

March 10, 1942.

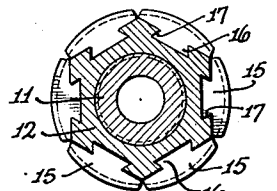
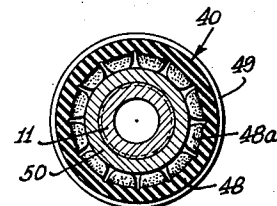
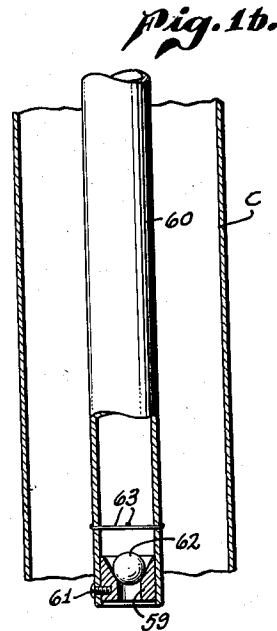
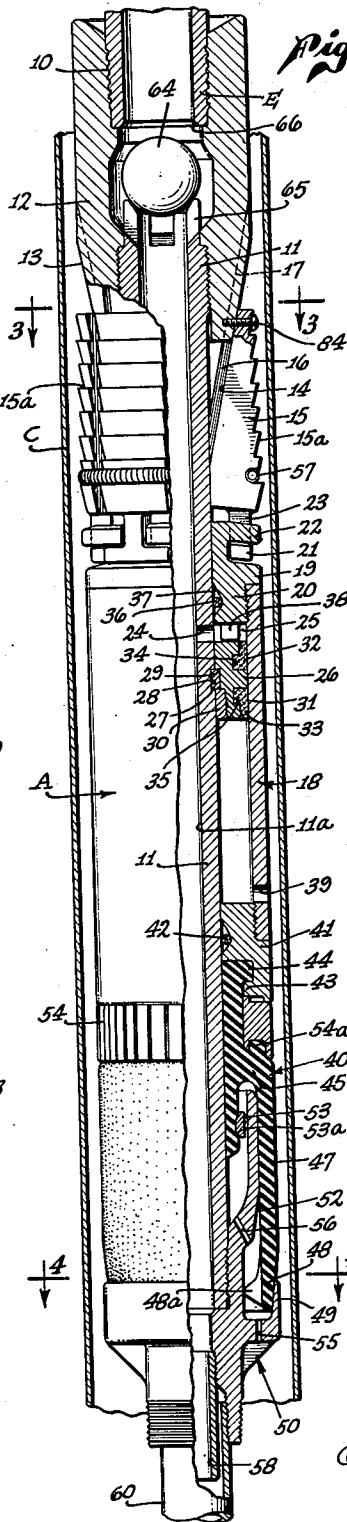
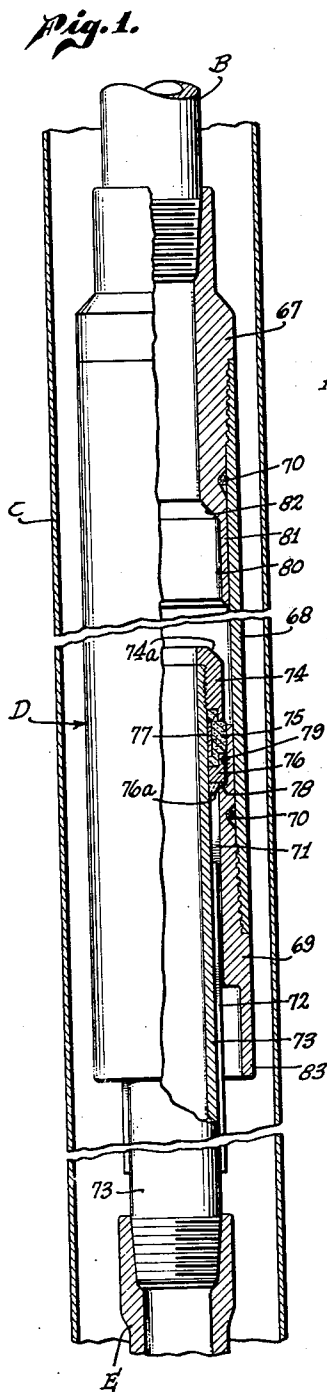
R. C. BAKER

2,275,935

WELL PACKER APPARATUS

Filed May 6, 1940

2 Sheets-Sheet 1



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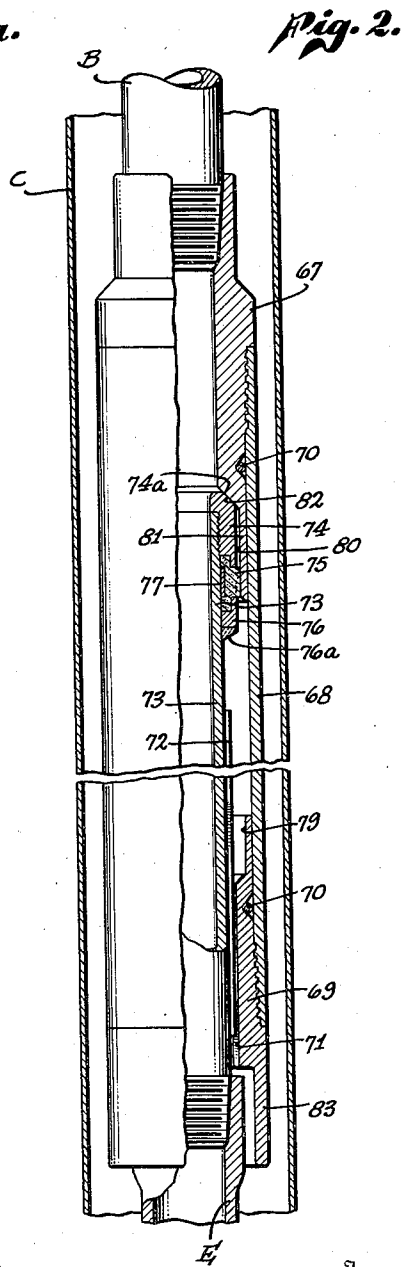
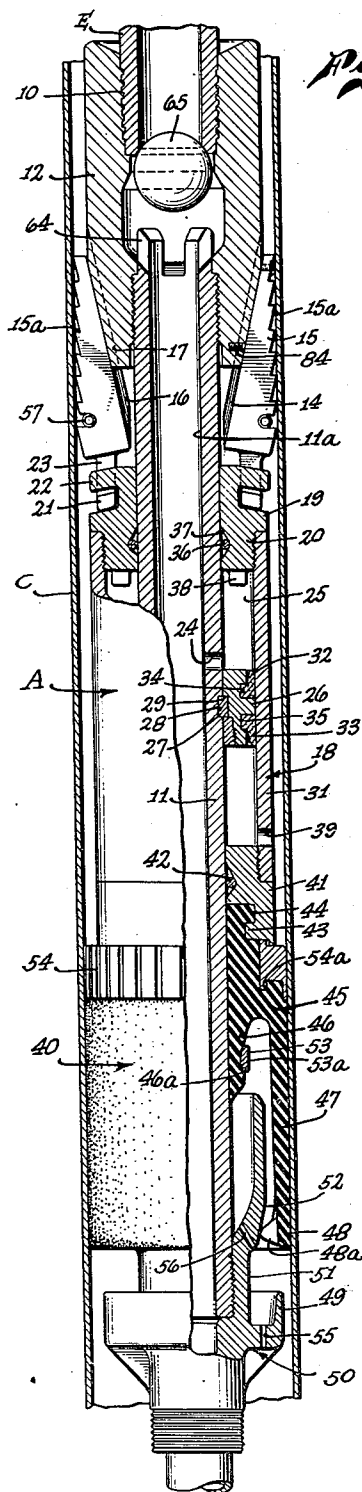
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WELL PACKER APPARATUS

Filed May 6, 1940

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,275,935

WELL PACKER APPARATUS

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Application May 6, 1940, Serial No. 333,491

36 Claims. (Cl. 166—12)

This invention relates to well packer apparatus, being particularly concerned with apparatus that can be anchored in packed-off condition in a well casing for the performance of desired functions therein, the apparatus being subsequently releasable and bodily removable from its anchored position without detriment to its parts.

Well packers are employed for performing many operations associated with the completion and production of oil, gas, water and other wells. In some circumstances, it is preferred that the packer be impermanently anchored in the well or well casing to permit its bodily removal or retrieval, rather than irretrievably anchoring the packer so as to require its removal by drilling or its disintegration by some other expedient. If its utility is not to be too limited, such retrievable well packer must be capable of remaining in its set and sealed off position under high pressure operating conditions, such as that encountered in squeeze cementing or when used as a high pressure production packer. These high pressures tend to move a packer up the well casing, and unless this tendency is prevented or offset, undesirable effects accrue to the packer and its associated mechanisms, in addition to failure of the packer, insofar as its ability to perform its intended functions is concerned.

Accordingly, it is an object of the present invention to provide an improved well packer capable of being anchored and packed off at any point in the well bore or casing, and subsequently removable bodily from such point for retrieval to the surface of the well bore or for resetting at the same or another point in the well casing.

Another object of the invention is to provide an improved retrievable well packer capable of being anchored and packed off at any desired point in a well bore or casing, and of remaining in such condition and position under high pressures.

It is a further object of the invention to provide a retrievable well packer of relatively simple, sturdy, and durable construction, capable of being anchored to a well casing and released therefrom without resort to the use of complex devices and manipulations.

Another object of the invention is to provide a hydraulically set well packer capable of withstanding and remaining in a set and operative condition under high pressures, release of the packer being effectuated mechanically merely by exerting a longitudinal upward pull on the tubular string to which the packer is connected.

Still another object of the invention is to pro-

vide a well packer which can be run in a well casing with its parts in retracted position, set and packed off at any desired point in such casing, and subsequently manipulated to effect return of all its parts to their initial retracted position.

Yet a further object of the invention is to provide a well packer having anchoring and packing off devices capable of being simultaneously set against the well casing, and simultaneously retractable from casing engaging position.

Another object of the invention involves the provision of a well packer having anchoring and packing devices hydraulically and positively expandable towards casing engaging position, the action of fluid under pressure within the packer tending to maintain the devices in such expanded condition.

The invention has other objects that will become apparent from a consideration of one of its embodiments shown in the drawings accompanying and forming part of the present specification. This form will now be described in detail, but it is to be understood that such detailed description is not to be taken in a limited sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figs. 1, 1a and 1b constitute a three-part longitudinal section through a well casing, showing a well packer apparatus in position for running in the casing prior to anchoring and packing off of the packer against the wall of the casing;

Figures 2 and 2a constitute a two-part longitudinal section, similar to Figures 1, 1a and 1b, with the packer anchored to and sealed off against the casing;

Figure 3 is a cross-section taken along the line 3—3 in Figure 1; and

Figure 4 is a cross-section taken along the line 4—4 in Figure 1.

In the form of invention shown in the drawings, a well packer A is attached to the lower end of a tubular string B of drill pipe or tubing for movement through the casing C to any desired setting point therein. Although not indispensable to its proper operation, it is preferred to interpose a circulation joint D in the tubular string by connecting its upper end to a section of tubing and its lower end to a sub E secured to the upper part of the packer by any suitable means, as the left-hand threads 10, to permit disconnection of the tubular string from the packer should such action become desirable or expedient.

The packer A consists of a tubular body 11

having an expander cone 12 threadedly or otherwise attached to its upper end. The outer surface 13 of the expander converges downwardly, and is engageable with companion surfaces 14 on a plurality of tapered segmental slips 15 adapted to slide along the surface of the cone into and out of anchoring engagement with the wall of the casing. The outer surface 13 of the cone and the cooperative slip surfaces 14 can assume various configurations, but it is preferred to form the cone polygonal in cross-section with straight and downwardly tapered sides thereon contactable with straight inclined faces on the slips. To provide a positive interconnection, the slips 15 are slidably interlocked with the cone by means of dove-tailed connections, the flaring tenon 16 of each connection being provided along the tapered face of each slip, while its cooperative groove 17 is formed along each tapered side of the cone expander. The tenon and groove could be interchanged, if desired, without altering the function of the device.

The slips 15 are coupled to a cylinder 18 for movement in unison. The specific coupling arrangement consists of a flange 19 on the cylinder head 20 abutting T-shaped heads 21 depending from the slips, to urge the latter along the diverging cone surfaces upon upward movement of the cylinder head on the tubular body 11. The slips are guided for radial movement during such motion along the expander surfaces to and from the casing by radial fingers 22 extending from the cylinder head and spaced from the flange 19 to project over the T-shaped heads 21 and slidably embrace their shank portions 23.

The slips 15 are urged upwardly along the cone 12 by imparting pressure to the fluid or liquid within the tubular body 11. This fluid passes through inlet ports or openings 24 extending through the body, and into the cylinder space 25 initially defined between the cylinder head 20 and a stationary piston 26. This piston is secured to the exterior of the tubular body 11 by a lock ring 27 received within a groove 28 at the exterior of the body and clamped against a shoulder 29 on the piston by a lock nut 30. A cylinder sleeve 31 is threaded onto the cylinder head 20 and extends downwardly along and below the piston 26 for a material extent, being in slidable engagement with the oppositely facing cup packings 32, 33 fitting within grooves 34, 35 on the exterior of the piston. Leakage between the piston 26 and cylinder sleeve 31 is accordingly prevented in both directions, while leakage between the cylinder head 20 and exterior of the tubular body 11 is prevented by a packing 36 received within a V-shaped annular groove 37 in the cylinder head, being urged by the tapered sides of the groove into sealing contact with the exterior surface of the tubular body.

The cylinder head 20 and piston 26 are initially separated a small distance by circumferentially spaced lugs 38 secured to the lower face of the cylinder head, which lugs abut the piston. Fluid under pressure will enter through the inlet ports 24 into this initial clearance space 25 and react against the high pressure side of the stationary piston 26 to move the cylinder sleeve 31 and head 20 upwardly, carrying the slips 15 with them in the same direction along the diverging surface of the cone expander 12 and into anchoring engagement with the casing. In pursuing this upward movement, any fluid below the piston on its low pressure side escapes from the cylinder

through the bleeder holes 39 provided near its lower end.

The hydraulically actuated cylinder 18 also serves as a means for moving a packing 40 into sealing engagement with the wall of the casing. A packing retainer ring 41 is threadedly attached to the lower end of the cylinder sleeve 31, being slidably sealed against the tubular body 11 by the ring 42 and coupled to the upper end of the packing 40 by means of the respective annular interlocking flanges 43, 44 provided on the retainer ring and packing. This packing 40 includes a base portion 45 and an inner sealing skirt 46 engageable with the outer surface of the tubular body 11 for preventing leakage of fluid therealong from below the packer. An outer skirt 47 also depends from the base portion 45 of the packing for sealing engagement with the wall of the casing C.

The packing 40 is formed so that its outer skirt 47 normally and inherently tends to assume a retracted position, as shown in Figure 1b. Although this position is maintained until it is desired to seal the packer in the casing, to insure against its inadvertent expansion, the lip 48 at the end of its skirt is initially confined within a protector cup 49, formed as part of a positive packing expander 50 screwed onto the lower end of the tubular body 11 of the packer.

It is desired to move the slips 15 and packing member 40 simultaneously to casing engaging position, and this can be accomplished since they are both coupled to a common prime mover mechanism 18, namely, the cylinder head 20 and the cylinder sleeve 31 attached thereto. Thus, as fluid under pressure acts upon the cylinder 18 to move the slips along their expander 12 into casing engaging position, the packing 40 is likewise shifted bodily upwardly with respect to the packing expander device 50 confined partially there-within. It will be noted that the outer surface 51 of this device is cylindrical in shape opposite the protector cup 49, but that it then diverges upwardly to form a cone expander 52 capable of acting on the inturned slotted lip portions 48a of the packing member for forcing its skirt 47 positively into sealing engagement with the wall of the casing. As the cylinder 18 moves upwardly, the packing 40 is shifted with it until its lip 48 is free from the protecting and confining action of the cup 49. Its inturned lip portion 48a then rides upon the packing expander surface 52 to be positively and forcibly urged into sealing engagement with the walls of the casing (see Figure 2a).

Following initial engagement of the packing lip 48 and skirt 47 with the casing wall, the pressure in the casing below the packing can act therewithin to force it into engagement with the wall of the casing along its entire outer skirt surface 47. The higher the pressure, the more firmly will the cup packing be sealed against the casing. Similarly, the action of fluid under pressure upon the inner skirt 46 will force it into firmer sealing engagement with the exterior of the tubular body 11. However, it has been found desirable to employ a ring 53 around the inner skirt member having a downwardly and outwardly tapering lower surface 53a engageable with a companion surface 46a on the packing skirt. As the packing is compressed and distorted radially into casing engaging position under the action of fluid under pressure, it is apparently the tendency for the metal ring 53 to be forced or pinched downwardly along the

inner skirt. The provision of the cooperative tapered surfaces 46a, 53a causes radial inward pressure of the skirt 46 against the exterior of the tubular body 11 upon downward forcing of the ring, increasing the sealing action of the skirt against the body and insuring that leakage will not occur therealong.

A plurality of metallic segments 54 are also attached to the base portion 45 of the cup packing in order to prevent flowing or dissipating of the packing material through the annular space between the packing retainer 41 and the wall of the casing C under high pressure operating conditions. These segments 54 are initially retracted, together with the base of the packing, from engagement with the casing, but upon application of pressure to the packing, its base portion 45 is compressed radially into contact with the casing, moving the segments 54 along with it into similar casing engaging position. Due to the increased circumferential extent of the segments they will be separated circularly to a small extent, but the intervening spaces are all too small in extent to enable the packing material to flow therethrough. Upon release of the pressure on the packing 40, it moves back toward its initial retracted position, acting on the segment projections 54a to effect their similar retraction from the casing and their return to initial position.

The packing segments 54 and metal ring 53 features just indicated are described in greater detail and are claimed in my copending application, Serial No. 374,471, filed January 15, 1941, and entitled Packing device.

As assurance that the packing 40 can be moved upwardly without restraint, and also to prevent its inadvertent expansion while moving through the casing, bleeder holes 55, 56 are formed through the protector cup 49 and the expander cone 52 to enable fluid to pass into the interior of the packing 40 and cone 52, causing equalizing in the pressure of the fluid both internally and externally of the packing prior to its intended sealing engagement with the wall of the casing.

The extent of inclination of the slip expander cone 12 and the packing expander cone 52 is preferably such as to cause substantially simultaneous engagement of the packing lip 48 and the wickers 15a on the slips with the casing C. To achieve such purpose, the inclinations of the slip and packing cones should be approximately equal, although the packing cone 52 is preferably inclined slightly more to the vertical to compensate for the radial movement of the slips along their cone 12 while the packing lip 48 is moving from its protector cup 49 and before its inner lip 48a engages the cone 52. Following such initial engagement, the pressure acting on the cylinder head 20 will force the slip wickers 15a more firmly into the casing wall, while the slight longitudinal movement incident to such firmer embedding of the slip wickers will cause the inner lip portions 48a to ride further upwardly on the cone surface 52 and urge the packing more strongly against the wall of the casing. However, as stated above, the packing 40 can be and is usually urged against the casing over the full extent of its outer skirt surface 47 by the pressure acting therewithin.

Since the slip expander cone 12, and also the packing expander cone 52, converge downwardly, it is necessary to move the slips 15 and packing 40 upwardly therealong into casing engaging position. With this relative arrangement of parts, retraction of the slips and packing from

casing engaging position is accomplished simply by taking an upward strain on the tubular string B to which the packer is connected. This pulls the slip and packing cones 12, 52 upwardly out of wedging engagement with their associated parts and produces radial retraction of the slips 15 from engagement with the casing, which is assisted by the encircling coil spring 57; and it also permits the packing skirt lip 48, 48a to ride downwardly along its expander 52 into its initially retracted position, with its lip 48 within the protector cup 49, a position which it inherently tends to assume upon release of the pressure within its skirt 47.

While the expander cone 12 converges downwardly, the wickers 15a on the slips face upwardly, being formed to dig into the casing upon being moved upwardly by any force acting thereon. Thus, the fluid under pressure acting on the cylinder head 20 digs the wickers on the slips more firmly into engagement with the casing, and this action is materially enhanced by the pressure of fluid acting within the packing member 40, which exerts an upward force directly onto the slips 15 through the medium of the packing retainer 41, cylinder skirt 31 and cylinder head 20. The hydraulic forces acting directly on the cylinder head 20 and on the packing member 40 do not move the entire well packer A up the casing since such forces are transmitted directly to the casing C through the upwardly facing wickers 15a on the slips anchored therein. In effect, these wickers, after their initial engagement, become more firmly embedded into the casing with increased pressure on the cylinder head and packing. This embedding action is enhanced if the wickers are provided with sharp edges. After the slips 15 have been anchored to the casing, the cylinder head 20 coupled thereto becomes a stationary reaction member, the fluid pressure within the cylinder space 25 acting downwardly on the piston 26 and exerting a force thereon tending to move its connected body 11 and slip expander 12 downwardly, wedging the latter more firmly into the slips 15 and their wickers 15a more securely into the wall of the casing.

This wedging action can also be achieved or increased by allowing part of the weight of the tubular string B to rest upon the cone 12 after the slips 15 have been engaged with the casing. However, the imposition of weight on this cone is not needed if the annular piston area around the tubular body is greater than the cross-sectional area of the body itself. The pressure of the fluid acting on the tubular body area tends to lift it, and if not counteracted, the cone 12 connected thereto would be elevated from wedging engagement with the slips, allowing their release and elevation of the entire packer by the action of fluid under pressure upon the interior of the cup packing 40. But by providing a greater piston area than tubular body cross-sectional area, the resultant hydraulic force on the tubular body 11 is in a downward direction, which maintains and forces the cone 12 into wedging engagement with the slips. Accordingly, so long as the fluid within the tubular body 11 and cylinder 18 is under pressure, the packer A will remain anchored in set and sealed off condition within the well casing. Release of this pressure and the taking of an upward strain on the tubular string B will raise the cones 12, 52 from the slips 15 and cup packing 40 and permit their retraction to their initial positions. The packer can

then be removed to any other desired position in the casing and pressure reapplied thereto to cause its setting in sealed off condition within the casing. Release can again follow, and this cycle of operation can be performed in the well casing as many times as are desired.

Pressure can be built up within the tubular body 11 and annular cylinder 18 in various ways. A preferred manner involves the simple expedient of incorporating an orifice 58 in the tubular passage 11a through the packer at any point below its inlet ports or openings 24, as by threading it in the packing expander 50. This orifice 58 is of less cross-sectional area than the passage through the body 11 itself, causing the building up of a back pressure within the tubular body and cylinder space 25 as fluid is pumped through the packer. Increase in the volumetric rate of fluid flow will correspondingly increase the pressure, whereas decrease or stoppage of flow will result in a relieving of this pressure.

The area of the orifice 58 need not be reduced very greatly below that of the area of the tubular passage 11a in order to develop sufficient pressure to effect engagement of the slips 15 and packing 40 with the wall of the casing. As a matter of fact, under many conditions of operation, the flow through the packer will be decreased materially upon engagement of the packing 40 with the casing, since fluid can no longer flow upwardly around the packer back to the surface of the well bore. This usually allows pressure to be built up within the tubular packer body 11 of a high degree, as much as 5,000 p. s. i. and over, which maintains the packer A in a set and effectively sealed off condition. Pressures of such magnitude are sometimes encountered during a squeeze cementing operation, or upon use of the packer as a production device in connection with high pressure zones existing below the point at which the packer is set within the casing.

Pressure may also be built up within the packer to accomplish its setting by entirely closing the passageway therethrough. In the example shown in Figure 1b, a tripping ball seat 59 is secured in a tail pipe 60 by means of a shear screw 61 or other frangible device, the tail pipe being threaded to the packing expander 50 to form an extension of the passageway 11a. The tripping ball 62 can be lowered or pumped down the tubular string B until it engages the tripping ball seat 59, or it may be placed on or adjacent the seat and lowered in that position with the packer into the casing, its material upward movement away from its seat being prevented by cross wires 63 secured to the tail pipe. However, upward flow of fluid through the packer is permitted by the one-way valve action of the tripping ball 62.

When the desired point in the casing has been reached and the ball 62 is positioned on its seat, the pumps at the surface of the well are started and a pressure built up within the tubular body 11 and cylinder 18 to cause movement of the slips 15 and the packing 40 to casing engaging position, as described before. Upon increase of the pressure to a sufficient degree, the screw 61 will be sheared and the tripping ball 62 and its seat 59 forced downwardly out of the tail pipe 60, permitting passage of fluid through the packer in both directions. The desired cementing or other operation can then be performed in the well, and the packer released from its set position simply by taking an upward strain on the tubular string B. If its positioning and setting

at the same point or another point in the casing is desired, it is only necessary to pass fluid through the packer body at the required minimum rate, the orifice 58 causing the building up of pressure essential to movement of the slips and packing to casing engaging positions.

There may be situations encountered in which it is desired to maintain the pressure within the body 11 after the slips and packing have been set against the casing, without resort to any external pressure creating devices, such as pumps at the surface of the well bore. To accomplish this purpose, a back pressure valve is incorporated in the top of the packer allowing fluid flow downwardly through the packer but preventing its reverse passage. In the present instance, the back pressure valve consists of a buoyant ball 64 normally resting upon by-pass fingers 65 upstanding from the tubular packer body 11. These fingers are spaced to allow fluid to pass down through the sub E and around the ball 64 into the tubular body passageway 11a. However, when reverse flow tends to occur, the ball is elevated from its supporting fingers and is forced against a valve seat 66 provided at the end of the sub, to close the passageway 11a. This one-way valve finds use in situations described below.

In the performance of many functions, the well packer device A can be attached directly to the tubing B, and set and released at will in the manners aforementioned. However, in performing certain specific operations, such as squeeze cementing of wells, it is preferred to interpose a circulation joint or valve D between the tubing and well packer.

Although more specifically described and claimed in my co-pending application, Serial No. 374,050, filed January 11, 1941, and entitled Control valve, a brief description of the circulation joint D will be given to indicate its cooperation with the well packer A shown in the drawings. The circulation joint includes a collar 67 threaded to the lower end of a joint of tubing B, and also threadedly secured to a cylinder or barrel 68 carrying a lower collar 69 at its bottom end by means of a threaded interconnection. Leakage between the collars and cylinder is prevented by the sealing rings 70, 70.

The lower collar 69 has a plurality of circularly spaced inner splines 71 cooperable with circularly spaced outer splines 72 provided on the exterior of a mandrel 73 telescopically related with the cylinder 68, but rotatably therewith because of the engagement between the respective splines 71, 72 aforementioned. The lower end of the mandrel 73 is threaded into the sub E, and its upper end carries a head 74 serving as an upper retainer for a flexible, nonmetallic sealing ring 75 of rubber held in position against the head by a lower retainer ring 76 welded to the mandrel. Loss of the ring 75 from the mandrel and head is obviated by preventing its material distortion through the incorporation of a filler ring 77 in an annular groove at its inner surface.

The lower surface 76a of the retainer ring 76, or of the welding material securing it to the mandrel, is bevelled for abutting engagement with a corresponding seat 78 formed near the upper end of the lower collar 69. The rubber ring 75 extends radially beyond the periphery of the head 74 and retainer ring 76 for slidable sealing engagement with a cylindrical surface 79 on a sleeve extension of the lower collar 69.

In the position shown in Figure 1, fluid can-

not pass from the interior to the exterior of the circulation joint D, since the rubber sealing ring 75 is confined within its cylindrical valve seat 79, effecting a seal between the mandrel 73 and the cylinder 68, and preventing the fluid from passing through the annular spaces (not shown) between the splines 71, 72 on the lower collar and mandrel. When the mandrel 73 moves upwardly to its full extent in the cylinder 68, the rubber ring 75 will move into the cylindrical valve seat surface 80 on a sleeve extension 81 of the upper collar 67, to similarly prevent passage of fluid between the interior and exterior of the circulation joint. This latter position will be determined by the abutting of the bevelled surface 74a on the mandrel head with a cooperating surface or seat 82 on the upper collar 67. (See Figure 2.)

It will, therefore, be seen that the circulation joint or valve D is in closed position when the mandrel 73 has been moved outwardly of the cylinder 68 to its fullest extent, and also when it has been moved inwardly of the cylinder or telescoped to its fullest extent. When placed intermediate these two positions, fluid can pass between the interior and exterior of the circulation joint by moving in either direction through the annular space between the sealing ring 75 and cylinder 68, and the circumferential spaces between the splines 71, 72.

For the purpose of using the well packer apparatus shown in the drawings in a cementing operation, it is assembled as shown in Figures 1, 1a and 1b with the parts in retracted position, and with or without the back pressure ball 64 and tripping ball 62 and its seat 59 in place. The use of these latter two features is optional, depending upon the specific operation to be performed. As the apparatus is being lowered through the well casing C on the end of the tubular string B, the circulation joint D will remain closed since the weight of the mandrel 73, sub E and well packer A tends to move the mandrel downwardly to its fullest extent and positions its sealing ring 75 within the lower cylindrical valve seat 79.

Upon reaching the desired point in the casing, the pumps at the surface of the well bore are started and fluid passed through the well packer body 11, building up pressure therein, and causing the slips 15 to move along their cone 12 into anchoring engagement with the casing, and the packing 40 to slide along its expander 52 for sealing engagement with the wall of the casing. The pressure may be increased to the extent necessary to break down the formation, after which the tubular string B can be lowered to move its cylinder 68 down along the mandrel to an intermediate point and open the circulation joint. This operation is sometimes desired to avoid the need for forcing the fluid in the tubular string ahead of the cement into the formation, allowing it to flow out of the circulation valve D back to the surface through the annular space between the tubing B and casing C. When the non-cementitious fluid has been pumped from the tubular string, and the bottom of the batch of cement slurry is adjacent the circulation joint, the tubular string can be elevated to again close the circulation joint and allow the cement slurry to be forced under the required pressure into the formation, thereby effecting the desired squeezing operation in the well.

It is to be noted that the cone 12, 52 will remain in wedging engagement with the slips 15

and packing 40 after these members have been engaged with the casing despite the fact that the pressure has been relieved in the interior 11a of the body during the time that the mud or fluid in the tubing ahead of the cement slurry is being pumped out through the circulation joint D. Upon closing of the joint and squeezing of the cement into the formation, the pressure of the fluid within the tubular body 11 and cylinder 18, and that acting on the packing 40, will embed the slips 15 more firmly into the casing, especially in view of the fact that the annular area of the piston 26 is greater than the cross-sectional area of the tubular string B, which results in urging of the cone downwardly to increase its wedging effectiveness on the slips.

After the desired quantity of cement slurry has been squeezed into the formation, the circulation joint D can be opened by lowering the tubular string B and the cylinder 68 to an intermediate point with respect to the sealing ring 75, any excess slurry being flushed out of the tubular string through the spaces between the circulation joint splines 71, 72 for conveyance through the annular space between the string B and casing C to the surface of the bore. An upward strain can thereafter be taken on the tubular string to lift the cone 12 out of wedging engagement with the slips and the lower cone 52 out of contact with the packing lip 48, 48a, permitting the retractor spring 57 to urge the slips away from the casing and into retracted position, and allowing the packing 40 to assume its inherent normal position with its lip 48 within the protector cup 49 and with its flow preventing segments 54 removed inwardly from engagement with the casing. The well packer apparatus is now free to be removed to another setting point or withdrawn entirely from the casing.

With the type of circulation joint shown in the drawings, it is also possible to apply pressure to the packer A after its initial setting by lowering the tubular string B until the mandrel head 74 abuts the seat 82 on the upper collar 67 with the sealing ring 75 engaged within the upper cylindrical valve seat 80. In connection with the squeeze cementing operation above described, after the mud or fluid preceding the cement slurry has been flushed through the open circulation joint, lowering of the tubing B will close the joint and also allow a squeeze to be imparted to the cement slurry for the purpose of forcing it under pressure into the formation. This lowering of the tubular string to close the circulation joint possesses the advantage that the pressure on the annular piston 26 tending to urge the cone 12 more firmly into the slips can be supplemented by placing several points of weight upon this cone. The supplementary weight or force is exerted between the abutting bevelled upper collar 67 and head 74 for transmission to the cone 12 through the mandrel 73 and sub E. By use of this expedient, further assurance is had that the pressures imposed within and below the packing body will be unable to release the cone 12 from the slips 15.

The circulation joint D is also preferably provided with a skirt 83 depending from its lower collar 69. When the joint is in open position, the end of this skirt will be positioned close to the slips 15 and will therefore cause their washing by the exiting fluid, insuring the flushing of substantially all cement slurry from the

region of the slips so as not to interfere with their retraction when desired.

Tests and actual field operations attest to the fact that cement slurry becomes dehydrated to a large degree upon being subjected to high pressures, such as are encountered in squeeze cementing operations. For that reason, it is apparently not essential that the packer be left anchored to the casing until the cement slurry has set, since there is very little tendency for the squeezed and dehydrated cement slurry to flow back into the casing or well bore after the packer has been released and removed. Accordingly, in such situations, the one-way back-pressure valve 64, 65, 66 shown in the drawings is not essential and can be omitted, although its use offers positive assurance that the cement slurry will not flow back into the casing provided that the packer is allowed to remain in set position until the cement slurry has stiffened sufficiently, after which it can be withdrawn from the casing. If the packer is to be left in the casing, the tubular string B can be rotated to the right and disconnected from the packer at the left-hand threads 10.

It is the lack of any tendency for the squeezed cement slurry to flow back into the casing, which permits the use of a free passage 11a through the packer whenever a squeeze operation is performed. Accordingly, sufficient pressure for setting purposes is obtainable by the mere use of the orifice 58, but if a greater initial anchoring of the packer to the casing is desired or essential, the tripping ball seat 59, ball 62 and shear screw 61 expedient can be employed. When they are used, the slips 15 and packing 40 can be positively maintained in retracted positions by a shear screw 84 connecting one of the slips to the cone. This shear screw will be disrupted by less pressure than the tripping ball seat screw 61, its fracture occurring after the packer is at the desired point and upon the building up of pressure in the cylinder 18 and body 11. After it fails, the cylinder 18 is free to move the slips 15 and packing 40 into contact with the casing, whereupon the pressure can be increased to force the tripping ball 62 and seat 59 from the tail pipe 60.

While specific mention has been made of employing the packer for squeeze cementing operations, it is susceptible to a wider range of operations. For example, it can be used for testing casing by anchoring it selectively at various points in the casing and applying pressure through the set packer in order to locate holes in the casing, leaks in collars, gun perforations, etc. It can be employed for displacing any fluid in the well, such as operations involving the displacement of cement slurry for water shut-off purposes or for the killing of wild wells. It finds further usage in connection with the acidizing of wells, and can be set in the casing to serve as a high pressure retrievable production packer. Fields of use are greater than those enumerated above, the list being given merely to illustrate the utility and applicability of the well packer apparatus described in this specification.

I claim:

1. A well packer, including a body, expander means carried by said body, slips cooperable with said expander means for anchoring said packer to the wall of a well casing, and fluid actuated means for moving said slips with respect to said expander means to casing anchoring position, said slips having wickers thereon facing in the

same direction as the slips are movable by fluid acting on said fluid actuated means.

2. A well packer, including a body, an expander having a downwardly converging outer surface carried by said body, slips cooperable with said expander for anchoring said packer to the wall of a well casing, and fluid actuated means for moving said slips upwardly along said surface to casing anchoring position, said slips having upwardly facing wickers on their exterior surfaces.

3. A well packer, including a body, expander means carried by said body, normally retracted slips cooperable with said expander means for anchoring said packer to the wall of a well casing, means for moving said slips with respect to said expander means to casing anchoring position, said slips having casing engaging wickers thereon facing in the same direction as the slips are movable by said moving means, and said expander means being in rigid relation to said body when said wickers are engaged with said casing.

4. A well packer, including a body, an expander having a downwardly converging outer surface carried by said body, normally retracted slips cooperable with said expander for anchoring said packer to the wall of a well casing, means for moving said slips upwardly along said surface to casing anchoring position, said slips having upwardly facing casing engaging wickers on their exterior surfaces, and said expander being in rigid relation to said body when said wickers are engaged with said casing.

5. A well packer, including a body, expander means carried by said body, normally retracted slips cooperable with said expander means for anchoring said packer to a well casing, fluid actuated means for moving said slips with respect to said expander means to casing engaging position, said slips having casing engaging wickers thereon facing in the same direction as said slips are movable by said fluid actuated means, and said expander means being in rigid relation to said body when said wickers are engaged with said casing.

6. A well packer, including a body, an expander having a downwardly converging outer surface carried by said body, normally retracted slips cooperable with said expander for anchoring said packer to a well casing, fluid actuated means for moving said slips upwardly along said surface to casing anchoring position, said slips having upwardly facing casing engaging wickers on their exterior surfaces, and said expander being in rigid relation to said body when said wickers are engaged with said casing.

7. A well packer, including a body, an expander having a downwardly converging outer surface fixed with respect to said body, normally retracted slips cooperable with said expander for anchoring said packer to a well casing, said slips having upwardly facing casing engaging wickers on their exterior surfaces, and means for moving said slips upwardly along said expander surface to anchor their wickers in said casing.

8. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, normally retracted slips having upwardly facing wickers on their exterior surfaces cooperable with said expander for anchoring said packer to a well casing, fluid actuated means on said body for moving said slips upwardly along said expander surface to casing anchoring position, and means providing communication between the interior of said body

and fluid actuated means for the passage of fluid therebetween.

9. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, normally retracted slips having upwardly facing wickers on their exterior surfaces cooperable with said expander for anchoring said packer to a well casing, cylinder and piston means for moving said slips upwardly along said expander surface to casing anchoring position, and means establishing communication between the body interior and cylinder means for the passage of fluid therebetween.

10. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their exterior surfaces cooperable with said expander for anchoring said packer to a well casing, cylinder and piston means for moving said slips upwardly along said expander surface to casing anchoring position, one of said means being secured to the body and the other of said means being cooperable with said slips, and means establishing communication between the body interior and cylinder means for the passage of fluid therebetween.

11. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces cooperable with said expander for anchoring said packer to a well casing, an annular piston secured to said body, an annular cylinder slidable on said piston and cooperable with said slips for moving them upwardly along said expander surface to casing anchoring position, said body having an opening for the passage of fluid between its interior and said cylinder.

12. A well packer, including a tubular body, expander means carried by said body, normally retracted slips cooperable with said expander means for anchoring said packer to a well casing, an annular piston secured to said body, an annular cylinder slidable on said piston and cooperable with said slips for moving them with respect to said expander means to casing engaging position, said slips having casing engaging wickers thereon facing in the same direction as said slips are movable by said annular cylinder, said body having an opening for the passage of fluid between its interior and said cylinder.

13. A well packer, including a tubular body, expander means carried by said body, normally retracted slips cooperable with said expander means for anchoring said packer to a well casing, cylinder and piston instrumentalities for moving said slips with respect to said expander means to casing engaging position, one of said instrumentalities being secured to the body and the other being cooperable with said slips, said slips having casing engaging wickers thereon facing in the same direction as said slips are movable by its cooperable instrumentality, and means establishing communication between the body interior and cylinder instrumentality for the passage of fluid therebetween.

14. A well packer, including a body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces cooperable with said expander for anchoring said packer to a well casing, and fluid actuated means for moving said expander and slips longitudinally with respect to each other, whereby said slips

are shiftable upwardly along said expander surface to casing anchoring position.

15. A well packer, including a body having a longitudinal passage, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their exterior surfaces cooperable with said expander for anchoring said packer to a well casing, cooperable cylinder and piston means for moving said slips upwardly along said expander surface to casing anchoring position, one of said means being secured to said body and the other of said means being cooperable with said slips, and means providing communication between said body passage and cylinder means for the flow of fluid therebetween, the cross-sectional area of said cylinder means being greater than the cross-sectional area of said body.

16. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces cooperable with said expander for anchoring said packer to a well casing, an annular piston secured to said body, an annular cylinder slidable on said piston and cooperable with said slips for moving them upwardly along said expander surface to casing anchoring position, said body having an opening for the passage of fluid between its interior and said cylinder, the fluid active cross-sectional area of said cylinder being greater than the cross-sectional area of said tubular body.

17. A well packer, including a body having a longitudinal passage, expander means carried by said body, normally retracted slips cooperable with said expander means for anchoring said packer to a well casing, fluid actuated means for moving said slips with respect to said expander means to casing engaging position, said slips having casing engaging wickers thereon facing in the same direction as said slips are movable by said fluid actuated means, said body having an opening for the flow of fluid between its passage and said fluid actuated means, and means below said opening for restricting flow of fluid through said longitudinal passage to enable fluid pressure to be increased therein.

18. A well packer as defined in claim 17, said flow restricting means comprising an orifice.

19. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces cooperable with said expander for anchoring said packer to a well casing, an annular piston secured to said body, an annular cylinder slidable on said piston and coupled to said slips for moving them upwardly along said expander surface to casing anchoring position, said body having an opening for the passage of fluid between its interior and said cylinder, and an orifice below said opening for restricting the flow of fluid through said body.

20. A well packer, including a body having a longitudinal passage, expander means carried by said body, normally retracted slips cooperable with said expander means for anchoring said packer to a well casing, fluid actuated means for moving said slips with respect to said expander means to casing engaging position, said slips having casing engaging wickers thereon facing in the same direction as said slips are movable by said fluid actuated means, said body having an opening for the flow of fluid between its passage

and said fluid actuated means, and a one-way valve above said opening permitting flow of fluid through said longitudinal passage in one direction only.

21. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces co-operable with said expander for anchoring said packer to a well casing, an annular piston secured to said body, an annular cylinder slidable on said piston and coupled to said slips for moving them upwardly along said expander surface to casing anchoring position, said body having an opening for the passage of fluid between its interior and cylinder, and a one-way valve above said opening permitting fluid flow down through said body, but preventing its reverse flow.

22. A well packer, including a body, expander means carried by said body, means co-operable with said expander means for anchoring said packer to a well casing, a packing for effecting a seal between said body and well casing, expander means for positively forcing said packing into sealing engagement with said casing, and fluid actuated means for simultaneously shifting said anchoring means and packing longitudinally of their respective expander means into contact with said casing.

23. A well packer, including a body, expander means carried by said body, normally retracted means co-operable with said expander means for anchoring said packer to a well casing, a normally retracted packing for effecting a seal between said body and well casing, and common means between said anchoring means and packing for shifting them into contact with said casing.

24. A well packer, including a tubular body, expander means carried by said body, normally retracted means co-operable with said expander means for anchoring said packer to a well casing, a normally retracted packing for effecting a seal between said body and well casing, and fluid actuated means coupled to said anchoring means and packing to shift them into contact with said casing.

25. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces co-operable with said expander for anchoring said packer to a well casing, a normally retracted packing for effecting a seal between said body and well casing, a packing expander having a downwardly converging outer surface carried by said body, and fluid actuated means coupled to said slips and packing for shifting them upwardly along their respective expanders into contact with the casing.

26. A well packer, including a body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces co-operable with said expander for anchoring said packer to a well casing, an inherently retracted downwardly facing cup packing for effecting a seal between said body and well casing, a packing expander having a downwardly converging outer surface carried by said body normally within said cup packing, and means coupling said slips and cup packing together for conjoint movement upwardly along their respective expanders into contact with the casing.

27. A well packer, including a body, an expander having a downwardly converging outer sur-

face carried by said body, slips having upwardly facing wickers on their outer surfaces co-operable with said expander for anchoring said packer to a well casing, a packing for effecting a seal between said body and well casing, a packing expander having a downwardly converging outer surface carried by said body, and means coupling said slips and packing together for simultaneous movement upwardly along their respective expanders into contact with the casing.

28. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces co-operable with said expander for anchoring said packer to a well casing, an inherently retracted downwardly facing cup packing for effecting a seal between said body and well casing, a packing expander having a downwardly converging outer surface carried by said body normally within said cup packing, a piston fixed to said body, a cylinder slidable on said piston and coupled to said slips and packing for moving them upwardly along their respective expanders to casing engaging position, said body having an opening through its wall through which fluid can pass between its interior and cylinder.

29. A well packer, including a tubular body, an expander having a downwardly converging outer surface carried by said body, slips having upwardly facing wickers on their outer surfaces co-operable with said expander for anchoring said packer to a well casing, an inherently retracted downwardly facing cup packing for effecting a seal between said body and well casing, a packing expander having a downwardly converging outer surface carried by said body normally within said cup packing, an annular piston fixed to said body, an annular cylinder slidable on said piston and coupled to said slips and packing therebetween to shift them upwardly along their respective expanders to casing engaging position, said body having an opening through its wall above said piston for the passage of fluid between the body interior and cylinder.

30. In a well packer, a body, an inherently retractable cup packing for effecting a seal between said body and a well casing, a frusto-conical expander carried by said body normally within said packing, a cup normally encompassing the free end of said packing to prevent its inadvertent expansion, the small end of said expander being spaced normally from the free end of said packing to permit its withdrawal from said cup before expansion to casing contacting position.

31. An apparatus including a well packer adapted to be moved through a well casing on the lower end of a tubular string, said packer comprising an expander having a downwardly converging outer surface and slips having upwardly facing wickers engageable with said surface and co-operable with said expander to anchor said packer to said casing, a circulation valve forming part of said tubular string, said valve comprising means for closing said valve when the weight of said tubular string is imposed on said expander, whereby said expander is held wedged in said slips.

32. An apparatus including a well packer adapted to be moved through a well casing on the lower end of a tubular string, said packer comprising an expander having a downwardly converging outer surface and slips having upwardly facing wickers engageable with said surface and co-operable with said expander to anchor said

packer to said casing, a circulation valve forming a part of said tubular string, said valve comprising telescopic members, which are fully telescoped when the weight of said tubular string is imposed on said expander to close said valve against the passage of fluid between its interior and exterior, whereby said expander is held wedged in said slips and fluid can be forced under pressure through said packer.

33. A well packer, including a body, expander means carried by said body, slips cooperable with said expander means for anchoring said packer to a well casing, cooperable cylinder and piston instrumentalities for moving said slips with respect to said expander means to casing anchoring position, one of said instrumentalities being secured to said body and the other of said instrumentalities being cooperable with said slips, the cross-sectional area of said cylinder instrumentality being greater than the cross-sectional area of said body.

34. A well packer, including a body, expander means carried by said body in rigid relation thereto, slips cooperable with said expander means for anchoring said packer to a well casing, and fluid operated means for moving said slips

with respect to said expander means to casing anchoring position, said fluid operated means acting on said expander means to wedge it into said slips and maintain them anchored to said casing.

35. A well packer, including a body, expander means carried by said body in rigid relation thereto, normally retracted means cooperable with said expander means for movement into engagement with a well casing, and fluid operated means for moving said normally retracted means with respect to said expander means to casing engaging position, said fluid operated means acting on said expander means to wedge it into said normally retracted means and maintain the latter in engagement with said casing.

36. A well packer, including a body, a conical expander fixed to said body, slips cooperable with said expander for anchoring said packer to a well casing, and fluid operated means for moving said slips along said expander to casing anchoring position, said fluid operated means acting on said body to wedge its attached expander into said slips and maintain them anchored to said casing.

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