METHOD AND APPARATUS FOR PRESSURING WELL BORES

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Drawings:

Fig. 1.

Fig. 2.

Fig. 3.

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METHOD AND APPARATUS FOR PRESSURING WELL BORES

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The present invention relates to the application of positive and negative fluid pressures to well bores, and more particularly to localized regions or zones in the well bores.

Henceforth, perforations in casing disposed in a well bore have been straddled by packing members to provide a localized zone or region between the packing members in which pressure could be applied to the casing, the pressure being imposed through the perforations to the formation in the well bore containing the casing. The packing members, if the tool is of the retrievable type, are secured together in some fashion at a fixed longitudinal distance apart, thereby corresponding to the length of the localized zone to a fixed distance. They are also incapable of withstanding safely relatively high pressures, such as are offertimes required in the performance of certain operations in the well bore, like formation fracturing, acidizing, cementing and testing.

It is an object of the present invention to provide an improved method and apparatus for straddling casing perforations and for applying high pressures safely to the locations surrounding the casing perforations.

Another object of the invention is to provide a method and apparatus for varying the distance that longitudinally spaced packing members or structures are separated from each other, in order to enable the most optimum spacing to be selected when the apparatus is disposed in the well casing.

A further object of the invention is to provide upper and lower packing structures in a well casing on opposite sides of casing perforations and selectively set the packing structures at any point in the well casing separated by various distances from each other, then releasing one or both of the structures for resetting at other locations in the well casing, or for complete removal from the well casing. In a more limited sense, the lower packing structure can be set in the well casing to withstand fluid pressures from above or below the structure, or both, which is also true of the upper packing structure.

In its general aspects, the invention includes the securing of an upper retrievable well packer to a tubular string, such as a string of tubing or drill pipe, this upper packer being releasably coupled to a lower retrievable packer or bridge plug. The combination of apparatus is run in the casing to the desired point, as below a series of casing perforations, at which the lower retrievable packer is to be set. This packer is then set in the well casing and the upper retrievable packer released therefrom, whereupon the upper packer can be elevated in the well casing away from the lower packer and set in the casing at any desired point, such as above the casing perforations. Pressure can now be applied to fluid in the tubular string, the fluid passing out of the upper packer and into the localized zone between the upper and lower packers, the pressure being imposed through the perforations on the formation surrounding the perforated region of the casing. During such imposition of pressure through the tubular string, the lower retrievable packer is set in the well casing, being anchored against downward movement therein and preventing leakage of fluid thereby.

If desired, instead of applying a positive pressure in the well casing between the upper and lower packers, a negative pressure can be applied therein, as, for example, by swabbing the tubular string, whereupon any fluid in the formation will tend to flow through the casing perforations into the localized zone between the packers, and then upwardly into the tubular string. Such application of negative pressure to the localized zone usually results in a greater pressure being present below the lower retrievable packer or bridge plug. Accordingly, this lower packer is preferably of the type that can also be anchored to the well casing against upward displacement, and which will also prevent upward passage of fluid between the lower packer and the well casing. The upper retrievable packer may also be of the type that will prevent fluid in the annulus between the tubular string and the well casing to pass down around the upper packer.

If desired, following the performance of the required pressuring operation at the particular zone in the well casing, the upper packer is released from the well casing and the tubular string lowered to recouple the upper packer to the lower packer, whereupon the lower retrievable packer is released from the well casing and the combination of upper and lower packers then moved either upward or downward in the well casing to a new location at which the lower packer can be reset, the lower packer then elevated any desired distance above the lower packer for the purpose of effecting resetting or anchoring of the upper packer against the well casing. Pressure can again be applied through the tubular string to the localized zone between the upper and lower well packers.

The foregoing procedure can be followed as many times as desired in the well casing without removing the packers from the well casing. When the packers are no longer required in the well bore, the upper packer can be recoupled to the lower packer, both packers being released, whereupon the tubular string can be elevated to remove both packers to the top of the hole and from the well casing.

For any particular setting of the lower packer in the well casing, the upper packer, after having been uncoupled from the lower packer, can be anchored and released as many times as possible without becoming reconnected to the lower packer, the upper packer being settable any number of times and at varying distances from the lower packer. As an example, in the applying of pressure to casing perforations, the lower packer may be set below the perforations, the upper packer uncoupled therefrom and placed a short distance above the lower packer, at which point the upper packer can be anchored in packed-off condition against the well casing. Pressure can then be applied through the tubular string to the localized zone in the casing between the packers, whereupon the upper packer may be released and elevated to a still higher position and the foregoing setting of the packer, pressuring of the localized zone between the packers and release of the upper packer repeated. This procedure can be instituted as often as necessary. After all of the perforations have been pressurized, in the manner described above, the upper packer can be released in the well casing and lowered for recoupling to the lower packer, whereupon the
lower packer is released and all of the apparatus elevated in and from the well casing. This invention possesses many other advantages and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. An apparatus for practicing the method is shown in the drawings accompanying and forming part of the present specification. Such apparatus and the method will now be described in detail, for the purpose of illustrating the general principles of the invention. It is to be understood, however, that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a side elevational view of an apparatus, with the parts in position for the apparatus to be raised or lowered in a well casing disposed in a well bore; Fig. 2 is a view similar to Fig. 1 disclosing the lower packer anchored to the well casing below the casing perforations, the upper packer being released from the lower packer and anchored in the well casing above the casing perforations; Fig. 3 is a fragmentary longitudinal section, on an enlarged scale, disclosing a portion of the lower retrievable packer anchored against downward movement in the well casing; Figs. 4 and 4a together constitute a longitudinal section through the lower retrievable packer and the device for coupling the upper packer to the lower packer and for retrieving the lower packer, Fig. 4a constituting a lower magnification of Fig. 4; Fig. 5 is a cross-section taken along the line 5—5 on Fig. 4a.

The apparatus disclosed in the drawings is adapted to be run in a well casing A on the lower portion of a tubular string B, such as a string of drill pipe or tubing. This tubular string is connected to the upper end of an upper retrievable packer C, of any suitable type, this retrievable packer being, in turn, connected to a coupling and retrieving device D releasably connected to a lower retrievable packer or bridge plug E.

The lower retrievable packer or bridge plug E may be of any suitable type, which is capable of effecting a releasable connection between the upper and lower retrievable packers C, E, in order to enable the packers to be disconnected from one another and then reconnected to one another. The coupling device specifically disclosed is more particularly described and claimed in our co-pending application for "Retrievable Bridge Plug," Serial No. 385,534, filed October 12, 1953, to which attention is invited. The coupling and retrieving device D may be of any suitable type, which is capable of effecting a releasable connection between the upper and lower retrievable packers C, E, in order to enable the packers to be disconnected from one another, and then reconnected to one another.

The upper retrievable packer is specifically disclosed, described and claimed in our co-pending application for "Retrievable Apparatus for Retrieving Subsurface Well Devices," Serial No. 385,535, filed October 12, 1953, now Patent No. 2,778,428. The upper retrievable packer is of any suitable type, the one specifically disclosed being described and claimed in the patent to Reuben C. Baker, Patent No. 2,368,400.

The upper retrievable packer, as particularly described in the above-identified Patent No. 2,368,400, includes a central mandrel or body 10 threadedly, or otherwise suitably secured to the lower end of the tubular string B. Secured to a lower portion of the mandrel or body 10 is a guide 11 on which a generally cylindrical packing sleeve 12 rests, the latter encompassing the body. This packing sleeve engages the lower end of a slip expander 13 that is slidable with respect to the body, the slip expander having in plurality of upwardly and inwardly tapering expander surfaces 14 engageable with slips 15 which are coupled together for joint longitudinal movement through a suitable swivel device 16, which is, in turn, connected to a friction drag device 17. In effect, the lower portion of the friction drag device 17 is connected to the slips 15 through the swivel 16 to prevent relative longitudinal movement between the device 17 and the slips 15. As disclosed, a coupling pin 19 is secured to the body 10, the pin being movable within a J slot 20 in a sleeve 21 forming part of the drag device 17 and slidably mounted on the body 10. When the pin 19 is located in the horizontal or foot portion 22 of the J slot, as such disclosed in Fig. 1, the slips 15 and packing sleeve 12 are held in retracted position, since relative longitudinal movement between the packer parts cannot occur. However, when the tubing string B is turned, as to the left, to place the pin 19 in alignment with the longitudinal leg 23 of the slot, then the body 10 of the tool is movable upwardly to shift the expander 13 upwardly within the slips 15, urging the latter radially outward into anchoring engagement with the well casing A, wherein a continuation of the upward movement of the packer body moves the guide 11 toward the expander 13 to foreshorten the packing sleeve 12 and expand it into tight sealing engagement with the well casing A. The set condition of the upper well packer C is disclosed in Fig. 2.

When it is desired to retract the upper packer C from the well casing, it is merely necessary to lower the body 10 of the packer, the drag device 17 preventing the slips 15 from moving longitudinally, which is accomplished by the guide 11 and expander 13 to be moved in a downward direction, the expander being removed from wedging engagement with the slips 15 to effect inward retraction of the latter from the well casing, the guide 11 moving longitudinally down away from the expander 13 to allow the packing sleeve 12 to be inwardly and downwardly to an unthreaded position, such as shown in Fig. 1. The tubular string B can then be turned to the right when the parts are in retracted position to move the pin 19 within the foot portion 22 of the J slot 26, which is the locking position. The packer is anchored in the tubbing string B can be lowered in the well casing A without danger of expanding the slips 15 and packing sleeve 12 outwardly against the well casing.

The lower portion of the upper retrievable packer C is connected to the coupling and retrieving device D which is, in turn, releasably connected to the upper portion of the lower retrievable packer or bridge plug E. This latter apparatus, as shown in the drawings, includes a central body 25 which may be of several portions, including an upper portion 26, the lower end of which is threaded onto the upper end of a lower body portion 27. A set of upper segmental slips 28 is disposed around the body, these slips having upper head portions 29 whose inner surfaces 30 are inclined in a downward and inward direction for cooperation with companion tapered surfaces 31 on an upper expander 32 suitably secured to the body 25 of the tool. When the upper expander 32 is moved downward with the body 25 relative to the upper slips 28, the latter are urged in an outward direction to embed their wickers 33 into the wall of the well casing or conduit A, thereby anchoring the body 25 of the tool to the conduit against downward movement.

The upper expander 33 is prevented from moving longitudinally of the body by having its lower smaller end engage a shoulder 34 on the body, with its upper end bearing against a packing cup thimble 35 receiving the lower or base portion of an upwardly facing packing cup 36, which may be made of rubber or rubber-like material. This upper cup 35 will thereby be urged to radially seal against the wall of the well casing, to prevent downward passage of fluid between the packing cup and the casing. The packing member 36 itself is pre-
vented from moving longitudinally with respect to the body by a clamp and valve cage 38, the lower portion of which is threaded onto the upper end of the body 25, bearing against the base of the packing cup 36, the latter, in turn, being slipped into a companion tapered surface 42 on a lower expander 43 secured to the body 25 of the tool. The lower expander 43 is prevented from moving longitudinally by the engagement of its upper smaller end against a shoulder 44 provided by the lower end of the upper body portion 26, its lower end engaging a lower thimble 45 surrounding the body and receiving the base portion of a lower packing member 46, which is similar to the upper packing member 36, although reversed in position on the body of the tool. The lower packing 46 faces in a downward direction, its lower lip portion 47 being adapted to slidably seal against the wall of the casing to prevent upward passage of fluid between the packing and the well casing. In a manner similar to the upper packing, the lower packing is prevented from moving longitudinally of the body by a lower retainer and valve cage 48 threaded onto the lowermost portion of the body 25, bearing against the base of the packing 46, clamping the latter against the thimble 45, which, in turn, engages the lower end of the lower expander 43, which is prevented from moving upwardly by the body shoulder 44.

When the body 25 of the tool and the lower expander 43 move inwardly with respect to the lower set of slips 39, the lower expander shifts the lower slips laterally outward, to embed their wickers 49 into anchoring engagement with the well casing, thereby preventing the tool from being moved inwardly within the well casing. The lower packing 46 prevents fluid from passing in an upward direction between the body 25 of the tool and the well casing.

Relative longitudinal movement between the body 25 and the expanders 32, 43 mounted thereon, on the one hand, and the sets of upper and lower slips 28, 39, on the other hand, is secured by resisting the longitudinal movement of the slips through the medium of a drag device. The drag device disclosed in the drawings includes longitudinally extending drag blocks 50 circumferentially spaced from one another and slidable mounted in longitudinal grooves 51 in a slip and drag block housing 52 sliding along the exterior of the tool body. The drag blocks 50 are urged outwardly into frictional engagement with the wall of the well casing by a plurality of helical compression springs 50a bearing against the bases of the confining housing grooves 51. Outward movement of the drag blocks 50 is limited by their engagement with upper and lower stop rings 50b secured to the housing in any suitable manner.

Both the upper and lower sets of slips 28, 39 are secured to the housing 52, in that the drag blocks 50 will resist movement of the slips within the well casing, and enable the body 25 and the upper and lower expanders 32, 43 to be shifted longitudinally with respect thereto. Thus, the upper slips 28 have depending arms 53 terminating in inwardly directed flanges 54 received within a circumferential groove 55 provided in the mid-portion of the housing 52 between the circumferentially spaced drag blocks 50. Each slip segment structure is longitudinally slotted throughout substantially their entire length to a region adjacent the flange 54, enabling the arms 53 to flex and allowing the slips to be deflected in an outward direction into engagement with the well casing wall. The flange portions 54 of the slips themselves are prevented from coming out of their companion grooves by an arcuate holding device 57 disposed across the flange portion and secured to the slip and drag block housing 52 by one or more screws 58.

The lower set of slips 39 is attached to the housing 50 in the same manner as the upper set of slips 28, this lower set of slips having upper inwardly directed flanges 54 received within arcutely spaced grooves 55 in the housing 52 between the drag blocks 50 and retained therein by the same slip holder 57 that maintains the upper slip flanges 54 in their grooves. The lower slips 39 are also longitudinally slotted from a region adjacent the flange 54 to the lower ends of the slips to provide flexible or spring-like arms 53a that will enable the head portions 40 of the slips 39 to be expanded laterally outward into anchoring engagement with the well casing.

The drag block stop rings 50b are spaced laterally outward away from the slip arms 53, 53a a sufficient distance to allow the heads 29, 40 of the slips 28, 39 to move without restraint laterally into engagement with the well casing. The slips themselves normally tend to remain in an inward direction because of the spring characteristics of their arm portions 53, 53a. However, assurance is had that the slips are held in a retracted position when they are not to be expanded outwardly into engagement with the well casing by slip retainer and retractor rings 60, 61 engageable with the upper and lower sets of slips 28, 39. Thus, an upper ring 60 is disposed around the shoulder portions 62 of the upper set of slips 28 and bearing against the head and arm portions 29, 53, the shoulder portions being thicker in radial dimension than the arm portions, their outer surfaces being adapted to engage the ring 60, which will prevent the wickers 33 of the slip heads from moving into engagement with the casing wall. The shoulder portions 62 are interconnected with the arm portions 53 by the tapered surfaces 63, which are capable of engaging the upper end of the ring 60, in order to urge the slip head 29 in an inward direction.

The retainer and retractor ring 66 is supported in position by a plurality of longitudinally extending bars 64 disposed between the slip segment 28, their lower ends being welded to the upper end of the ring 60 and their upper portions being clamped between the upper expander 32 and upper thimble 35, the upper portions of the bars being prevented from disconnecting from the upper expander by a holding ring 65 encompassing the bars and suitably secured to the expander.

The lower set of slips 39 is similarly held in retracted position against inadvertent outward movement by the lower retainer and retractor ring 61 encompassing the enlarged shoulder portions 67 of the lower slips, the lower end of this ring being engageable with the tapered surfaces 68 on the slip segments which interconnect the shoulders 67 and the arm portions 53a, to urge the lower slip heads 40 inwardly away from engagement with the casing. The lower ring 61 is held in appropriate position by a plurality of circumferentially spaced and longitudinally extending bars 69 welded to the lower end of the ring 61, the bars being clamped between the lower expander 43 and the lower thimble 45, and held in appropriate position on the lower expander by an encompassing holding ring 70 suitably secured to the lower expander. As is true of the upper slips 28, the lower stop ring 50b is spaced sufficiently away from the lower slip arms 53a to avoid interference with the laterally outward movement of the lower slips 39 into engagement with the well casing. Since the drag blocks 50 are resisting longitudinal movement of the upper and lower sets of slips 28, 39 in the well casing, relative longitudinal movement of the body 25 and the upper and lower expanders 32, 43 connected thereto will expand either the upper or the lower slips into anchoring engagement with the wall of the well casing, depending upon the direction of longitudinal movement of the body 25 and the expanders 32, 43, should the body and expanders be moved downwardly, then the upper expander 32 will be moved down within the upper slips 28, shifting the latter radially outward into anchoring engagement with the well casing, these slips,
in effect, bending or rocking about their lower flange portion 54. It is to be noted that when the upper slip heads 29 are in their retracted position, the tapered slip surfaces 30 are not parallel to the expander surface 31, but make an acute angle therewith. The difference in inclination is provided so that when the slips 25 are rocked outwardly into engagement with the well casing the surfaces 30, 31 and substantially parallel, the expander surface 32, making full bearing contact against the slip surfaces 30.

The relative downward movement of the body 25 and expanders 32, 43 with respect to the slips will anchor the upper slips 28 against the well casing. However, the lower slips 29 will remain in a retracted position, since the lower expander 43 is moving downward away from them. On the other hand, should the body 25 be moved in an upward direction, then the body and expanders 32, 43 will be shifted upwardly with respect to the slips, the upper expander 32 moving out of wedged engagement within the upper slips 28, this upward movement causing the retainer and retractor ring 60 to engage the tapered slip surfaces 63, to insure the inward movement of the slip heads 29 out of engagement with the well casing, the ring 60 moving at least slightly over the shoulder portions 62 to retain the slips 28 in this retracted position.

Upward movement of the lower expander 43 will move the lower retainer and rettractor ring 61 out of a position to engage the lower slip shoulders 67, whereupon the lower expander 43 can be wedged upwardly within the lower slips 29 to urge the latter radially outward into engagement with the wall of the well casing. As inside of the upper expander 32 and upper slips 28, the tapered surfaces 42, 41 on the lower expander 43 and lower slips 39 are not parallel to one another when the lower slips are in retracted position, the surfaces making an acute angle with one another. However, when the lower expander 43 moves upwardly within the lower slips 39, the latter are rocked or pivoted about their flange portions 54 outwardly against the casing, in which position their tapered surfaces 41 will be substantially parallel to the lower expander tapered surface 42 to insure full bearing engagement between the expanders 43 and slips 39.

The ability of either the upper or the lower sets of slips to be moved in a lateral outward direction depends upon the relative longitudinal movement of the body and expanders with respect to the slips. Each relative longitudinal movement is prevented by securing an anchoring of the lower retrievable well packer or bridge plug E in the well casing. As disclosed in the drawings, the slip and drag block housing 52 is provided with a pair of diametrically opposed longitudinal slots 73 in its inner wall in which the outer ends of the flat cross-piece or bar 74 are received, such outer ends of this bar being adapted to bear against the lower ends 73a of the slots or the upper ends 73b of the slots. This cross-piece 74 extends through diagoymatically opposed longitudinal slots 75 in the body in alignment with the housing slots 73.

The cross-piece 74 also extends through a transverse slot 76 in a control rod 77 extending completely through the packer body 25. This control rod has an upper reduced diameter portion 78 slidable through the transverse portion 79 of the upper valve cage 38. It also has a lower reduced diameter portion 80 slidable through the lower transverse portion 81 of the lower valve cage 44. Thus, the valve cages 38, 44 retain the control rod 77 coaxial of the body 25 of the tool, while permitting the rod 77 to slide longitudinally in an upward or downward direction relative to the tool body 25. The main intermediate portion of the control rod 77, through which the cross-piece 74 extends, has a diameter smaller than the inside diameter of the body 25, to afford ample passage area for the flow of fluid through the body.

When the control rod 77 is shifted downwardly with respect to the body, the cross-piece 74 will engage the lower ends 73a of the housing slots 73 and will shift the housing 52 in a downward direction along the body 25 a comparatively short distance until the control rod 77 engages the lower ends 73b of the body slot 75. The distance that the slip and drag block housing 52 is thus moved is comparatively short, the parts being so proportioned that the drag block housing 52 and the slips 28, 39 connected thereto are moved substantially coincidently and between the upper and lower expanders 32, 43. When the cross-piece 74 engages the lower ends 73a, 73b of the body slots 75 and housing slots 73, downward movement of the control rod 77 will carry the body 25 and the drag block housing 52 downwardly as a unit, permitting no relative downward movement of the upper and lower expanders 32, 43 with respect to the upper and lower slips 28, 39, the slips remaining in their neutral retracted positions, such as disclosed in Fig. 4a. Similarly, in the event the control rod 77 is moved upwardly within the housing, the upper and lower expanders 32, 43, engage the upper ends 75a, 75b of the body slots 75 and the housing slots 73, further upward movement of the control rod then carrying the body 25 and housing 52 upwardly as a unit with it, the body being prevented from moving upwardly relative to the housing 52, and thereby preventing relative upward movement of the expanders 32, 43 with respect to the slips 28, 39, which causes the slips to remain in their neutral unexpanded position.

The placing of the cross-piece 74 in an intermediate position within the housing and body slots 73, 75 allows the body 25 and the upper and lower expanders 32, 43 connected thereto to move in both an upward and downward direction a sufficient distance to either wedge the upper expander 32 into the upper slips 28, in the event downward movement of the body 25 and expanders 32, 43 occurs, or to wedge the lower expander 43 into the lower slips 39. The upward movement of the body 25 and expanders 32, 43 occurs when downward movement of the body 25 and its expanders occurs, the upper slips 28 are embedded in the well casing, to prevent downward movement of the lower packer E, and, conversely, when upward movement of the body and expanders occurs, the lower expander 43 is embedded into the lower slips 39, to wedge them into anchoring engagement with the well casing and prevent upward movement of the well packer in the well casing A.

When there are no upward or downward directed forces imposed on the control rod 77 tending to shift its cross-piece 74 away from it, the expanded 32, 43 and compressed 77, 73, 75, or upwardly therewithin, the control rod and its cross-piece are disposed in a central neutral position with respect to the slots, such as disclosed in Fig. 3. This central disposition is provided by upper and lower springs 85, 86, which are availal of to locate the control rod 77 in a central or neutral position, and also to determine the open or closed position of the passage 87 through the packer or bridge plug body 25.

The upper helical compression spring 85 is disposed on the upper reduced diameter portion 78 of the control rod, this spring engaging the upper valve cage 38 and also an upper valve head 88 slidable in a downward direction along the reduced diameter portion 78 of the control rod into engagement with the valve seat 89 provided within the upper portion of the tool body 25. The spring 85 tends to urge the valve head 88 downwardly, so that its cylindrical valve seat portion 89 is urged against the valve seat 89, as determined by engagement of the valve head stop flange 90 with the upper end 91 of the body 25. The valve head 88 is provided with a suitable rubber or rubber-like seal ring 92 adapted to engage the cylindrical valve seat portion 89 of the body. Leakage of fluid between the control rod 78 and valve head 88 is prevented by a rod packing ring 94 engaging the periphery of the rod 78.

A lower valve device is also provided, including a lower valve head 96 urged in an upward direction into
sealing engagement with a cylindrical valve seat 97 provided at the lower end of the packer body 25. The helical compression spring 65 surrounds the lower reduced diameter portion 80 of the control rod 77, to which the ret rod 78, its lower end bearing against the valve cage 48 and its upper end 5 against the valve head 96, urging the latter in an upward direction to shift it within the lower cylindrical valve seat 97, as determined by engagement of a flange 98 on the valve head with the lower end 99 of the body 25. Leakage of fluid between the head 96 and the cylinder valve seat 97 is prevented by a side seal ring 100 mounted in the valve head 96 and adapted to sealingly engage the valve seat 97. Leakage of fluid between the lower reduced diameter rod portion 80 and the lower valve head 96 is prevented by a rod packing ring 102 in the valve head 96 slidably and sealingly engaging the control rod portion 80.

The upper spring 85 not only urges the upper valve head downwardly into sealing engagement with the upper valve seat 89, but also engages the upper valve head 88 with an upper shoulder 104 formed on the control rod 77 to shift the control rod in a downward direction. Similarly, the lower spring 86 urges the lower valve head 96 in an upward direction toward a position of engagement with its valve seat 97, this lower valve head being engageable with a lower downwardly directed shoulder 105 on the rod and tending to elevate the rod 77 within the packer body 25. When the rod 77 is unまった by external forces, the springs 85, 86 shift the valve heads into engagement with their seats, the heads 88, 96 engaging the rod shoulders 104, 105 and disposing the rod in a central position in which the cross-piece 74 is located approximately midway within the body, and mounting slots 75, 73 (such as shown in Fig. 3) to allow the body 25 and expanders 32, 43 to be shifted relative to the slips 28, 39 for the purpose of urging either the upper or the lower slips outwardly into engagement with the well casing.

The springs 85, 86 and valve heads 88, 96 are effective in the manner described above, through engagement with the rod shoulders 104, 105. Conversely, the rod shoulders 104, 105 are effective to engage the valve heads 88, 96 and hold them in open positions. Thus, a downward force imposed on the control rod 77 will cause the lower shoulder 105 to engage the head 96 and shift it to its valve seat 97 to open position. Similarly, upward movement of the control rod 77 will shift the upper shoulder 104 into engagement with the upper valve head 88 to move it out of engagement from its companion seat 89 against the force of the upper spring 85.

The springs 85, 86 are effective to place the control rod 77 in a central position, as described above. They are also cooperational with their respective valve heads 88, 96 to shift the latter to valve closing position. In effect, the valve heads 88, 96 and springs 85, 86 constitute one-way or check valves, the fluid pressure within the tool being effective to shift the valve heads 88, 96 to open positions against the force of the springs 85, 86 during the actual elevating or lowering of the tool in the well casing, or the fluid pressure is effective to act on the heads 88, 96 to shift them to closed position, supplementing the force of the springs.

The lower retrievable plug or packer E, as stated above, is releasably coupled to the upper retrievable packer C by means of a suitable coupling and retrieving device D, which is disclosed in the drawings as being a form of overshot. It includes an outer housing or cylinder 120 threaded onto a sub 121 which is, in turn, threaded into a collar 122 threadedly secured to the tubing member 122a depending from the body portion 10 of the upper retrievable well packer C. The cylinder 120 has a depending wash-over sleeve 123 secured to it to facilitate the location of the overshot or retrieving apparatus centrally with respect to the bridge plug E. The lower portion of the wash-over sleeve 123 can encompass the upper valve cage 38 and will tend to centralize the housing or cylinder 120 with respect to the control rod 77, as described above.
motion of the tubing 122a, collar 122, sub 121 and cylinder 120 being transmitted through the spider to the control rod 77, the latches 127 and collar 122 being moved downwardly within the body 75, the lower rod shoulder 103 holding the valve 96 open, and the cross-piece 74 being disposed at the lower ends of the housing and body slots 73, 75, precluding setting of the plug E in the casing A. During such lowering movement, it is immaterial whether or not the latches 127 are coupled to the control rod 77 by being engaged under the rod shoulder 125, since the downward movement can be transmitted between the overshot housing 120 and the control rod 77. As disclosed in Fig. 4, the latches 127 are in a position to engage the collar 122 when the cross-piece 147 and will, when engaged, engage the shoulder. The spring 134 is urging the piston 125 in a downward direction, but the piston cannot move downwardly since the latch noses 126 engage the spider sleeve 147.

When it is desired to remove the overshot or retrieving tool B, the tubing string B, upper packer C and overshot D are moved in a downward direction, the control rod 77, shifting the latter downwardly of the body 25 of the lower retrievable packer E, locating the cross-piece 74 in engagement with the lower ends of the housing and body slots 73, 75, which hold the slips 28, 39 in their neutral position and causing the lower control rod shoulder 105 to engage the lower valve 29 of the overshot D. The fluid is forced downwardly from its seat 97 against the force of the helical spring 86. The combination of apparatus is inserted in the well casing until the point is reached at which it is desired to set the lower retrievable packer E. As an example, it is desired to set the packer immediately below casing perforations P, then the apparatus is lowered until the lower packer E is located at such position. During such lowering movement of the apparatus, the fluid in the well casing A can pass upwardly through the tubing string B by flowing through the openings in the upper valve cage 48 and through the open lower valve seat 97 into the body 25, the fluid forcing the upper valve head 88 from its seat 89 against the force of the spring 85 and passing out through the openings in the upper valve cage 38 and into the well casing thereabove. This fluid can flow around the wash-over sleeve 123 between the tubing string 122a and the casing A.

If it is desired to remove the overshot D to the control rod 77, the tubing string B, upper packer C and overshot D are lowered, the nosed 126 of the latches 127 engaging the upper tapered head 124 of the control rod, which will shift the latches 127 outwardly and the piston 125 upwardly against the spring 134, until the latch noses 126 are disposed lower than the shoulder 125, whereupon the spring 134 is effective to shift the latches downwardly along the outer cylinder tapered surface 141, which will urge the latch noses 126 under the control rod shoulder 125. The tubing string B may now be elevated to completely remove the retrieving device or overshot D from the control rod 77, thereby disconnecting the upper packer C from the lower packer E, the entire tubing string retrieving device D and upper packer C being moved upwardly in the well casing A. Whereupon the plug E, to allow the latter to anchor itself in the well casing A, the tubing string B and upper well packer C need merely be elevated, which will elevate the housing 12 with respect to the control rod 77, thereby removing the downward force on the control rod and allowing it to assume its neutral position, as disclosed in Fig. 3. Should the force of the spring 134 be sufficient to shift the latch noses 126 under the shoulder 125, upon upward movement of the cylinder 120 and mandrel 129, release can be effected simply by applying pressure to the fluid in the tubing string B, this pressure passing downwardly through the sub 121 and the mandrel 129, being throttle because of the narrow space or annular orifice provided between the spider sleeve 147 and the narrow portion of the passage through the cylinder 120. Such throttling action builds up sufficient back pressure under the piston 125 to shift it in an upward direction against the force of the spring 134, carrying the latches 127 upwardly and causing the latch noses 126 to engage the lower end 138 of the inner cylinder member or mandrel 129, which shifts them laterally outward to a position in which the noses are incapable of engaging the control rod shoulder 125. The tubing string B may now be elevated to completely remove the retrieving device or overshot D from the control rod 77, thereby disconnecting the upper packer C from the lower packer E, the entire tubing string retrieving device D and upper packer C being moved upwardly in the well casing A.

When the location in the well casing is reached at which the lower retrievable packer is to be set, as below the casing perforations P, it is merely necessary to apply pressure to the fluid in the tubing string B, the fluid under pressure being restricted by the orifice or passage formed between the spider 144 and the outer cylindrical member 120, which builds up a back pressure capable of acting on the lower surface of the annular piston 128, moving the latter in an upward direction against the force of its spring 134, which shifts the latches 127 upwardly and, through engagement with the lower tapered nose 138 of the inner cylindrical member 129, expands the latches 127 in an outward direction, whereby they are incapable of engaging the latching or locking shoulder 125 on the upper end of the rod 77. The tubing string B may now be elevated to remove the tubing string B, upper packer C and overshot D, and the tubing string being moved upwardly to as great a distance as desired. As an example, the tubing string may be elevated until the retrievable packer C is located just above the casing perforations P.

When the overshot D is removed from the control rod 77, the springs 85, 86 are effective to shift the control
(2,806,532) 13 rod to a central position, which is accompanied by the centering of the cross-piece 74 in the housing and body slots 73, 75. The friction of the packing cups 36, 46 against the casing A will tend to hold the lower packer E in the position to which it has been run in the well casing, but, should a predominance of pressure either above or below the lower retrievable packer E, then such pressure will act on either the upper or the lower valve 88 or 96 to close the body passage 87. It will also act on either of the packing cups 36 or 46 to shift the body 25 and expanders 32, 43 in a particular direction to expand one set of slips outwardly into firm anchoring engagement with the well casing. Should there be a pressure differential between the packer E, it will shift the lower valve 96 into engagement with the lower seat 97 to close the body passage, whereupon the pressure will act on the body 25 of the tool and the lower packing cup 46 to shift the body 25 and the expanders 32, 43 in an upward direction, to wedge the lower expander 43 into the lower slips 39 and expand the latter outwardly against the well casing A. A pressure differential above the packer E will close the upper valve 88, 89, shifting the upper packing 36 downward, as well as the body 25 and expanders 32, 43, to wedge the upper expander into the upper slips 28.

The foregoing relative movement between the body 25 and expanders 32, 43, on the one hand, and the slips 28, 39, on the other hand, can take place, since the longitudinal movement of the slips is resisted by the friction drag blocks 50, the cross-piece 74 being in a central position within the slots 73, 75, so as to avoid interference with their respective longitudinal movement.

The upper retrievable packer C can now be anchored to the well casing above the perforations P, as by turning the tubing string B to the left, for example, to place the pin 19 in alignment with the longitudinal leg 23 of the slot 20, the friction drag springs 17 resisting longitudinal movement of the slips 15 and allowing the tubing string B and body 10 to move upwardly for the purpose of causing the expander 13 to move upwardly within the slips 15 and expand the latter radially outwardly into anchoring engagement with the well casing A, then shortening and expanding the packing sleeve 12 into sealing engagement with the well casing A.

Fluid under pressure may now be imposed on the fluid in the tubular string B, this fluid passing out through the lower end of the overshot D into the localized casing zone between the upper and lower packers C, E, the fluid passing through the casing and formation surrounding the perforations. The downward pressure in the localized zone shifts and maintains the upper valve head 88 in close engagement with its companion valve seat 89, the pressure then acting across the upper body area 25 and the upper packing 36, urging the upper body 25 in a downward direction to wedge the upper expander 32 into the slips 28, anchoring the latter against the casing. Thus, the lower packer E is prevented from moving downwardly in the well casing, its packing cup 36 and closed valve 88, 89 at the upper portion preventing fluid from leaking past the lower packer E. The upper retrievable packer C prevents fluid from passing from the localized zone upwardly thereafter.

Pressures of a comparatively high order can be imposed on the fluid in the tubing string B, localized zone, perforations P and the formation opposite the perforations, the lower packer E being capable of withstanding exceedingly high pressures, which is also true of the upper packer C.

If desired, the fluid level in the tubing string B can be lowered by a swabbing operation, the packing sleeve 12 of the upper retrievable well packer C being held against the casing A in sealing engagement therewith by the upward strain taken on the tubing string, so as to prevent the hydrostatic head of fluid in the tubing-casing annulus above the upper packer C from being imposed on the localized zone. In effect, the fluid in the formation may be caused to flow through the perforations P into the localized zone and into the tubing B by the plunger action. If this occurs, the lower packer E will still remain at its desired position in the well casing, since a predominance of pressure in the localized zone over that in the casing below the lower packer E will hold the latter anchored to the well casing against downward movement. On the other hand, should the pressure in the localized zone become less than that in the well casing below the lower packer, then the fluid pressure from below will close and hold the lower valve 96 in closed position against the body 25, such pressure acting on the body 25 and the lower cup packing 46 to urge the body 25 in an upward direction relative to the slips 28, 39, which do not move longitudinally because of the resistance offered by the friction drag blocks 50 against the wall of the well casing, thereby causing the lower expander 43 to wedge upwardly within the slips 39 and expand the latter outwardly into firm sealing engagement with the wall of the well casing.

Accordingly, it is evident that despite the presence of a greater pressure in the localized zone than below the lower packer E, or a lesser pressure in the localized zone than below the packer, the lower packer E still remains anchored to the well casing at the desired location. Following completion of the operation through the perforations P, the tubing string B may be lowered, to effect retraction of the slips 15 and packing sleeve 12 of the upper packer C, whereupon the tubing string B may be rotated to place the pin 19 in the foot portion 22 of the J slot 20, to lock the upper packer C with its parts in retracted position. The tubing string may now be lowered, to relocate the overshot D over the tapered head 124 of the control rod 77, the head urging the latches 127 in an outward direction against the force of the piston spring 134 until the latches are disposed below the control rod shoulder 125, whereupon the spring 134 is effective to shift the piston 138 downwardly to force the latches 127 under the shoulder 125, in view of the downward movement of the latches along the retracting surfaces 141, 143 of the outer cylinder member 120. When the latches 127 are disposed under the shoulder 125, then an upward strain taken on the tubular string will move the holding surfaces 143 of the outer cylinder member 120 behind the latches and hold them locked under the shoulder.

The tubing string B can now be elevated, to correspondingly elevate the upper retrievable packer C, which is now recoupled to the well casing at a point in the upward movement shifting the control rod 77 upwardly with respect to the body 25 of the lower packer until the cross-piece 74 is again disposed in engagement with the upper ends of the body and housing slots 75, 73, which positions the slips 28, 39 in a neutral location relative to the upper and lower expanders 32, 43 and precludes relative upward longitudinal movement between the various parts of the lower packer. The tubing string B may now be further elevated, the upper retrievable packer parts C remaining in their retracted position during such elevating movement, which is also true of the lower packer E. The lower packer, of course, is moved upwardly with the tubing string B, the control rod shoulder 104 having previously engaged the upper valve head 88 to shift it and hold it in an open position, thereby allowing the fluid in the well casing to pass down through the body passage 87, unseating the lower valve head 96 and passing outwardly through the lower valve cage 48 into the casing below the lower packer E.

The tubing string B may now be elevated in the well casing to completely remove the apparatus from the well casing, or it may be elevated to place the lower packer E in another position in the well casing at which it is to be set. When this position is reached, all that need be done
is to apply pressure to the fluid in the tubular string, this pressure acting on the underside of the piston 128 to urge it and the latches 127 against the direction, causing the latches to be released from the control rod shoulder 125 and allowing the tubular string B, upper retrievable packer C and overshot D to be elevated away from the lower packer. The upper packer C may be disposed at the desired location in the well casing A, whereupon it can be set and pressure again directed, causing the string B and into the localized zone in the casing between the upper and lower packers C, E. Following the completion of the operation in the well casing, the tubular string B may again be lowered, to retract the slips 15 and packing sleeve 13 of the upper packer C, and lock the parts in their appropriate position. The tubular string B, upper packer C and overshot D are then reelevated and again recoupled to the control rod 77 of the lower packer, whereupon the parts can again be elevated, the elevating movement on the control rod 77 again locating the slips 28, 39 of the lower packer in a neutral position, preventing their expansion, which allows the lower packer E to be elevated in the well casing.

If desired, the combination can be lowered in the well casing instead of being elevated therewithin, to locate the lower packer E at any desired point in the casing, whereupon the overshot D can again be lowered to allow the lower packer to be set and the upper packer C shifted to an appropriate location above the lower packer, after which the upper packer can be anchored in packed-off condition in the well casing and another operation performed in the well bore.

It is evident that following the release of the upper packer C from the lower packer E, it can be moved any desired distance above the lower packer E and anchored in packed-off condition within the well casing. It can be anchored in packed-off condition at one point in the well casing and then it can be shifted to another point and reset in the well casing without becoming recoupled to the lower packer. After each setting, a pressuring operation can be performed, the lower packer E in each instance preventing fluid from passing down the well casing beyond its setting point, as well as preventing fluid from passing upwardly in the well casing past the lower well packer.

After all of the operations have occurred in the well casing, the upper packer C can be recoupled to the lower packer E and all of the apparatus elevated to the top of the well bore for future removal.

It is evident that the combination of packers provides a straddling apparatus that can be run simultaneously in the well casing and set therein at any desired separated points, the distance between the packers being varied to suit conditions. At any time, the upper and lower packers can be recoupled to one another and then later disconnected from one another, the entire arrangement affording great flexibility in performance of operations in the well casing.

The inventors claim:

1. The method of applying fluid pressure to a formation zone in a well bore, which comprises simultaneously lowering upper and lower well packers on a tubular string in the well bore to a desired location therein, setting the lower packer in the well bore against downward movement therein and to prevent downward passage of fluid therethrough, elevating the upper packer from the lower packer, setting the upper packer in the well bore, applying fluid pressure through the tubular string and upper packer to the zone in the well bore between the set upper and lower packers, thereby forcing the fluid toward the lower packer, and lowering it toward the lower packer, then connecting the upper packer to the lower packer, releasing the upper packer and lowering it toward the lower packer, then connecting the upper packer to the lower packer, and moving the upper and lower packers longitudinally in the well bore.

2. The method of applying fluid pressure to formation zones in a well bore, which comprises simultaneously lowering upper and lower well packers on a tubular string in the well bore to a desired location therein, setting the lower packer in the well bore against downward movement therein and to prevent downward passage of fluid therethrough, elevating the upper packer from the lower packer, setting the upper packer in the well bore, applying fluid pressure through the tubular string and upper packer to the zone in the well bore between the set upper and lower packers, thereby forcing the fluid toward the lower packer, then connecting the upper packer to the lower packer, releasing the lower packer, moving the upper and lower packers longitudinally in the well bore to another location therein, resetting the lower packer in the well bore against downward movement therein and to prevent downward passage of fluid therethrough, elevating the upper packer from the lower packer, setting the upper packer in the well bore, applying fluid pressure through the tubular string and upper packer to the zone in the well bore at said another location between the set packers, thereafter releasing the upper packer and lowering it toward the lower packer, then reconnecting the upper packed to the lower packer, releasing the lower packer, and simultaneously moving the upper and lower packers longitudinally in the well bore.

4. The method of applying fluid pressure to a formation zone in a well bore through a lateral opening in a well casing disposed in the well bore, which comprises lowering upper and lower well packers on a tubular string in the well casing to the region of the casing opening, setting the lower packer in the casing below the opening, against downward movement thereby to prevent downward passage of fluid therethrough, elevating the upper packer from the lower packer, setting the upper packer in the well casing above the opening, applying fluid pressure through the tubular string and upper packer to the region of the casing opening, thereby forcing the fluid toward the lower packer, and lowering it toward the lower packer, then connecting the upper packer to the lower packer, releasing the lower packer, and moving the upper and lower packers longitudinally in the well casing.

5. The method of applying fluid pressure to a formation zone in a well bore through a lateral opening in a well casing disposed in the well bore, which comprises lowering upper and lower well packers on a tubular string in the well casing to the region of the casing opening, anchoring the lower packer in packed-off condition in the casing below the opening against downward movement therein and to prevent downward passage of fluid therethrough, elevating the upper packer from the lower packer, anchoring the upper packer in packed-off condition in the casing above the opening, applying fluid pressure through the tubular string and upper packer to the well casing between the anchored packers, thereafter releasing the upper packer from the casing and lowering it toward the lower packer, then connecting the upper packer to the lower packer, releasing the lower packer from the casing, and moving the upper and lower packers as a unit longitudinally in the well casing.

6. The method of applying fluid pressure to a formation zone in a well bore through a lateral opening in a well casing disposed in the well bore, which comprises lowering upper and lower well packers on a tubular string in the well casing to the region of the casing opening, anchoring the lower packer in packed-off condition in the casing below the opening against downward movement therein and to prevent downward passage of fluid therethrough, elevating the upper packer from the lower packer, anchoring the upper packer in packed-off condition in the casing above the opening, applying fluid pressure through the tubular string and upper packer to the well casing between the anchored packers, thereafter releasing the upper packer from the casing and lowering it toward the lower packer, then connecting the upper packer to the lower packer, releasing the lower packer from the casing, and moving the upper and lower packers as a unit longitudinally in the well casing.
packer to the lower packer, releasing the lower packer from the casing, and elevating the upper and lower packers as a unit in the well casing.

6. The method of applying fluid pressure to a formation zone in a well bore through a lateral opening in a well casing disposed in the well bore, which comprises lowering upper and lower packers on a tubular string in the well casing to the region of the casing opening, anchoring the lower packer in packed-off condition in the casing below the opening against downward movement in the casing and to prevent downward passage and fluid therethrough through elevating the upper packer from the lower packer, anchoring the upper packer in packed-off condition in the casing above the opening and against upward movement in the casing, applying fluid pressure through the tubular string and upper packer to the well casing between the anchored packers tending to urge the lower packer downwardly and the upper packer upwardly, thereafter releasing the upper packer from the casing and lowering it toward the lower packer, then connecting the upper packer to the lower packer, releasing the lower packer from the casing, and moving the upper and lower packers as a unit longitudinally in the well casing.

7. In subsurface apparatus for applying pressure in a well bore: an upper retrievable packer adapted to be lowered in the well bore on a tubular running-in string and to be anchored in the well bore against upward movement therein; a lower retrievable packer adapted to be lowered in the well bore and anchored therein against downward movement and to prevent downward passage of fluid therethrough; and means providing a releasable connection between said upper and lower packers which enables said upper packer to be disconnected from said lower packer while in the well bore and then reconnected to said lower packer while in the well bore.

8. In subsurface apparatus for applying pressure in a well bore: an upper retrievable packer adapted to be lowered in the well bore on a tubular running-in string and to be anchored in the well bore against upward movement therein; a lower retrievable packer adapted to be lowered in the well bore and anchored therein against downward movement and to prevent downward passage of fluid therethrough; and an overshot releasably connecting said upper and lower packers together for movement as a unit in the well bore for and releasing said upper packer from said lower packer while in the well bore.

9. In subsurface apparatus for applying pressure in a well bore: an upper retrievable packer adapted to be lowered in the well bore on a tubular running-in string and to be anchored in the well bore against upward movement therein; a lower retrievable packer adapted to be lowered in the well bore and anchored therein against downward movement and to prevent downward passage of fluid therethrough; and an overshot secured to said upper packer and adapted to be piloted over and connected to a portion of said lower packer to couple said packers together.

10. In subsurface apparatus adapted to be lowered in a well casing disposed in a well bore: an upper retrievable packer adapted to be lowered on a tubular string in and anchored to the well casing; a lower retrievable packer adapted to be lowered in and anchored to the well casing, against downward movement therein and to prevent downward passage of fluid therethrough; said lower packer embodying means movable longitudinally with respect to other portions of said lower packer to positions selectively preventing or permitting anchoring of said lower packer in the well casing; and a releasable coupling between said upper packer adapted to be disconnected from said means, said coupling including means for disconnecting said upper packer from said means and for reconnecting said upper packer to said means in response to lowering of said upper packer in the well casing, whereby longitudinal movement of said upper packer in the well casing shifts said means longitudinally relative to other portions of said lower packer to a position preventing anchoring of said lower packer in the well casing and allow said upper and lower packers to be moved as a unit longitudinally in the well casing.

11. In subsurface apparatus adapted to be lowered in a well casing disposed in a well bore: an upper retrievable packer adapted to be lowered on a tubular string in and anchored to the well casing; a lower retrievable packer adapted to be lowered in and anchored to the well casing, against downward movement therein and to prevent downward passage of fluid therethrough; said lower packer embodying means movable longitudinally with respect to other portions of said lower packer to positions selectively preventing or permitting anchoring of said lower packer in the well casing; and a releasable coupling between said upper packer adapted to be disconnected from said means, said coupling including means for disconnecting said upper packer from said means and for reconnecting said upper packer to said means in response to lowering of said upper packer in the well casing, whereby longitudinal movement of said upper packer in the well casing shifts said means longitudinally relative to other portions of said lower packer to a position preventing anchoring of said lower packer in the well casing and allow said upper and lower packers to be moved as a unit longitudinally in the well casing.

12. In subsurface apparatus adapted to be lowered in a well casing disposed in a well bore: an upper retrievable packer adapted to be lowered on a tubular string in and anchored to the well casing; a lower retrievable packer adapted to be lowered in and anchored to the well casing, against downward movement therein and to prevent downward passage of fluid therethrough; said lower packer embodying means movable longitudinally with respect to other portions of said lower packer to positions selectively preventing or permitting anchoring of said lower packer in the well casing and allow said upper and lower packers to be moved as a unit longitudinally in the well casing.

13. In subsurface apparatus adapted to be lowered in a well casing disposed in a well bore: an upper retrievable packer adapted to be lowered on a tubular string in and anchored to the well casing; a lower retrievable packer adapted to be lowered in and anchored to the well casing, against downward movement therein and to prevent downward passage of fluid therethrough; a releasable coupling between said upper and lower packers, said coupling including means for disconnecting said upper and lower packers from each other and for reconnecting said packers, while in the well casing, for longitudinal movement as a unit in the well casing.

14. In subsurface apparatus adapted to be lowered in a well casing disposed in a well bore: an upper retrievable packer adapted to be lowered on a tubular string in and anchored to the well casing, against downward movement therein and to prevent downward passage of fluid therethrough; said lower packer embodying means movable longitudinally with respect to other portions of said lower packer to positions selectively preventing or permitting anchoring of said lower packer in the well casing and allow said upper and lower packers to be moved as a unit longitudinally in the well casing.
upper packer in the well casing shifts said means longitudinally relative to other portions of said lower packer to a position preventing anchoring of said lower packer in the well casing to allow said upper and lower packers to be moved as a unit longitudinally in the well casing.