Jan. 21, 1964 C. B. COCHRAN 3,118,502

WELL COMPLETION APPARATUS

Filed Feb. 24, 1960 2 Sheets-Sheet 1

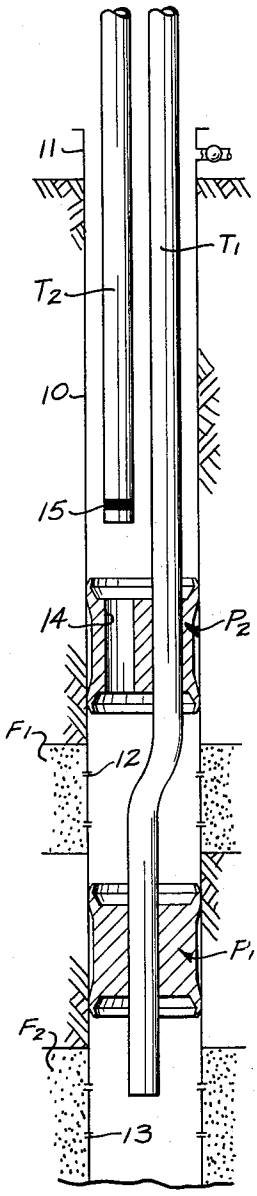


Fig. 1

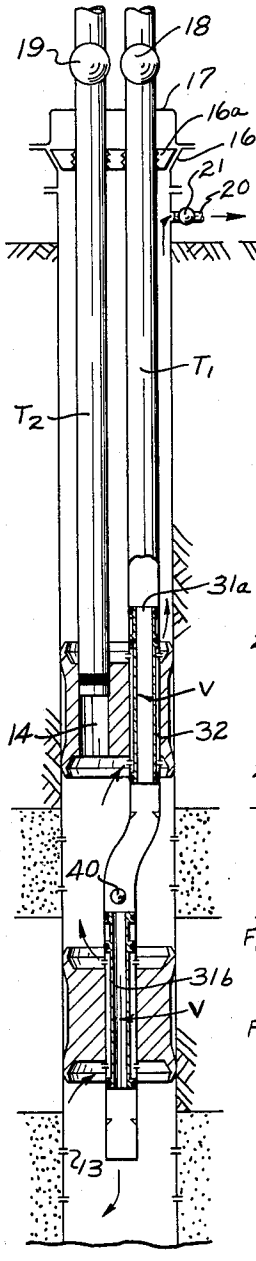


Fig. 2

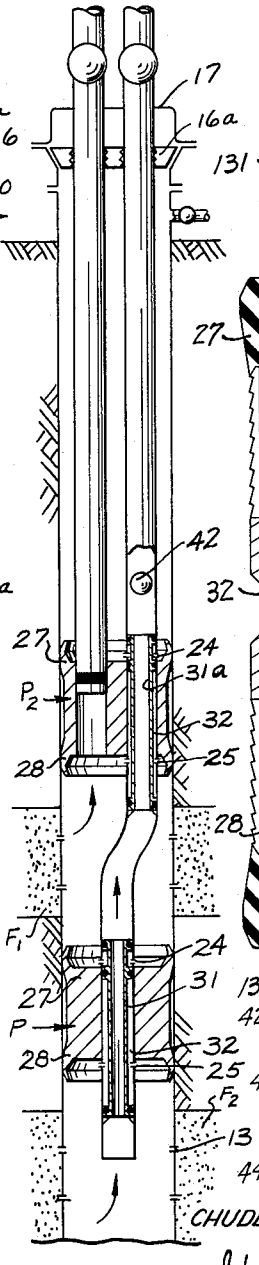
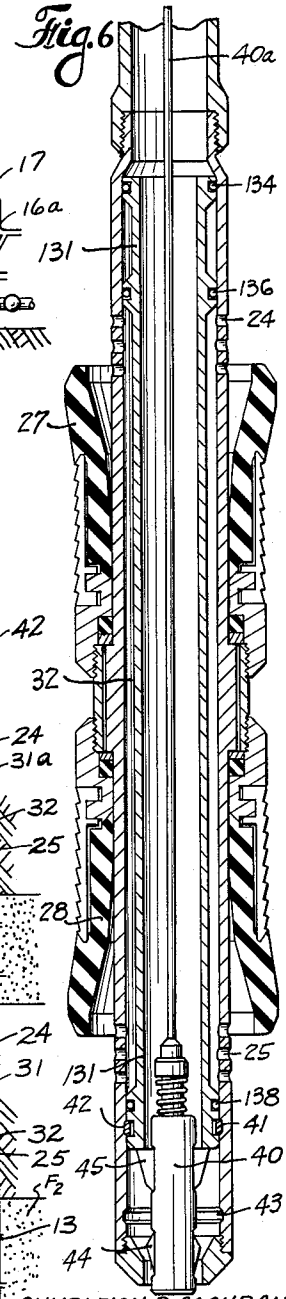


Fig. 3

Fig. 6



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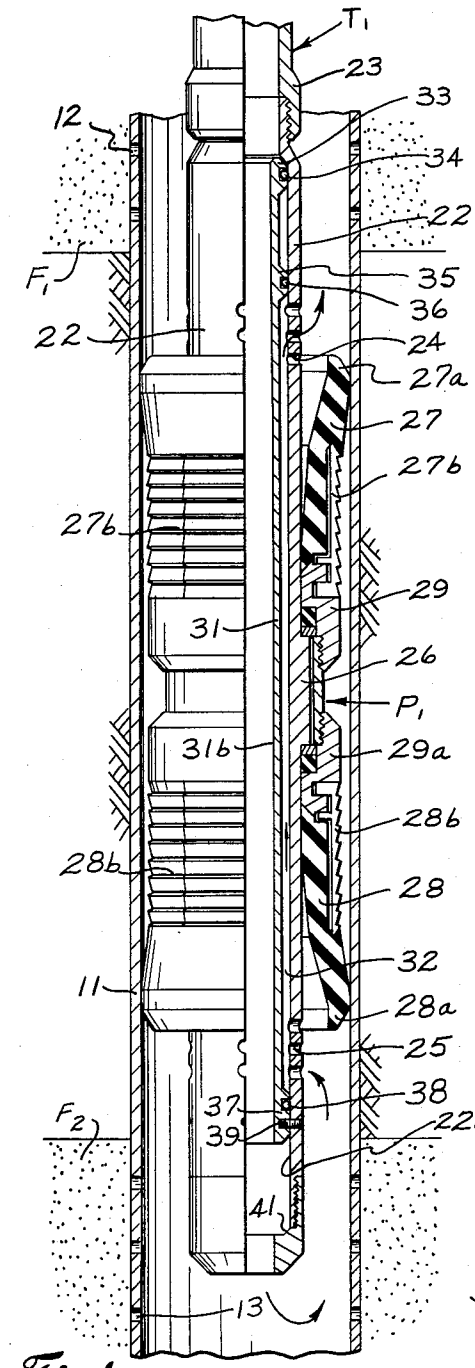

Fig. 4

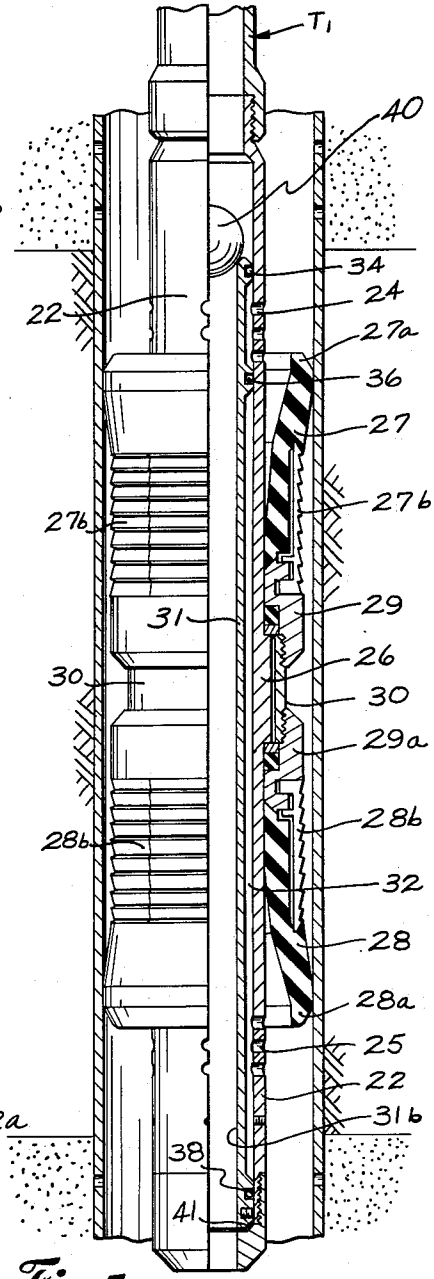

Fig. 5

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WELL COMPLETION APPARATUS

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Filed Feb. 24, 1960, Ser. No. 10,603
14 Claims. (Cl. 166—129)

This invention relates to new and useful improvements in well completion apparatus for use in producing well fluids from a plurality of production zones and relates particularly to an improved well packer.

In the prior patent to Brown 2,903,066, issued September 8, 1959, a well packer apparatus and method is disclosed wherein a plurality of well packers may be finally positioned in a well bore in unset position, after which the tubing strings are landed and the surface control head equipment is mounted to maintain the well under control. Thereafter, circulation around the unset packers may be accomplished and then the packers may be moved to set or sealing position, all without disturbing the tubing strings and the control head equipment, whereby full control of the well is maintained at all times. The particular advantages in such prior patent are obtained by the use of well packers which may be selectively set without requiring any movement, either longitudinal or rotative, of the well tubing strings.

Experience has shown that in some instances it may be desirable to employ well packers which are of the type set by the pressure-differential across the packer. Such differential-pressure setting packer normally employs annular packing cups which are acted upon by the pressure above and below said packer and because of the use of the pressure-actuated cups, a constant contact between the packing cups and wall of the well pipe is maintained. For this reason circulation around this type of packer is not possible and heretofore the cup-type or differential-pressure setting packers have been incapable of use with a method wherein the tubing strings are in final position and the surface control head equipment placed prior to any circulation operation and prior to the final setting of the packers.

It is, therefore, one object of this invention to provide a well completion apparatus which includes spaced well packers of the differential-pressure setting type wherein each packer has means for initially permitting a by-pass of fluid around the packer elements whereby circulation past the packer may be accomplished, after which said by-pass means may be closed to allow the packer elements to be moved into sealing position; the apparatus lending itself to use in a method wherein the tubing strings are finally landed and the surface control head equipment is in place prior to closing of the by-pass means in each packer, whereby circulation may be carried out with the well under full control, following which said by-pass may be closed to set the packers.

An important object is to provide an improved well packer for use in well completion apparatus, which packer is moved into set position by the pressure differential thereacross and which has a normally open by-pass means allowing flow through and around the sealing elements of the packer, said by-pass means being arranged to be closed from the surface of the well without requiring any movement of the packer or of the well pipe on which said packer is mounted.

Another object is to provide a well packer, of the character described, having a by-pass passage which is opened and closed by a movable valve element; said element being actuated either by the pressure within the well pipe or tubing on which the packer is mounted or being actuated by a mechanical means which is controlled from the surface of the well.

The construction designed to carry out the invention

will be hereinafter described, together with other features thereof.

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

FIGURE 1 is a diagrammatic view illustrating the well completion apparatus showing the well packers, constructed in accordance with the invention, being lowered into a well bore on a first tubing string;

FIGURE 2 is a similar view, showing the second tubing string in position, with both tubing strings and the surface control head equipment in final position and with the by-pass around each packer open;

FIGURE 3 is a similar view illustrating the by-pass around each well packer closed and with the packers set to separate the producing formations;

FIGURE 4 is a view, partly in section and partly in elevation of one of the well packers and showing the valve which controls flow through the by-pass in a position maintaining the by-pass open;

FIGURE 5 is a similar view, showing the valve in a position closing the by-pass; and

FIGURE 6 is a longitudinal sectional view of a slightly modified form of the invention.

In the drawings the numeral 10 designates a well bore which traverses an upper well fluid producing formation F1 and a lower well fluid producing formation F2. The usual well casing 11 extends downwardly within the bore of the well and is provided with perforations 12 opposite the formation F1 and similar perforations 13 opposite the formation F2 whereby the well fluids from these formations may flow into the bore. Since it is desirable to produce the well fluids from each formation through a separate well tubing string, it is necessary to separate the formations by means of well packers and to lower separate tubing strings into the bore.

The well casing normally contains the usual mud or weighted fluid which fills the casing and acts against the producing formations to maintain the well under control. For separating the production from the two producing formations F1 and F2, a pair of well packers P1 and P2, which will be hereinafter described in detail, are mounted on a first tubing string T1 and are located in proper spaced relation on said string. By means of the tubing string, the packers are lowered through the fluid within the bore and into the position shown in FIGURE 1 to locate the lower packer P1 between the formations F1 and F2 and to locate the upper packer P2 above the upper formation F1. The lower end of the tubing string T1 communicates with the well fluid producing formation F2 whereby the well fluids from this formation may flow upwardly through said tubing.

After the first tubing string and the packers P1 and P2 are positioned as illustrated in FIGURE 1, a second tubing string T2 is lowered downwardly within the well bore in parallel relationship to said first tubing string and the lower end of said second tubing string is engageable within a bore or passage 14 formed in the upper packer P2. A suitable seal ring 15 may be mounted on the lower portion of the tubing string T2 so that when said string is in place within the passage, a suitable seal between this tubing string and packer P2 is maintained. If desired, the lower end of the second tubing string may be releasably connected to the upper packer by means of the well-known J-slot (not shown) or other suitable means. When in position, the lower end of the second tubing string T2 communicates with the area between the packers whereby well fluids from the upper formation F1 may be conducted to the surface through the second tubing string.

After the tubing strings T1 and T2 have been positioned within the well bore, said strings are supported or suspended from their upper portions by means of the usual tubing head 16 having the supporting slip members 16*a*. The usual tubing head cap or closure 17, which seals off around the tubing strings and closes in the upper end of the well casing 11, is then positioned in the manner shown in FIGURES 2 and 3. The tubing string T1 is provided with a control valve 18 in its upper end while tubing T2 has a similar control valve 19 therein, said valves controlling flow through said strings. The usual side outlet line 20 having control valve 21 connected therein extends from the upper portion of the casing at a point just below the tubing head 16. After the tubing strings and packers are positioned with the packing elements of said packers performing their sealing function, the well fluids from each formation will be conducted to the surface through its particular tubing string.

Because the well casing is normally maintained full of weighted fluid or mud to hold the well under control while the packers and tubing strings are being run, it is desirable that each packer be provided with a by-pass around its external packing element so that said packing element does not function as a seal while the packers are being lowered and positioned within the well bore. Also, after the tubing strings have been suspended in the manner shown in FIGURE 2, it is desirable to circulate the weighted fluid or mud out of the well bore prior to the final setting of the packing elements of the packers P1 and P2.

The particular type of packers P1 and P2 are of the pressure differential setting type, that is, each packer is moved into tight sealing engagement with the wall of the casing by the differential in pressures acting across the packer. Such a packer normally employs lip-type packing elements which are subject to the action of the fluid against said lips and as a result a circulation through or around the packer is not possible.

To adapt the pressure differential type of packer for use in the present method, each packer is provided with a by-pass passage therethrough and such passage is controlled by a slidable valve V; the valve is in the form of a tubular sleeve which is mounted within the support or mandrel of its respective packer. When the packers are initially run, the valve sleeve of each packer is in a position maintaining the by-pass passage through the packer open so that during running in of the packers, the by-pass remains open to permit equalization of pressure across the packing elements of the packers and thereby prevent each packing element from effecting a tight seal with the casing wall. After the packers reach final position as shown in FIGURE 2, their by-pass passages may remain open to allow the desired circulation through said packers.

After the circulation step is complete, the sleeve valves V of the two packers, as will be hereinafter explained, are actuated to move said valves to a position closing the by-pass passages and when this occurs, the pressure differential across the packer elements moves said elements into a sealing position with the wall of the well casing to effectively separate the well fluids from the two producing formations.

In FIGURES 4 and 5 the detailed construction of the lower packer P1 is illustrated. This packer includes a tubular support or mandrel 22 which has its upper end adapted to be connected through a coupling 23 with the tubing string T1 and which has its lower end open to communicate with the area therebelow. A plurality of upper by-pass openings 24 extend through the wall of the mandrel at its upper portion while similar by-pass openings 25 are provided in the lower portion of said mandrel. Intermediate the upper and lower by-pass openings, the mandrel is formed with an external annular enlargement or flange 26 adjacent which is mounted an upper packer cup or element 27 and a lower packer cup or element 28. The upper packer cup comprises a body portion having an upwardly directed sealing lip 27*a* and the base of said cup is molded or otherwise attached to a supporting collar 29 which surrounds the mandrel above said enlargement 26. The lower cup comprises a body portion having a downwardly directed sealing lip 28*a* and the base of said cup is molded or attached to a supporting collar 29*a* which surrounds the mandrel below the enlargement or flange. The supporting collars are secured to each other by a short nipple 30 which encompasses the enlargement 26 of the mandrel and with this arrangement the packer cups or elements are retained in position on the mandrel.

The packer cup 27 is preferably provided with arcuate slip sections 27*b* which are molded or otherwise secured in the exterior surface of said cup and which have gripping teeth formed thereon. When the packer cup 27 is deformed outwardly into sealing engagement by the pressure acting thereon, the slip sections are displaced radially outwardly to engage their teeth with the casing to assist in holding the packer in position. Similar arcuate slip sections 28*b* are embedded within the lower packer cup 28 and engage the casing when said cup is deformed outwardly into sealing position. It is evident that pressure acting against the lower cup 28 will move its sealing lip into sealing position while pressure acting downwardly on the upper cup 27 will move the sealing lip thereof into sealing engagement with the casing 11. Therefore, the packer elements are actuated by the differential of pressure across the packer and regardless of which pressure is greater, a proper and effective sealing with the wall of the well casing is accomplished.

Co-acting with the upper and lower by-pass openings 24 and 25 is an elongate, tubular valve sleeve 31 which is slidable within the bore 22*a* of the mandrel. The valve sleeve has the major portion of its outer surface of a diameter less than the diameter of the bore 22*a* of said mandrel, whereby an annular flow space or passage 32 is formed between the parts. The extreme upper end of the valve sleeve has an enlarged annular flange 33 which slidably fits the bore 22*a* and an annular sealing ring 34 which seals with the bore is carried by said flange. Spaced downwardly from the upper annular flange 33 is a second similar annular flange 35 having a sealing ring 36 mounted thereon. A third annular flange or enlargement 37 is formed at the lower end of the valve sleeve and has a sealing ring 38 therein for slidably sealing with the bore 22*a* of the mandrel. The valve sleeve 31 is normally maintained in a raised position with respect to the mandrel 22 by means of a frangible shear pin 39, as illustrated in FIGURE 4.

With the valve sleeve in its raised position (FIGURE 4), the upper flanges 33 and 35 and their respective seals 34 and 36 are above the upper by-pass openings 24 while the lower flange 37 and its seal 38 are below the lower by-pass openings 25. In this position of the valve sleeve, fluid entering the lower by-pass openings 25 from the area below the packer flows upwardly through the annular passage 32 formed between the exterior surface of sleeve 31 and the bore 22*a* of the mandrel and then passes outwardly through the upper by-pass openings 24 into the area above the packer, whereby a free by-pass of fluid through the packer and around the sealing elements 27 and 28 occurs. The valve sleeve 31 is in this position during the lowering of the well packer into position and during the time that a circulation around the packer is desired.

After the packer has been positioned and the circulating of fluid around the packer has been accomplished, it is then desirable to close the by-pass passage 32. In the form of the invention shown in FIGURES 1 to 5, this is accomplished by dropping a closure 40, which is illustrated as a ball, downwardly through the tubing string T1. The closure or ball 40 is of a size to engage the upper end of the sleeve 31 to close the bore of the sleeve and thereafter the application of a fluid pressure applies a downward force to the sleeve sufficient to frac-

ture the frangible pin 39. When the frangible pin 39 is broken, the sleeve may move downwardly to the position shown in FIGURE 5 with its lower end in engagement with an annular seat or shoulder 41 provided at the lower end of the mandrel 22. In such position the uppermost seal 34 has moved to a position just above the upper by-pass openings 24 while the seal 36 on the valve sleeve has moved below said by-pass openings. With the seals 34 and 36 disposed on opposite sides of the upper by-pass openings, flow through the annular passage 32 is effectively closed. It is then possible for the differential of pressure acting across the packing elements 27 and 28 to move said elements into effective sealing engagement with the well casing.

In FIGURES 4 and 5 the lowermost packer P1, having the mandrel 22 extending axially therethrough, is illustrated. In the case of the upper packer, the mandrel 22 is disposed at one side of the packer so as to provide space for the longitudinal opening or passage 14 which receives the second tubing string T2. The upper packer P2 is provided with the same type of by-pass passage and the same type of valve sleeve 31. The only difference between the valve sleeve 31 of the upper packer and the valve sleeve 31 of the lower packer is that the bore 31*a* of the valve sleeve of the upper packer is larger than the bore 31*b* of the valve sleeve of the lower packer. By making the bore 31*a* of the upper packer valve sleeve larger, the closure or ball 40 may be dropped downwardly and may pass through the valve sleeve of the upper packer to seat upon the sleeve of the lower packer to actuate the same.

After the valve sleeve of the lower packer has been actuated, the ball 40 is removed by permitting an upward flow through tubing string T1 which flows the ball to the surface. However, if a different closure, such as a plug is used, it may be removed by a wire line operation. Thereafter, a second closure also shown as a ball 42, which is of larger diameter, is dropped downwardly through the tubing string to engage the upper end of the sleeve 31 of the upper packer P2. The application of pressure thereafter will move the valve sleeve of the upper packer downwardly to close the by-pass passage through said upper packer. Upon subsequent flow of well fluids upwardly through the tubing string T1, the closure 42 will be carried back to the surface and recovered or said closure could be recovered by a suitable retrieving means.

Although the by-pass passage and the valve sleeve 31 of the upper packer P2 have been shown as communicating with the tubing string T1, it is apparent that said by-pass and valve may be disposed within the passage 14. In such case, the closure 42 would be dropped downwardly through the second tubing string T2 in order to actuate the valve to close said by-pass.

The use and operation of the apparatus is believed evident from the foregoing. Packers P1 and P2 are connected to the first tubing string T1 and each of these packers has its valve sleeve 31 in a position maintaining its by-pass 32 open; each sleeve, as above noted, is held in such position by the frangible shear pin 39. The tubing string T1 having the packers thereon is run into the well bore and is properly positioned with respect to the producing formations F1 and F2 as shown in FIGURE 1. Since the by-pass 32 of each packer is open, a free flow of fluid through the packers and past the sealing elements thereof may occur and the pressures across the packing cups 27 and 28 of each packer are equalized. Thereafter, the second tubing string T2 is lowered and has its lower end connected in or engaged with the passage 14 of the upper packer P2.

The tubing string T1 is then landed in the tubing head 16 after which the second string T2 is properly supported; thereafter, the upper end of the bore is closed by the cap or closure 17. At this time the valve sleeves 31 of the packers are still in a position holding the by-pass passage 32 open and any desired circulation downwardly through either tubing string and back upwardly through the annulus may be carried out. This circulation or flow is indicated by the arrows in FIGURE 2.

After the circulation step is complete, the first ball or closure 40 is dropped downwardly through tubing string T1 and this ball passes through the upper packer P2 to finally land on the upper end of valve sleeve 31 of the lower packer P1. Application of pressure through the tubing string T2 sufficient to fracture the pin 39 moves the valve sleeve downwardly to the position shown in FIGURE 5 to locate the seals 34 and 36 at the upper portion of the valve sleeve 31 in a position spanning the upper by-pass openings 24 whereby the by-pass passage 32 of the lower packer is effectively closed. After the by-pass passage of the lower packer P1 has been closed, upward flow from the formation F2 is permitted to flow the closure 40 upwardly and out of the well.

The second closure or ball 42 is thereafter dropped downwardly through the first tubing string T1 and such ball seats upon the upper end of the valve sleeve 31 of the upper packer P2. Application of pressure results in fracturing the pin maintaining the valve sleeve of the upper packer in its raised position with the result that said sleeve moves downwardly to effectively close the by-pass through the upper packer P2. Upon subsequent upflow of fluids through tubing T1, the closure or ball 42 is carried to the surface and thereby removed from the well. With the by-pass passages through the packers closed, the differential of pressure across said packers may act upon the packing cups 27 and 28 of said packers to move one or the other thereof into effective sealing engagement with the well casing. Thereafter, production of well fluids from the formations F1 and F2 may be carried out through the independent tubing strings T1 and T2.

In the form of the invention shown in FIGURES 1 through 5 the sleeve valve 31 of each packer is actuated by hydraulic pressure applied through the tubing strings after a closure or plug has been dropped into position. In this first form the frangible shear pin 39 is utilized to initially retain the sleeve in position closing the by-pass passage and the application of the pressure fluid shears the pin and moves the sleeve to a position closing the by-pass.

In FIGURE 6 a modified form of the invention is illustrated wherein a valve sleeve 131 is selectively moved by means of a wire line tool 40. The structure of FIGURE 6 is substantially identical, insofar as the packer is concerned, to the structure of the first form and includes the mandrel 22 having upper by-pass openings 24 and lower by-pass openings 25. The upper packer cup 27, having its lip directed upwardly, and the lower packer cup 28, having its lip directed downwardly, are confined on the mandrel 22 in the manner heretofore described.

Instead of the valve sleeve 31 of the first form, the modification includes the valve sleeve 131 which is similar in construction except that it is not retained in position by a frangible shear pin. The sleeve 131 includes spaced upper seals 134 and 136 which are initially above the upper by-pass openings 24; it also includes the lower seal 138 which is initially disposed below the lower by-pass openings. For initially retaining the sleeve 131 in its upper position, which allows flow through the annular by-pass passage 32, the lower end of the sleeve 131 is provided with an annular, split snap ring 41 which is engageable within an annular groove 42 formed in the lower portion of the mandrel 22. Spaced below the groove 42 is a second groove 43, which is engageable by the snap ring 41 when the sleeve is moved to a lower position closing the by-pass passage 32.

The operation of the modification of FIGURE 6 is believed obvious. Initially the valve sleeve 131 is in its raised position within the mandrel and is retained therein by the fractional engagement of the snap ring 41 with the

groove 42; in such position, the by-pass passage 32 is open and the packer may be lowered into position and desired circulation carried out.

After circulation has been completed and it is desired to close the by-pass, the actuating tool 40 is lowered downwardly by means of the wire line 40*a*. The tool 40, which is of well-known construction, has lower expansible elements 44 which would expand to engage the upper end of sleeve 131, whereby a downward force may be applied to the sleeve to shift it to its lower position. In such lower position the snap ring 41 will engage and frictionally lock within groove 43. As has been explained, downward shifting of the sleeve will close the by-pass passage 32.

After the sleeve has been shifted, the tool 40 is removed from the pipe string and returned to the surface.

If it should be desired to reopen the by-pass 32 for any reason, tool 40 is again lowered and is passed downwardly through the bore of the sleeve to a point below the sleeve. Upon subsequent upward movement of the tool, expansible elements 45 will engage the underside of the sleeve 131 in the manner shown in FIGURE 6 so that an upward pull will return the sleeve to its initial upper position to reengage snap ring 41 with the groove 42. The tool 40 is so arranged that after the shifting has been accomplished, the expansible elements 45 are retracted to permit the tool to be removed from the pipe string. The form of the invention shown in FIGURE 6 permits the valve sleeve to be selectively shifted to selectively open and close the by-pass around the packing cups as conditions may require.

The invention makes it possible to employ a pressure differential setting type of packer in a well completion apparatus which requires the circulation of fluid out of the well bore prior to final effective sealing of the packers. In the pressure differential setting type of packer, the sealing lips of the packer cups are constantly urged toward a full sealing engagement. However, by providing a by-pass which may be selectively closed, the packing cup of the packers are rendered noneffective until such time as the particular by-pass is closed. The sleeve valve which controls each by-pass is actuated from the surface and is, therefore, under control of the operator.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What I claim is:

1. A well completion apparatus including, a well casing within the well bore, a first well tubing string within the well casing, a pair of well packers mounted in spaced longitudinal relationship on said well tubing string, the upper packer having a pair of passageways extending therethrough, one of the tubing strings extending through one of the passageways of said upper packer, a separate and independent second well tubing string extending through the well casing and having its lower portion connected with the other of the passageways in the upper packer, a well head assembly mounted at the upper end of the well casing for controlling fluid flow through the tubing strings and through the casing, support means in said well head assembly for suspending said well tubing strings longitudinally within the well casing, means communicating said first tubing string with the area below the lower packer, means communicating said second tubing string with the area between the packers, each packer including an annular sealing means movable into sealing engagement with the well casing for sealing with said well casing, each packer also having a by-pass passage therein for by-passing flow from the area in the well casing below the sealing means to the area in the well casing above said sealing means when said sealing means is in sealing engagement, and movable valve means forming part of each packer and associated with said by-pass passage and movable to one position to open said by-pass and movable to a second position to close said by-pass.

2. A well completion apparatus as set forth in claim 1, wherein each packer has its sealing means exposed to fluid pressure thereabove and therebelow, whereby said sealing means is actuated and moved into final sealing engagement with the well casing by the differential pressure thereacross, together with means for releasably retaining the valve means in a position opening the by-pass passage whereby the packers may be lowered into the well without moving the pressure-actuated sealing means into sealing position, and means operable from the well surface for releasing said retaining means to move the valve means to a position closing said by-pass passage, release of the retaining means being effected while the tubing strings remain stationary within the well bore.

3. A well completion apparatus as set forth in claim 1 wherein the pressure-actuated sealing means on each packer comprises an upwardly directed sealing cup member at the upper end of said packer and a downwardly directed sealing cup member at the lower end of the packer.

4. A well completion apparatus as set forth in claim 2, wherein each valve means is a tubular sleeve element slidable within a bore formed in its packer and wherein the means for releasably retaining said sleeve in a position opening the by-pass passage is a frangible pin, said means for releasing said frangible pin comprising a plug adapted to close the bore of the tubular sleeve element whereby a predetermined fluid pressure sufficient to fracture said pin may be applied to said sleeve element.

5. A well completion apparatus including, a first tubing string having its lower end communicating with a lower producing formation, a lower well packer adapted to seal with the well wall on the lower portion of the first tubing string, a second well packer adapted to seal with the well wall mounted on said first tubing string and spaced above the first packer, a second tubing string connected to the upper packer and having its lower end communicating with a second formation between said packers, said lower packer including a tubular support having a by-pass passage therein, the lower end of said passage communicating with the well bore annulus surrounding the first tubing string below the lower packer and having its upper end communicating with said annulus above said packer, a tubular valve sleeve within the support movable to an upper position to open the by-pass passage and movable to a lower position to close the by-pass passage, means releasably retaining the valve sleeve in its upper position, said upper packer including a tubular support having a by-pass passage therein, the lower end of said passage communicating with the well bore annulus below the upper packer and having its upper end communicating with said well bore annulus above said upper packer, a tubular valve sleeve within the support movable to an upper position to open the by-pass passage and to a lower position to close said by-pass passage, means releasably retaining the valve sleeve in its upper position, and means actuated by fluid pressure within the tubing strings for releasing the valve sleeves of both packers and moving the same downwardly within their respective supports to close their respective by-pass passages.

6. A well completion apparatus including, a first tubing string having its lower end communicating with a lower producing formation, a lower well packer adapted to seal with the well wall on the lower portion of the first tubing string, a second well packer adapted to seal with the well wall mounted on said first tubing string and spaced above the first packer, a second tubing string connected to the upper packer and having its lower end communicating with a second formation between said packers, said lower packer including a tubular support having a by-pass passage therein, the lower end of said passage communicating with the well bore annulus surrounding the first tubing

string below the lower packer and having its upper end communicating with said well bore annulus above said packer, a tubular valve sleeve within the support movable to an upper position to open the by-pass passage and movable to a lower position to close the by-pass passage, means releasably retaining the valve sleeve in its upper position, said upper packer including a tubular support having a by-pass passage therein, the lower end of said passage communicating with the well bore annulus below the upper packer and having its upper end communicating with said annulus above the upper packer, a tubular valve sleeve within the support movable to an upper position to open the by-pass passage and to a lower position to close said by-pass passage, means releasably retaining the valve sleeve in its upper position, the bore of the valve sleeve within the upper package being larger in internal diameter than the internal diameter of the bore of the valve sleeve within the lower packer, a plug lowerable within one of the tubing strings and of such size as to pass through the bore of the valve sleeve of the upper packer but to engage the valve sleeve of the lower packer, whereby fluid pressure within said tubing may be applied to the valve sleeve of the lower packer to release the retaining means and move the sleeve downwardly to close the by-pass through the lower packer, and a second plug of a size larger than the bore of the valve sleeve of the upper packer lowerable through one of said tubing strings and engageable with the last-named sleeve, whereby fluid pressure may be applied to said valve sleeve of the upper packer to release the retaining means and move the same downwardly to close the by-pass passage.

7. A well completion apparatus as set forth in claim 5, wherein each well packer includes packing means on its exterior which is movable into sealing position with the wall of the well bore by the pressure differential acting across said packer.

8. A well completion apparatus as set forth in claim 6, wherein each well packer includes packing means on its exterior which is movable into sealing position with the wall of the well bore by the pressure differential acting across said packer.

9. A well completion apparatus as set forth in claim 5, wherein each well packer includes a pair of superposed elastic sealing cup elements, the sealing lip of the upper cup being directed upwardly and the sealing lip of the lower cup being directed downwardly.

10. A well packer including, a tubular support having a lower by-pass opening and an upper by-pass opening, a packing means actuated by the pressure differential thereacross mounted on the exterior of the support and located between the upper and lower by-pass openings, a valve sleeve slidable within the bore of the support and having a length greater than the spacing between the upper and lower by-pass openings, a portion of the sleeve being of less external diameter than the diameter of the bore of the support to define a by-pass passage around the packing means, sealing means for sealing the upper and lower ends of the valve sleeve with the bore wall of the support whereby when the sleeve is in a position with its upper end above the upper by-pass opening and its lower end below the lower by-pass opening said by-pass passage is open, and means for releasably retaining the valve sleeve in said position permitting flow of fluid through the by-pass passage whereby pressure across the packing means is equalized and flow around said packing means may occur.

11. A well packer as set forth in claim 10, wherein the packing means comprises a pair of annular sealing cups, the upper cup being directed upwardly and the lower cup being directed downwardly.

12. A well packer as set forth in claim 10, together with means for releasing said retaining means to permit downward movement of said valve sleeve, means within the tubular support for limiting said downward movement of the valve sleeve to a predetermined distance to locate the upper portion of the sleeve and its sealing means between the upper and lower by-pass openings to thereby close the by-pass passage.

13. A well packer as set forth in claim 10, wherein the means for releasably retaining the valve sleeve in position allowing flow through the by-pass passage is a frangible element, a closure adapted to be lowered within the tubing string to close the bore of the valve sleeve, whereby a fluid pressure may be applied to the valve sleeve to fracture the element and move the valve sleeve downwardly, and means for limiting downward movement of said sleeve to locate its upper portion and the sealing means thereon between the by-pass openings to close said by-pass passage.

14. A well packer including, a tubular support having a lower by-pass opening and an upper by-pass opening, packing means mounted on the exterior of the support and movable into a final sealing engagement with the wall of the well bore, said packing means being located upon the support between the upper and lower by-pass openings, a valve sleeve slidable within the bore of the support and having a length greater than the space between the upper and the lower by-pass openings, a portion of the sleeve being of less external diameter than the diameter of the bore of the support to define a by-pass passage around the packing means, sealing means for sealing the upper and lower ends of the valve sleeve with the bore wall of the support whereby when the sleeve is in a position with its upper end above the upper by-pass opening and its lower end below the lower by-pass opening said by-pass passage is open, and means for releasably retaining the valve sleeve in said position permitting flow of fluid through the by-pass passage, whereby pressure across the packing means is equalized and flow around said packing means may occur.

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