.

Should the first standing valve means V_1 be unable to provide a sufficient pressure differential in the first passage for any reason, communication through the circulation channel 19 can still be established for circulating down the first tubing T_1 and back up the tubing T_2 to the surface S . This is accomplished by first increasing the pressure in the bore G_2 of the tubing T_2 for seating the second standing valve means V_2 to provide the pressure differential to operate the piston means 30 for rotating open the ball 21 to establish flow in the circulation channel 19 and to substantially simultaneously operate the first plug means 50 for blocking in the first passage 15. While holding the increased pressure in the second passage 16 above the standing valve means V_2 to maintain the circulation channel 19 open and the first plug means 50 closed, the pressure in the bore G_1 of the tubing T_1 is increased at the surface S for circulating down the bore G_1 of the tubing T_1 through the circulation channel 19 and upwardly in the bore G_2 of the tubing T_2 back to the surface. This circulation pattern will enable the running of a pump down retrievable tool through the bore G_1 to engage the malfunctioning standing valve V_1 without exposing the formation F_1 to circulation pressure because of the blocking operation of the first plug means 50. After the retrievable tool has engaged and secured to the latch sleeve 68, the direction of flow through the circulation channel 19 may be reversed to move the retrieval tool and first standing valve means V_1 back to the surface while maintaining the fluid pressure in the passage 16 above the second standing valve means V_2 to hold the first plug means 50 closed and the circulation channel 19 open. A properly operating first standing valve means V_1 along with a running tool may then be moved into the operating location in the passage 15 through the bore G_1 of the tubing T_1 by again circulating downwardly through the tubing T_1 and upwardly through the tubing T_2 to the surface. When the standing valve means V_1 is secured in the lower portion 12 of the housing 10 with latch dog 67, circulation may again be reversed to move the running tool back to the surface S through the bore G_1 of the tubing T_1 . Of course, the second standing valve means V_2 may be retrieved or installed in a similar manner and in either instance the well formations F_1 and F_2 are isolated from the increased circulation pressure by operation of either the first plug means V_1 or the second plug means V_2 to prevent possible damage to the formations.

In the use and operation of the present invention the housing 10 is basically assembled as illustrated in detail in FIGS. 2A, 2B, 3A and 3B. The sequence of assembly as well as the arrangement of sealing O-rings and the like is readily apparent to those skilled in the art and will not be considered in detail. For ease of assembly, the ball pivot pins 29, 79 and 179 are preferably assembled in a location other than that illustrated for explaining operation of the tool. When assembled the spring

28 will normally hold the ball 21 in the closed position for blocking communication through the circulation channel 19 while the first and second plug means 50 and 51, respectively, will be maintained in the open position by the urging or springs 80 and 180.

The housing 10 is then connected with well tubings in a desired well arrangement such as that illustrated schematically in FIG. 1. However, it should be clearly understood that other well arrangements including single tubing completions in which the bore O of the casing C provides an annular passageway for circulating well fluids for performing well operations may be used with the present invention.

Typically the housing 10 will be made up in the tubing strings T_1 and T_2 and lowered in the bore O in the casing C to the desired subsurface location where the packers Q_1 and Q_2 may be set in any well known manner. Perforating operations may then be conducted through the bore G_1 and G_2 of the tubings T_1 and T_2 respectively to form the perforation P_1 and P_2 respectively. The first and second standing valve means V_1 and V_2 may then be run through the bores G_1 and G_2 respectively to their operating locations in the housing 10 for securing therein in the manner previously explained. To complete the well it is only necessary to increase pressure in the bore of either of the tubings T_1 and T_2 and operate the well apparatus in the manner previously set forth to circulate a lighter density fluid down the bore of one of the tubings through the circulation channel 19 and up the bore of the other production tubing to displace the heavier drilling fluid which is present in the bore G_1 and G_2 of the production tubings prior to well completion. Many other well operations may be performed using the well apparatus A of the present invention such as, but not in way of limitation, running and retrieval of subsurface safety valves or other well tools.

The foregoing disclosure and description of the invention are 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 without departing from the spirit of the invention.

I claim:

1. A method of operating a well apparatus having a plurality of flow conductor passages therethrough to establish a desired flow path between the flow conductor passages for performing well operations while protecting the well producing formation from fluid pressure conditions while performing the well operations, including the steps of:

- a. increasing the fluid pressure in a first flow conductor passage sensed by the well apparatus;
- b. establishing a circulation channel between the first flow conductor passage and a second flow conductor passage for communicating therebetween to provide a desired flow path for well fluids in response to the increased fluid pressure in the first flow conductor passage; and
- c. blocking flow through the second flow conductor at a desired location by operation of a plug means in response to the increased fluid pressure in the first flow conductor passage communicated to the plug means separate from the circulation channel while substantially simultaneously establishing the circulation channel wherein a desired circulation flow path for well operations is provided.

2. The method as set forth in claim 1, including the step of:
circulating well fluids through the circulation channel in a desired flow path for accomplishing well operations.
3. The method as set forth in claim 1, including the step of:
flowing well fluids through the circulation channel from the second flow conductor passage into the first flow conductor passage for performing well operations.
4. The method as set forth in claim 3, including the step of:
increasing the fluid pressure in the second flow conductor channel to a pressure greater than that of the fluid pressure in the first flow conductor passage for circulating well fluids through the circulation channel into the first flow conductor passage.
5. The method as set forth in claim 1, including the step of:
controlling the increased pressure in the first flow conductor passage for creating a pressure differential in the first flow conductor passage.
6. The method as set forth in claim 1, wherein the step of establishing a circulation channel between the first flow conductor and a second flow conductor includes the step of:
operating a valve for enabling communication through the circulation channel.
7. The method as set forth in claim 6 wherein the step of operating a valve includes the step of:
rotating a valve element for enabling communication through the circulation channel.
8. The method as set forth in claim 7, including the step of:
rotating a ball element for enabling communication through the circulation channel.
9. The method as set forth in claim 1, wherein the step of blocking flow through the second flow conductor includes the step of:
operating a plug means for blocking flow through the second flow conductor.
10. The method as set forth in claim 9, wherein the step of operating a plug means includes the step of:
rotating a plug element for blocking flow through the second flow conductor.
11. The method as set forth in claim 10, including the step of:
moving the plug element longitudinally in the second flow conductor while rotating for blocking flow therethrough.
12. A method of operating a well having a plurality of flow tubings communicating with a housing at a subsurface location in the well with each flow tubing communication one of a plurality of flow conductor passages through the housing with well head control equipment, including the steps of:
 - a. increasing the fluid pressure in a first flow conductor in communication with a first flow conductor passage for increasing the fluid pressure in the first flow conductor passage;
 - b. establishing a circulation channel between the first flow conductor passage and a second flow conductor passage in the housing communicating through a second flow conductor with the well head control equipment; and

- c. blocking flow through the second flow conductor passage at a location below the circulation channel and a standing valve operably secured in the second flow conductor substantially simultaneously with establishing the circulation channel wherein a desired flow path for well operations is provided.
13. The method as set forth in claim 12, including the step of:
circulating well fluids through the circulation channel in a desired flow path for performing well operations.
14. The method as set forth in claim 13, wherein the step of circulating includes:
flowing well fluids through the circulation channel from the first flow conductor passage into the second flow conductor passage for performing well operation.
15. The method as set forth in claim 13, wherein the step of circulating includes:
flowing well fluids through the circulation channel from the second flow conductor passage into the first flow conductor passage for performing well operations.
16. A method of moving well tools to and from a subsurface operating location through a flow conductor including the steps of:
 - a. increasing the fluid pressure in a first flow conductor extending downwardly into the well for blocking flow through a second flow conductor extending downwardly into the well below the subsurface operating location of the well tool; and
 - b. establishing a circulation channel between the first flow conductor and the second flow conductor to enable circulation of well fluids for moving well tools to and from the subsurface operating location.
17. The method as set forth in claim 16, including the step of:
circulating well fluids through the circulation channel for moving well tools through the first flow conductor.
18. The method as set forth in claim 16, including the step of:
circulating well fluids through the circulation channel for moving well tools through the second flow conductor.
19. The method as set forth in claim 16, including the steps of:
flowing well fluid in a first direction through the circulation channel for moving well tools to the subsurface location.
20. The method as set forth in claim 19, including the step of:
flowing well fluid in a second direction through the circulation channel for moving well tools from the subsurface location.
21. A well apparatus adapted for disposal in a well at a subsurface location, including:
 - a housing having first and second flow conductor passages formed therethrough and having means for operably securing a standing valve in each of said first and said second flow conductor passages;
 - a circulation channel formed in said housing for communicating said first and said second flow conductor passages;
 - valve means mounted with said housing for movement to and from open and closed positions for

controlling communication between said first and said second flow conductor passage through said circulation channel; and

actuator means operable connected with said valve means and in separate fluid communication with said first and said second flow conductor passages for moving said valve means to the open position in response to the urging on said actuator means of a predetermined pressure differential resulting from increasing the fluid pressure in one of said first or said second flow conductor passages above well pressure;

plug means mounted with said housing below said circulation channel and the operating location of the received standing valve for blocking flow through the other of said first or said second flow conductor passages in response to the increased fluid pressure in said one of said first or said second flow conductor passages communicated to said plug means wherein said valve means is operated to communicate said first and said second flow conductor passages through said circulation channel above said plug means.

22. The structure as set forth in claim 21, wherein: said valve means including a ball member having a flow port formed therethrough, said ball member rotatable to and from an open position aligning said flow port with said circulation channel for enabling flow through said circulation channel and a closed position for substantially blocking flow of fluid through said circulation channel.

23. The structure as set forth in claim 21, wherein said actuator means includes: biasing means for urging movement of said valve means to the closed position.

24. The structure as set forth in claim 21, wherein said actuator means includes:

a. an operator member operably connected with said valve means for moving said valve means to and from the open and closed positions in response to movement of said operator member; and

b. piston means arranged to move said operator member for moving said valve means to the open position in response to the urging on said piston means of a predetermined pressure differential resulting from increasing the fluid pressure in either said first or said second flow conductor passages to a value greater than well fluid pressure.

25. The structure as set forth in claim 24, wherein: a. said piston means and said housing forming a first expandible chamber communicating with said first flow conductor passage;

b. said piston means having a first pressure responsive surface exposed to the fluid pressure in said first expandible chamber for urging thereon to move said operator member to open said valve means;

c. said piston means and said housing forming a second expandible chamber communicating with said second flow conductor passage; and

d. said piston means having a second pressure responsive surface exposed to the fluid pressure in said second expandible chamber for urging thereon to move said operator member to open said valve means wherein increased fluid pressure in either of said flow conductors greater than well pressure operates said valve means open.

26. The structure as set forth in claim 25, wherein:

a. said piston means and said housing forming a third expandible chamber communicating with well fluid pressure;

and

b. said piston means having a third pressure responsive surface exposed to well fluid pressure for urging thereon in a direction opposite the urging on said first and said second pressure responsive surfaces wherein the urging of increased fluid pressure in either of said first and said second flow conductor passages greater than the urging of the fluid pressure on said third pressure responsive surface urges said operator member to move said valve means to the open position.

27. The structure as set forth in claim 26, wherein:

a. said piston means and said housing forming a fourth expandible chamber communicating with well fluid pressure;

and

b. said piston means having a fourth pressure responsive surface exposed to well fluid pressure in said fourth expandible chamber for urging thereon in a direction opposite the urging on said first and said second pressure responsive surface wherein the urging of fluid pressure in said first and said second flow conductor passage greater than the urging of the fluid pressure on said third and said fourth pressure responsive surface moves said operator member to open said valve means.

28. The structure as set forth in claim 27, including:

a. said third expandible chamber communicating with the well fluid pressure present below said housing and communicating with said first flow conductor; and

b. said fourth expandible chamber communicating with the well fluid pressure present below said housing and communicating with said second flow conductor.

29. The structure as set forth in claim 21, including: first plug means mounted with said housing for blocking flow through said first flow conductor passage at a location spaced from said circulation channel when the fluid pressure in said second flow conductor passage is increased for effecting the desired pressure differential to communicate said first and said second flow conductor passages through said circulation channel.

30. The structure as set forth in claim 29, wherein: said first plug means includes a ball member having a flow port formed therethrough, said ball member rotatable to and from an open position aligning said flow port with said first flow conductor passage for enabling flow through said first flow conductor passage and a closed position for substantially blocking flow of fluid through said circulation channel.

31. The structure as set forth in claim 30, wherein: said ball member moves longitudinally in said first flow conductor passage in rotating to and from the open and closed positions.

32. The structure as set forth in claim 29, wherein:

a. said first plug means including a first plug operator means for moving said first plug means to and from the open and closed position;

b. said first plug operator means having a first pressure responsive surface communicating with the fluid pressure in said second flow conduit passage

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for urging movement of said first plug means to the closed position for blocking flow through said first conductor passage when the fluid pressure in said second flow conductor passage is increased to communicate said first and said second flow conductor passages through said circulation channel.

33. The structure as set forth in claim 32, wherein: said first plug operator means having a second pressure responsive surface communicating with well fluid pressure for urging movement of said first plug means to the open position.

34. The structure as set forth in claim 29, including: a standing valve means located in said second flow conductor passage for effecting a desired pressure differential urging on said actuator means for operating said first plug means when the pressure in said second flow conductor passage is increased wherein said valve means is operated to communicate said first and said second flow conductor passages through said circulation channel and said first plug means blocks flow through said first conductor passage.

35. The structure as set forth in claim 34, wherein: said first plug means blocks flow through said first conductor flow passage at a location for flowing fluids communicated through said circulation channel from said second flow conductor into said first flow conductor in a desired direction in said first flow conductor.

36. The structure as set forth in claim 34, wherein: said housing having said first plug means spaced from said circulation channel for receiving at an operating location therebetween in said first flow conductor passage a first flow conductor passage standing valve means movable through said first flow conductor passage, said first flow conductor passage standing valve means operably located therein for flowing fluids communicated through said circulation channel from said second flow conductor into said first flow conductor in a desired direction in said first flow conductor.

37. The structure as set in claim 36, wherein: said first plug means blocking flow of fluids through said first conductor flow passage at a location in said first flow conductor passage to separate the well fluid pressure in said first flow conductor passage below said plug means from the fluid pressure communicated through said circulation channel.

38. The structure as set forth in claim 37, including second plug means mounted with said housing for blocking flow through said second flow conductor passage when the fluid pressure in said first flow conductor passage is increased for effecting the desired pressure differential to communicate said first and said second flow conductor passage through said circulation channel.

39. The structure as set forth in claim 38, wherein:
a. said standing valve means in said second flow con-

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ductor passage is movable therethrough to an operating location between said circulation channel and said second plug means;

b. said second plug means blocking flow of fluids through said second conductor flow passage below the operating location of said second flow conductor passage standing valve means to separate the well fluid pressure in said second conductor passage below said plug means from the fluid pressure communicated through said circulation channel.

40. A well apparatus adapted for disposal in a well at a subsurface location for performing well operations as desired, including:

a. a housing having a flow conductor passage formed therethrough adapted to be mounted with a well tubing at a subsurface location with said passage in communication with the bore of the well tubing;

b. a circulation channel formed in said housing for communicating said flow conductor passage and the bore of a second well conductor;

c. valve means mounted with said housing for movement to and from open and closed positions for controlling communication through said circulation channel;

d. actuator means operably connected with said valve means and in fluid communication with the bore of the second well conductor for moving said valve means to the open position in response to the urging on said actuator means of an increased fluid pressure in the bore of the second well conduit; and

e. plug means mounted with said housing for blocking flow through said flow conductor passage at a location below said circulation channel in response to the increased fluid pressure in the bore of the second well conduit communicated to said plug means independent of said circulation channel wherein the well apparatus is operated by increased fluid pressure in the bore of the second well conduit communicated to said plug means.

41. The structure as set forth in claim 40, including: a standing valve means operably located in said flow conductor passage above said plug means.

42. The structure as set forth in claim 41, wherein: said standing valve means is movable through said flow conductor passage to the operating location, said plug means blocking flow through said flow conductor passage during movement of said standing valve means to separate the well fluid pressure in said flow conductor passage below said plug means from the fluid pressure in said flow conductor passage adjacent said circulation channel.

43. The structure as set forth in claim 40, wherein: said plug means is located to block flow in said flow conductor passage to enable the performing of well operation by flowing fluids through said circulation channel in a desired manner.

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