ABSTRACT: A retrievable well-packer apparatus including a body member having upper and lower expander means slidably mounted thereon for movement toward and away from each other, slip means between said expander members and slidably coupled to said body member and one of said expander means, and packing means for sealing off a well bore in response to movement of said body member relative to slip and expander means in one longitudinal direction, said packing means including elastomeric packing elements and pressure responsive parts subject to fluid pressure acting in the opposite longitudinal direction for exerting compressive force on said packing elements.
3,603,392

1 WELL PACKER ANCHOR

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This invention relates generally to retrievable well packers used in well bores and more specifically, to a new and improved retrievable well packer which can be run and set in casing on a pipe string and which will hold high pressure from above or below.

In conducting pressure operations such as fracturing, acidizing, squeeze cementing and testing in a well bore, well tools commonly called packers are run into the well bore on tubing or drill pipe and set at a selected point in order to isolate the zone to be pressurized. After the operation is completed, the packer can be retrieved to the surface. Particularly where such pressure operations are conducted at relatively shallow depths in a well, any above 3000 to 4000 feet, it is good practice to use what is commonly called a tension set packer because there may not be sufficient pipe weight available to set a compression set packer and maintain it set against high pressure from below. In tension packers, the slips and packing are generally arranged to be set by upward strain or tension in the pipe string so that high pressure below the packer reinforces the setting, instead of opposing it as is the case of a compression set packer.

However, conditions may arise when using a retrievable tension packer when the high pressure is in favor of the annulus above the tool. This may occur, for example, during swab-testing of a cement job or the like where the static head of fluids below the packer is substantially reduced. In such event, the downward force on the tool due to high pressure from above adds to the strain or tension already applied to the pipe string to set the packer so that the risk arises of overstraining and possibly pulling the pipe string in two. This is, of course, undesirable and cannot be effectively prevented by reducing the tension in the pipe string because the packer, being tension set, may become unseated or may slide downwardly in the casing to an improper location.

The present invention provides a new and improved retrievable well packer which is settable in tension to isolate a well zone to be pressurized, and which is provided with various features to obviate the aforementioned problems. The packer remains sealed off and set whether the higher pressure is acting from below or above.

SUMMARY OF THE INVENTION

Generally speaking, a retrievable well packer in accordance with the concepts of the present invention comprises a body member adapted for connection to a pipe string and carrying upper and lower expander and drag means which are mounted for limited longitudinal movement on the body member. Normally retracted slip means are also mounted on the body member between the expander means and can be shifted into anchoring engagement with a well conduit by movement of the expander means relatively toward each other. The slip means can have a sliding connection to one of the expander means as well as to the body member, and are supported in anchoring engagement with the well conduit by both expander means acting simultaneously.

The well packer further includes a packing assembly including packing elements which are sealed against the well conduit in response to force applied to the body member in one longitudinal direction, movement in said one direction being prevented, however, by the slip means. In response to fluid pressure acting in the opposite longitudinal direction, the packing assembly and the body member are shiftable to a limited extent along the well conduit in said opposite direction while the packing elements remain sealed against the well conduit, whereupon coengaging means coating between the body member and said expander and slip means function to cause the slip means to prevent further shifting in said opposite direction. Thus the well packer of the present invention will hold pressure acting in either longitudinal direction, and the shifting mentioned is quite limited in order to protect the pipe string from undue strain. When desired, the slip means and the packing elements can be retracted so that the packer can be moved to another setting point or removed from the well bore.

The novel features of the present invention are particularly set forth in the appended claims. One preferred embodiment of the present invention is illustrated in the accompanying drawings in which:

FIGS. 1A and 1B are longitudinal sectional views, with portions in side elevation, of a well packer in accordance with this invention, FIG. 1B forming a lower continuation of FIG. 1A;

FIG. 2 is a cross section on line 2—2 of FIG. 1A;

FIG. 3 is a cross section on line 3—3 of FIG. 1A;

FIG. 4 is a schematic plan view of a slot configuration which is used to enable selective control over relative movement between parts;

FIGS. 5A and 5B are views similar to FIGS. 1A and 1B except with the packer set in a well conduit;

FIGS. 6A and 6B are similar views showing the relationship of packer parts when a sufficiently high pressure exists in the well annulus above the packer; and

FIG. 7 is a longitudinal sectional view with portions in side elevation, of a modified structure in accordance with the present invention.

Referring initially to FIGS. 1A and 1B, an apparatus which incorporates the principles of the present invention includes a tubular body member 12 and mandrel 13 having a central passage through which fluid can flow. Threaded collars 14 and 15 can be provided at the upper and lower ends of the mandrel 12, the upper collar 14 being coupled to a running-in string of tubing or drill pipe 16 which extends to the earth's surface. The mandrel 12 carries an anchoring structure 18 which includes a tubular cage 19 and drag elements 20, the cage 19 being secured to a tubular sleeve 21 which is coupled by a swivel connection 22 to an upper expander member 23. One or more lug elements 24 extend outwardly from the mandrel 12 and engage within a slot system 25 formed on the interior of the sleeve 21, the lugs and slot system cooperating to provide control over relative longitudinal movement between the mandrel and the anchoring structure as will be more fully described.

Circumferentially spaced slip elements 27 are slidable coupled to the expander member 23 and are mounted on the mandrel 12 for both longitudinal and lateral movement relative to the mandrel. The slip elements 27 have peripheral wickers or teeth 28 which can bite into and grip the well casing in order to prevent movement in either direction in a well casing.

A lower tubular cage 29 carries drag elements 30 and is secured to a lower expander member 31. The cage and expander member 29 and 31 are slidable upwardly relative to the mandrel 12 to a position where respective shoulders 32 and 33 on the cage and the mandrel engage to limit relative movement. A bore 34 in the cage and expander member is, however, sized to permit unlimited upward relative movement of the mandrel 12 within the cage and expander member.

A packing structure 36 is slidable carried by the mandrel 12 and includes an inner sleeve 37 having a lower abutment 38, and an outer sleeve 39 having an upper abutment 40. The respective sleeves 37 and 39 are slidable along each other and can have a spline connection 41 to prevent relative rotation. One or more converging elastomeric packing rings 42 are mounted around the inner sleeve 37 between the upper and lower abutments 40 and 38, the rings being expandable into sealing engagement with a well casing wall by movement of the abutments 40 and 38 relatively toward each other. The outer sleeve 39 has an inwardly extending annular piston section 44 which is sealed against an outer peripheral surface of the mandrel 12 by an O-ring seal 45 or the like. Moreover, an O-ring seal 46 prevents fluid leakage between the inner and outer sleeves 37 and 39, whereby a variable volume chamber 47 is formed between the outer sleeve 39 and the mandrel 12.

This chamber 47 is communicated with the well annulus
below the packing rings 42 by a suitable passage which can conveniently be formed by an annular space 48 between the mandrel 12 and the inner sleeve 37. Consequently, fluid pressure below the packing rings 42 can act on the lower face 49 of the piston section 44, while fluid pressure above the packing rings can act on the upper face 50 of the piston section. With this arrangement, once the packing rings 42 are expanded into sealing engagement with a well casing wall, high pressure in the well annulus above the packing rings can act on the piston section 44 to impose compressive force on the packing rings for purposes which will become more apparent hereafter. Upward movement of the packing assembly 36 along the mandrel 12 is limited by engagement of the piston section 44 with the lower cage 29, and upward movement of the mandrel 12 within the packing assembly is limited by a transverse surface 51, which may be conveniently provided by the collar 15.

Turning now to a more detailed consideration of various other structural features of the present invention, the upper tubular cage 19 has a plurality of circumferentially spaced, radially directed recesses 54 which receive drag blocks 20. The drag blocks 20 can be urged outwardly by coil springs 55 or by frictional engagement with a well casing, and outward movement of the blocks can be limited by bands 56. A seal barrier 57 prevents debris in the well bore from getting into the well bore and the mandrel. The swivel connection 22 can be suitably formed by flanged sleeves 58 and 59 which are threadedly secured to the extension sleeve 21 and the upper expander member 23, respectively. The sleeves 58 and 59 have coengaging annular portions 60 and 61 to provide a rotational coupling.

The slip elements 27 are mounted on a ring member 63 which is relatively slidable on the mandrel 12 below an annular stop shoulder 64. The ring member 63 can be an integral piece as shown in cross section in FIG. 2, or can be formed in segments secured together by threaded studs. In any event, the ring member 63 has circumferentially spaced, axially disposed recesses 65, each of which receives a central portion 66 of a respective slip element 27 to provide a lateral guide therefor. As previously noted, the ring member 63 can slide downwardly relative to the mandrel 12, however upward movement is limited by the downwardly facing stop shoulder 64 on the mandrel.

The slip elements 27 have upper inner-inclined surfaces 67 which are cooperable with the outer inclined surfaces 68 on the expander member 23 whereby longitudinal movement of the elements relative to the expander member will cause lateral shifting thereof. A "dove-tail" flange and groove connection 69 slidably couples each slip element 27 to the upper expander member 23 so that the slip elements are retracted by upward movement of the expander member 23 relative to the slip elements.

The lower drag cage 29 has recesses 71 receiving drag blocks 30 which are urged outwardly by coil springs 72. Outer inclined surfaces 73 on the expander member 31 are engageable with inner inclined surfaces 74 on the slip elements 27 for wedging the elements outwardly. However, there is no sliding connection between the lower expander member 31 and the slip elements 27.

The slot system 25 which cooperates with the mandrel lugs 24 may be best understood by considering FIGS. 3 and 4. As shown in FIG. 3, there can be three lugs 24 circumferentially spaced about the mandrel 12, each of which engages in a slot configuration formed interiorly of the sleeve extension 21 and shown somewhat schematically in FIG. 4. Each slot configuration is longitudinally stepped and includes lower and upper transverse channels 77 and 78 connected by a short vertical channel 79. An elongated vertical channel 80 connects with upper transverse channel 78. In the running-in condition of parts shown in FIGS. 1A and 1B, the lugs 24 are positioned in the lower transverse channels 77 to prevent relative movement of the upper expander member 23 along the mandrel 12. However, it will be appreciated that by applying right-hand torque to the mandrel 12 while lifting the mandrel upwardly, the lugs 24 can be moved into the elongated vertical channels 80 to permit a substantial amount of relative movement between the upper expander member 23 and the mandrel.

Moreover, the transverse form of the upper channels 78 provides transverse surfaces or shoulders 81 which can be engaged by the lugs 24 in response to downward movement of the mandrel 12, whereby downward force on the mandrel can be applied to the upper expander member 23 for reasons which will be subsequently pointed out. Of course, it will be understood that more or less than three lugs 24 can be on the mandrel 12, in which case the slot system 25 will include a like number of slot configurations in which the lugs engage.

In operation of the structure thus far described, it will be apparent that the assembled tool can be connected to the lower end of the pipe string 16 and pushed downwardly along the well casing to setting depth as additional joints of the pipe string are added in end-to-end relation. The lower drag blocks 30 slide along the pipe casing wall, and the coengaged shoulders 32 and 33 on the mandrel and lower cage maintain the lower expander member 31 in spaced relation to the slip elements 27. The upper drag blocks 20 are also sliding along the casing wall as the downward motion of the mandrel 12 is being transmitted to the anchor assembly 18 by engagement of the lugs 24 with the lower transverse channels 77. The upper elements 27 are being held in retracted positions by their sliding connections 69 with the upper expander member 23, together with engagement of the mounting ring 63 underneath the mandrel shoulder 64. Of course, the packing rings 42 are in their inherently retracted positions so that well fluids can pass between the rings and the well casing wall.

When it is desired to set the packer, right-hand torque coupled with an upward strain on the pipe string 16 will position the lugs 24 within the elongated vertical channels 80 as previously described, the drag blocks 20 functioning to prevent movement of the upper cage member 19 and the upper expander member 23. As the mandrel 12 is pulled upwardly, the lower mandrel shoulder 51 engages the lower end of the inner sleeve 37 to elevate the packing assembly 36 as well as the lower drag assembly 29 and the lower expander member 31 toward the slip elements 27 until their teeth 28 bite into and grip the well casing wall. Then the lower expander member 31 and the outer sleeve 39 of the packing assembly 36 cannot move any further upwardly, whereby continued upward movement of the mandrel 12 telescopes the inner sleeve 37 within the outer sleeve 39 and effects compression and lateral expansion of the packing rings 42 until their outer peripheries seal against the well casing wall. A predetermined amount of upwardly strain is maintained in the pipe string 16 at the earth's surface in order to maintain the tool in set condition as shown in FIGS. 5A and 5B.

It should be specifically noted at this point that both of the expander members 23 and 31 are engaging the slip elements 27. This engaged relationship will be maintained during the operation of the packer and until it is desired to release the tool for retrieval from the well. With the slip elements 27 set and the packing 42 expanded, the well bore below the tool can be pressurized as desired and the slip elements will prevent upward movement while the packing rings seal off the well annulus.

Should a sufficiently high pressure exist in the annulus above the packer, various of the tool parts can shift to the positions shown in FIGS. 6A and 6B where the slip elements 27 remain anchored against movement and the packing rings 42 remain expanded. This shifting action results due to the high pressure acting downwardly on the expanded packing rings 42 with the resulting force being transmitted to the pipe string 16 through the lower shoulder 51, tending to stretch the pipe string. A limited amount of such stretching can occur and is accompanied by downward movement of the mandrel 12, thereby moving the lugs 24 downwardly within the vertical channels 80 until the lugs bottom against the shoulder surfaces 81 at the lower end of the channels.
During this movement, the packing rings 42 merely slide downwardly along the casing in expanded condition and remain sealed against the well casing wall. This will occur because the lower fluid pressures are acting on the lower face 49 of the piston section 44 while the high pressures are acting on the upper face 50, the pressure differential acting on the area A as downward force which is applied to the upper end of the packing rings 42 by the upper abutment 40. It will be remembered that upward strain is still being exerted on the pipe string 16 so that compressive force is being applied to the lower end of the packing rings 42 by the lower abutment 33. Accordingly, since compressive force is being exerted on both ends of the packing rings, the rings will not retract but can slide downwardly along the casing wall in expanded and sealing condition. However, when the lugs 24 engage the shoulder surfaces 81, further downward shifting is not possible and the load on the tool due to high pressure from above is transmitted through the lugs 24 and shoulder surfaces 81 to the upper expander member 23 which is supported by the slip elements 27 and cannot move downwardly. Thus the casing itself supports the load and there is no danger of damaging the pipe string by overstretching it. The actual extent of downward shifting of the mandrel 12 and packing assembly 36 is actually quite short compared to prior art devices of this general type, and may be only two or three inches. This feature provides a significant advantage over such prior tools, particularly when the packer is set near the surface and depths and the length of the pipe string is consequently short.

If the pressure in the annulus is reduced, tension is still being held in the pipe string 16 and the string can contract and shift the packing assembly 36 and the mandrel 12 back upwardly to their original position with the upper and lower expander members 23 and 31 cooperating with the slip elements 27 to expand the casing. In fact, as long as tension is held on the pipe string, the packing assembly 36 and the mandrel 12 can shift to and fro and it will be appreciated that the well bore remains sealed off to prevent any fluid movement past the tool. The slip elements 27 remain anchored against the well casing wall and remain supported in anchoring condition by both the upper and lower expander members 23 and 31.

To unseat the tool, pressures above and below the packer are equalized by operation of a suitable bypass valve (not shown) as upward strain on the pipe string 16 is relieved and as the mandrel 12 is moved downwardly by lowering the pipe string. This relieves the compressive force on the packing assembly 36 and the packing rings 42 will inherently retract. The mandrel shoulder 32 will engage shoulder 33 and cause the slip elements 27 to shift inwardly along the inclined surfaces 68 of the expander member 23 to their retracted positions, whereupon the tool is free to be moved upwardly or downwardly within the casing.

If a tubing tester valve is utilized which is opened and closed by movement of the pipe string 16, it will be appreciated that the slip elements 27 can be set against the casing by merely manipulating the pipe string as previously described in order to position the lugs 24 within the vertical channels 80 of the slot system 25. Then the pipe string 16 can be lowered to engage the lugs 24 with the shoulder surfaces 81, whereupon the slip elements 27 can be shifted outwardly into gripping contact with the casing by movement of the upper expander member 23 toward the lower expander member 31. With the slip elements 27 set and the lugs 24 engaging the shoulder surfaces 81, a false bottom is provided for the lower end of the pipe string 16 to enable operation of a tubing tester valve or a circulating valve or the like.

It is sometimes desirable to be able to "safety" the tool during removal of same from the well. In other words, some operators may desire to completely disarm the tool immediately before retrieving it so that it is impossible to again set the slips and the packing in the well bore. A structure for accomplishing this end is also shown in FIG. 1A. An inwardly biased latch lug 84 is received in a radial bore 85 in the wall of the cage extension sleeve 21. The latch lug 84 is normally retained outwardly and in inoperative position by a retaining sleeve 86 which is threaded at 87 to the expander member 23 and slidably and corotatively coupled to the flanged sleeve 58 on the cage extension sleeve 21. By rotation of the extension sleeve 21 relative to the expander member 23, the retaining sleeve 86 can be fed upwardly and the threads 87 of position clear of the latch lug 84, whereupon the lug can spring inwardly against the mandrel 12 and into a detent groove or recess 88 formed above a shoulder 89 on the mandrel. When this occurs, it is impossible to again manipulate the mandrel lugs 24 within the slot system 25 in a manner to enable setting the slips and packing.

To operate the disarming mechanism, the mandrel 12 is first manipulated to place the mandrel lugs 24 in the long vertical channels 80, and then the pipe string 16 is moved downwardly to set the slip elements 27 against the casing wall. With a small amount of pipe weight being applied, the slip elements cannot be rotated within the casing, and the upper expander member 23 cannot rotate due to the "dove-tail" connection between the slip elements and the expander member. Accordingly, sufficient torque can be applied to the pipe string 16 to rotate the upper drag elements 20 within the casing and relative to the expander member 23, such relative rotation being permitted by the swivel connection 22. Although the upper drag elements are sufficiently resistant to movement to enable setting and unsetting the tool as previously described, the elements can be forced by a torque applied thereto by the mandrel lugs 24 against the sides of the channels 80 to slide around the inner periphery of the casing. Such relative rotation causes the retaining sleeve 86 to feed upwardly until the latch lug 84 is released. Then the mandrel 12 can be lowered and manipulated to place the lugs 24 back within the transverse channels 77, and whereupon the mandrel recess 89 is located adjacent the lug, thus allowing the lug to snap into the recess. Now it is impossible to elevate the mandrel 12 relative to the upper expander member 23 or the slip elements 27. Accordingly, the tool cannot again be set on this trip into the well and the operator can pull the tool from the well as fast as he desires without the fear that the tool will, by some fortuitous circumstance, accidentally hang up and set in the casing, as desired, a lower detent groove 90 can be provided in the mandrel 12 so that the mandrel can be locked relative to the upper expander member 23 with the lugs 24 in the upper transverse channels 78 as well.

A modified form of the packing assembly of the present invention is shown in FIG. 7. In this embodiment, the inner sleeve 37, on which the packing rings 42 are mounted, and the lower abutment 93 are rigidly secured to the lower end of the mandrel 12 by threads 94. The annular passage 95 between the sleeve 92 and the mandrel is communicated with the well annulus by one or more ports 96. Moreover, clutch lugs 97 and 98 are provided respectively on the outer sleeve 99 and the lower end of the cage 100, the clutch lugs being engaged by upward movement of the packing assembly.

The structure shown in FIG. 7 operates in a similar fashion to the first described embodiment. However, if the threads 94 are formed as relatively coarse left-hand threads, an additional safety or disarming feature is provided. The slip elements 27 and the packing rings 42 can be expanded by upward strain on the pipe string 16 and then the mandrel 12 can be rotated to the right. Due to the frictional engagement between the lower expander member 31 and the slip elements 27, the clutch engagement between the cage 100 and the outer sleeve 99, and due further to the spline connection between the outer sleeve 99 and the inner sleeve 92, the lower abutment 93 will be held
against rotation so that rotation of the mandrel 12 will disengagethe threads 94. When this occurs, the mandrel 12 can be pulled upward through the packing assembly as well as the lower expander and drag assembly, leaving these elements in the well bore where they can be subsequently pushed to the bottom or retrieved in a conventional manner as desired.

It will be appreciated that the entire tool shown in the drawings could be inverted or turned upside down and then run into a well bore, in which case the tool could be set in compression by pipe weight if desired. Also, the rotational directions for setting and unsetting movement applied to the pipe string at the surface are a function of the slot system 25, which can be arranged for right-hand or left-hand torque as desired.

It will be apparent that the present invention provides a new and improved retrievable well packer which is settable in tension and which will hold pressure in either direction. Since certain changes or modifications may be made in the present invention without departing from the inventive concepts, it is the aim of the appended claims to cover all such changes and modifications falling within the true spirit and scope of the present invention.

I claim:
1. Apparatus for use in a well bore comprising: a body member; normally retracted slip means capable of being shifted laterally of said body member; expander means having a slidable spline connection to said slip means so that movement in one direction relative to said slip means causes expansion of said slip means and movement in the opposite direction causes retraction of said slip means; annular ring means having a radially slidable coupling to said slip means for mounting said slip means for sliding movement along said body member; and stop means including coengageable shoulder surfaces on said ring means and said body member for limiting sliding movement of said slip means along said body member in said opposite direction.
2. The apparatus of claim 1 wherein said radial slidable coupling is provided by recess means in said slip means, portions of said ring means being slidably received in said recess means.
3. The apparatus of claim 1 further including selectively operable coengageable means on said body member and expander means for securing said expander means to said body member in movement transmitting relationship in spaced longitudinal relative positions of said body member and said expander means.