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# PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

## Well Packer Assembly

We, DRESSER INDUSTRIES, INC., a corporation organised and existing under the laws of the state of Delaware, United States of America, of Republic National Bank Building, Dallas, Texas, 75221, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a fluid pressure-actuated, retrievable well packer assembly.

According to the invention, there is provided a fluid pressure-activated, retrievable well packer assembly, comprising a tubular mandrel; first and second longitudinally spaced slip means encircling said mandrel; first and second longitudinally spaced expander means encircling said mandrel and each movable thereon by fluid pressure into engagement with a respective one of said slip means; and means operable in response to longitudinal movement only of the mandrel to disengage said slip means from their respective expander means to enable said packer assembly to be retrieved from a well.

According to the invention, there is also provided a fluid pressure-actuated, retrievable packer assembly for use in a well bore, comprising a tubular mandrel; packing means encircling said mandrel and deformable into sealing engagement with the wall of said well bore; first and second longitudinally spaced slip means carried by said mandrel and located, relatively, on opposite sides of said packing means, said slip means being movable into holding engagement with the wall of the well bore; first and second longitudinally spaced expander means movable on said mandrel and engageable with a respective one of said slip means to move said slip means into holding engagement with the wall of the well bore, said expander means being movable into engagement with said slip means in response to fluid pressure in said tubular mandrel; an enlargement on said mandrel engageable with said first expander means to position said first expander means for engagement with said first slip means, said enlargement being moved out of engagement with said first expander means, upon upward movement of said mandrel, to release said first slip means from the wall of the well bore; and means engageable with said mandrel and second expander means, upon said upward movement of said mandrel, to move said second expander means out of engagement with said second slip means releasing said second slip means from holding engagement with the wall of the well bore to place said packer assembly in condition for retrieval upon only upward movement of said mandrel.

Embodiments of the invention will now be described by way of example only in conjunction with the accompanying drawings, in which:—

Figs. 1A, 1B and 1C are views, partly in cross-section and partly in elevation, illustrating a packer assembly, constructed in accordance with the invention, having the components thereof disposed in the positions they occupy during insertion of the packer assembly into a well bore.

Fig. 2 is a transverse cross-sectional view taken generally along the line 2—2 of Fig. 1A.

Fig. 3 is a transverse cross-sectional view taken generally along the line 3—3 of Fig. 1A.

Fig. 4 is a schematic cross-sectional view of a portion of the packer assembly of Figs. 1A, 1B and 1C disposed in a well casing

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and showing the various components of the packer assembly in the positions they occupy when the packer assembly is set.

Figs. 5A and 5B are schematic cross-sectional views similar to Fig. 4, but showing the packer assembly during retrieval of the packer assembly from the well bore.

Fig. 6 is an enlarged, partial cross-sectional view illustrating a modification of the packer assembly that is also constructed in accordance with the invention showing a modified bypass passageway and valve in the open position.

Fig. 7 is a view similar to Fig. 6, but showing the bypass passageway and valve in the closed condition.

Description of the Preferred Embodiment

Referring to the drawing and to Figs. 1A, 1B and 1C in particular, shown therein and generally designated by the reference character 10 is a packer assembly constructed in accordance with the invention. The packer assembly 10 includes an adapter 12 that is threadedly connected with the lower end of a tubing string 14.

The packer assembly 10 also includes a tubular mandrel 16 having an upper end 18 threadedly connected with the interior of the adapter 12, and a lower end 20 (See Fig. 1C) threadedly connected with a lower slip cage carrier 22. As shown in Fig. 1B, a fluid pressure port 23 extends through the medial portion of the mandrel 16. An annular recess 25 encircles the mandrel 16 immediately below the pressure port 23.

As shown in Fig. 1A, annular abutment member 24 is threadedly connected with the exterior of the adapter 12 and includes an inwardly extending flange 26 that engages an outwardly extending flange 28 on a setting sleeve 30. The sleeve 30 encircles the upper end 18 of the tubular mandrel 16. The setting sleeve 30 is constructed as a separate member for manufacturing purposes, but, as can be appreciated from viewing Fig. 1A, functions as an enlargement on the mandrel 16 as will be described more fully hereinafter.

The setting sleeve 30 has a bevel 32 formed on its lower end and has a pair of diametrically opposed slots 34 (See also Fig. 2) formed in an outer cylindrical surface 35 thereon. The slots 34 are sized and arranged to receive the inner end of a pair of support pins 36. The support pins 36 are carried by an upper slip cage 38 that slidingly encircles the setting sleeve 30.

The slip cage 38 is retained on to the setting sleeve 30 in spaced relation to the annular abutment member 24 during the extension of the packer assembly 10 into the well bore by a pair of shear pins 40 (See also Fig. 2). The shear pins 40 extend through the slip cage 38 into the setting sleeve 30 locking the cage 38 to the sleeve 30.

At its lower end, the slip cage 38 is provided with a plurality of T-shaped slots 42. The slots are sized and arranged to receive upper slips 44, which have outwardly extending lugs 45 thereon, permitting radial movement of the slips 44 relative to the upper slip cage 38, but preventing longitudinal movement therebetween.

Each of the upper slips 44 also includes outwardly facing wickers or teeth 46 that are engageable with a well casing 47 (See Fig. 4), and an inwardly and downwardly facing tapered surface 48. The slips 44 are each biased relatively inwardly by a spring 50 that is connected to the slip 44 and engages the upper slip cage 38.

A plurality of expander segments 52 (See also Fig. 3) slidingly encircle the mandrel 16 below the setting sleeve 30. Each of the expander segments 52 includes an upwardly and inwardly tapered surface 54 arranged to mate with the tapered surfaces 48 of the slips 44, a chamfer 56 that is arranged to engage the bevel 32 on the lower end of the setting sleeve 30 and an untapered inner surface 57 that is engageable with the surface 35 on the sleeve 30 for the purposes that will be described hereinafter. A garter spring 58 resiliently biases the expander segments 52 radially inwardly.

Each of the expander segments 52 carries a pin 60 that extends outwardly therefrom through a mating opening 62 formed in an expander housing 64. The relationship between the pin 60 and the opening 62 permits radial outward movement of the expander segments 52, but prevents longitudinal movement of the expander segments 52 relative to the housing 64.

An inwardly extending flange 66 on the housing 64 slidingly engages the exterior of the tubular mandrel 16. A counter-bore 68 formed in the lower end of the housing 64 provides, in conjunction with a bypass valve member 70, a chamber 72 in which a free piston 74 is disposed. A port 76 extends through the housing 64 providing communication with the chamber 72 for purposes which will be described more fully hereinafter.

The bypass valve member 70 is attached to the mandrel 16 by lock-rings 78 and 80 and is, therefore, movable with the mandrel 16. An O-ring seal 82 carried in the exterior of the valve member 70 sealingly and slidingly engages the housing 64. A main valve seal 84 encircles the lower end of the valve member 70 and, as will be described, is arranged to sealingly engage the interior of a packing sleeve 86 that is threadedly attached to the lower end of the housing 64.

The housing 64 also has a plurality of upper bypass ports 88 extending through the lower end thereof and communicating with a

bypass passageway 90 that is formed by an annular space between the interior of the packing sleeve 86 and the exterior of the mandrel 16. It will be noted that there is no seal provided between the valve member 70 and the mandrel 16 so that fluid can pass therebetween into the lower portion of the chamber 72 below the free piston 74. (In Figs. 4, 5A and 5B, the annular space between the valve member 70 and the mandrel 16 is illustrated by dash lines as a passageway identified by the reference character 91).

The free piston 74 is provided with an exterior annular seal 92 that is in sliding and sealing engagement with the housing 64. A second annular seal 94 is carried by the interior of the free piston 74 that is in sliding and sealing engagement with the exterior of the tubular mandrel 16.

Returning to the packing sleeve 86, it can be seen in Fig. 1B that the lower end thereof is provided with an annular flange 96 that is in engagement with an inwardly extending shoulder 98 on a cylinder 100. It can also be seen that the exterior of the packing sleeve 86 is of smaller diameter than the outer diameter of the housing 64 and of the outer diameter of the cylinder 100.

Annular packing rings 102 encircle the exterior of the sleeve 86 and are held in spaced relation thereon by spacer rings 104. The packing rings 102 are preferably constructed from a resilient material capable of being deformed into sealing engagement with the wall of the well bore. While the packing rings 102 and spacers 104 are illustrated as having a particular configuration, there are many other constructions and arrangements that are well known to those skilled in the art that may be substituted therefor.

As shown in Fig. 1B, the inwardly extending shoulder 98 of the cylinder 100 slidingly encircles the lower end of the packing sleeve 86. Lower bypass ports 106 extend through the cylinder 100 provided communication with the bypass passageway 90 below the packing rings 102. An inwardly extending flange 108 located on the cylinder 100 below the port 106 carries an O-ring seal 110 that slidingly and sealingly engages the exterior of the mandrel 16. Thus, it can be appreciated from the foregoing that the upper bypass port 88, the bypass passageway 90, and the lower by-pass port 106 provide a fluid passageway bypassing the packing rings 102 when the valve member 70 is disposed in the open position as illustrated in Fig. 1A.

The inwardly extending flange portion 108 of the cylinder 100 is provided with an annular groove 112 that receives the upper end of a plurality of locking dogs 114. The locking dogs 114 are arranged about the tubular mandrel 16 in the groove 112. Each of the locking dogs 114 includes a lug 116 that, when the packer assembly 10 is in the running-in position shown in Figs. 1A, 1B and 1C, is positioned in the annular recess 25 formed in the exterior of the mandrel 16. A garter spring 118 encircles the locking dogs 114, biasing the dogs 114 relatively toward the mandrel 16 and thus, resiliently retaining the lugs 116 in the annular recess 25.

An axial flange 120 is located on the upper end of an annular enlargement 122 that forms the upper end of a piston 124. The axial flange 120, when the piston 124 is in the position illustrated in Fig. 1B, engages the locking dogs 114 holding the lugs 116 in the annular recess 25 to positively retain the tubular mandrel 16 and cylinder 100 in the locked condition. With the lugs 116 located in the recess 25, the tubular mandrel and cylinder 100 are locked together preventing relative longitudinal movement therebetween.

The enlargement 122 carries an outer seal 126 that slidingly and sealingly engages the cylinder 100 and an inner seal 128 that slidingly and sealingly engages the exterior of the mandrel 16. As clearly illustrated in Fig. 1B, the inwardly extending flange 108 on the cylinder 100 is located above the pressure port 23 and the piston 124 is located below the pressure port 23 forming a pressure chamber 130 therebetween that is in fluid communication with the interior of the mandrel 16 through the pressure port 23.

As shown in Fig. 1C, the lower end of the cylinder 100 has an upwardly facing surface 131 encircling the piston 124 and a downwardly and outwardly facing tapered surface 132 adjacent the lower end of the piston 124. Located within the cavity formed by the tapered surface 132 are a plurality of ratchet dogs 134 having downwardly biting teeth 136 disposed adjacent the exterior of the piston 124. (A single split-ring ratchet is preferably used in smaller packers in lieu of the dogs 134). A tapered exterior surface 138 on each of the ratchet dogs 134 mates with the tapered surface 132 in the cylinder 100. A spring 140, which has one end in engagement with the cylinder 100 and the other end engaging each of the ratchet dogs 134, resiliently biases the ratchet dogs 134 upwardly, maintaining the mating tapered surfaces 132 and 138 in engagement and the teeth 136 in engagement with the piston 124. As can be appreciated, the ratchet dogs 134 permit movement of the piston 124 relatively downwardly with respect to the cylinder 100, but prevent movement between the cylinder 100 and piston 124 in the opposite direction.

The lower ends of the cylinder 100 and the piston 124 are connected against relative movement while the packer assembly 10 is being lowered into the well bore by a plurality of shear pins 142. As will be explained more fully hereinafter, the shear pins 142 are designed to shear at a predetermined value to

permit relative movement between the cylinder 100 and piston 124.

Threadedly connected with the lower end of the piston 124 is a lower expander 144. The expander 144 includes an exterior downwardly and inwardly tapering surface 146. The expander 144 is also provided with an upwardly facing shoulder 148 at its lower interior end.

The tapered surface 146 is arranged to mate with a tapered surface 150 located on the interior of a plurality of lower slips 152. The lower slips 152 are carried by a lower slip cage 154 that has a plurality of T-shaped slots 156 therein. The slots 156 receive projecting lugs 158 on the slips 152 to permit radial movement of the slips 152 while preventing longitudinal movement of the slips 152 relative to the slip cage 154. Located on the exterior of each of the slips 152 is a plurality of wickers or teeth 160 that are arranged to holdingly engage the well casing 47. A spring 162 is connected with each of the slips 152 and is in engagement with a slip cage 154 to bias the slips 152 relatively inwardly; that is, relatively toward the mandrel 16.

Located between the slip cage carrier 22 and the lower slip cage 154 is a retrieving sleeve 164. The retrieving sleeve 164 has a downwardly facing shoulder 166 encircling its upper end that is engageable with the upwardly facing shoulder 148 on the lower expander 144. The lower end of the retrieving sleeve 164 is threadedly connected with the slip cage 154.

As illustrated in Fig. 1C, the lower slip cage 154 and retrieving sleeve 164 are fixed to the slip cage carrier 22 by a shear pin 168. The shear pin 168 is designed to part upon the application of a predetermined force to permit retrieval of the packer assembly 10 from the well bore.

Located within the lower end of the lower slip cage 154 is a downward and inward tapered surface 170 that mates with an outer tapered surface 172 on a plurality of lock members 174 that are located between the surface 170 and the exterior of the lower slip cage carrier 22. The lock members 174 are each provided with a plurality of upwardly facing teeth 176 that are arranged to mate, during retrieval of the packer assembly 10, with a plurality of downwardly facing exterior teeth 178 that are formed on the lower exterior end of the slip cage carrier 22. In smaller packer sizes, a single, split-ring lock member is preferably used in lieu of the plurality of lock members 174.

For convenience of illustration, an annular seat 180 is illustrated as being located within the interior of the slip cage carrier 22. The seat 180 is provided to receive a closing ball 182 (shown in dash lines in Fig. 1C) that lands on the seat 180 to close the interior of the tubular mandrel 16 and the slip carrier 22 so that fluid pressure can be built up within the packer assembly 10. Normally, an auxiliary device incorporating some means for closing the passageway extending through the packer 10 would be attached to the threads 184 located on the lower end of the slip cage carrier 22. It should also be pointed out that the seat 180 is constructed so that the seat can be pumped out upon the application of sufficient fluid pressure, whereby the passageway extending through the packer assembly 10 will be open during retrieval or after setting as desired.

Operation

When the packer assembly 10 is to be run into the well casing 47, the adapter 12 is connected to the lower end of the tubing string 14 with the various components of the packer 10 located in the positions previously described in detail with respect to Figs. 1A, 1B and 1C. The packer assembly 10 and the tubing string 14 are then lowered into the casing 47 to the location in the well bore (not shown) wherein the packer assembly 10 is to be set.

To prevent inadvertent setting of the packer assembly 10 as it is being lowered in the well bore, the upper slips 44 are retained in the position illustrated in Fig. 1A, in which position they cannot engage the expander segments 52, by the shear pins 40, which as illustrated in Fig. 2, extend through the upper slip cage 38 into the setting sleeve 30. The expander segments 52 cannot move upwardly into engagement with the upper slips 44 because the lugs 116 on the locking dogs 114 are retained in the annular recess 25 in the mandrel 16 by the axial flange 120 located on the upper end of the piston 124.

Downward movement of the lower expander 144 into engagement with the lower slips 152 is prevented by the shear pins 142 which extend through the cylinder 100 into holding engagement with the piston 124. Since the lower expander 144 is attached to and carried by the piston 124 and movement of the cylinder 100 relative to the tubular mandrel 16 is prevented by the locking dogs 114, no movement of the lower expander 144 can take place. The lower slips 152 cannot move upwardly into engagement with the lower expander 144 due to the shear pin 168 which extends through the lower slip cage 154 into engagement with the lower slip cage carrier 22 and due to the engagement of the lock members 174 with the lower slip cage 154 and the lower slip cage carrier 22. Thus, it can be appreciated that the upper slips 44, the expander segments 52, the lower slips 152, and the lower expander 144 are positively retained in the positions illustrated in Figs. 1A, 1B and 1C during the lowering of the packer

assembly 10 into the well bore and that they, therefore, cannot become inadvertently set.

It should also be pointed out that the bypass passageway 90, during the lowering of the packer assembly 10 into the well bore, is open permitting fluid flow through the ports 106, the passageway 90, and the ports 88 around the packing rings 102 so that there is no possibility that the packing rings 102 will be washed off the packing sleeve 86 or that they will be deformed by a fluid pressure drop into sealing engagement with the well casing 47 as the packer assembly 10 is lowered therethrough.

Upon reaching the desired location, the setting ball 182 is dropped into the tubing string 14 passing downwardly therethrough and through the packer assembly 10 until it engages the seat 180 (See Fig. 4). Fluid is then pumped through the tubing string 14 into the packer assembly 10 creating a fluid pressure therein. The fluid pressure, through the pressure port 23 in the mandrel 16, exerts a downwardly directed force on the piston 124 and an upwardly directed force on the cylinder 100. When the magnitude of the pressure becomes sufficiently high, the shear pin 142 parts, permitting the piston 124 to move downwardly relative to the mandrel 16.

As the piston 124 moves downwardly, the axial flange 120 thereon moves past the lugs 116 on the lower ends of the locking dogs 114. When this occurs, the locking dogs 114 can move radially outwardly of the annular recess 25 in the mandrel 16 permitting the cylinder 100 to move upwardly in response to the fluid pressure.

Downward movement of the piston 124 carries the lower expander 144 downwardly, bringing the surface 146 on the expander 144 into engagement with the surface 150 on the lower slips 152 and forcing the lower slips 152 outwardly into engagement with the well casing 47. The downward movement continues until the slips 152 are in firm holding engagement with the casing 47.

Simultaneously, the cylinder 100 moves upwardly and, through its engagement with the lower end of the packing rings 102, carries the packing sleeve 86, the expander housing 64, the packing rings 102, and the upper expander segments 52 upwardly relative to the mandrel 16. As the packing sleeve 86 moves upwardly, it sealingly engages the seal 84 carried by the valve member 70, closing the bypass passageway 90. Also, the chamfers 56 on the expander segments 52 engage the bevel 32 on the lower end of the setting sleeve 30, moving the expander segments 52 radially outwardly until the untapered inner surface 57 on the expander segments 52 rest on the cylindrical surface 35 of the setting sleeve 30. In this position, the expander segments 52 are positioned to engage the upper slips 44.

Continued upward movement of the expander segments 52 in response to the fluid pressure, brings the tapered surfaces 54 on the expander segments 52 into engagement with the tapered surfaces 48 on the slips 44, forcing the slips 44 radially outwardly and moving the teeth 46 on the slips 44 into engagement with the casing 47. The radial movement of the slips 44 continues until the teeth 46 are in secure holding engagement with the casing 47.

It should be pointed out that the initial engagement between the expander segments 52 and the slips 44 produces a slight upward movement in the slip cage 38 parting the shear pins 40. The slip cage 38 moves upwardly until it engages the annular abutment member 24.

Once the upper slips 44 and the lower slips 152 are firmly set in engagement with the casing 47, the fluid pressure acting through the pressure port 23 continues to exert an upwardly directed force on the cylinder 100. Due to the resiliency of the packing rings 102, the cylinder 100 moves upwardly, deforming the packing rings 102 outwardly into sealing engagement with the well casing 47. The packer assembly 10 is now in the set position as illustrated in Fig. 4.

The packer assembly 10 remains in the set position even though the fluid pressure is released because the setting sleeve 30 is disposed under the expander segments 52, holding them in a position firmly engaging and retaining the upper slips 44 in holding engagement with the casing 47. Also, the cylinder 100 and piston 124 are prevented from returning to their initial telescoped condition by the ratchet dogs 134 which have been carried upwardly along the piston 124 by the cylinder 100. The teeth 136 in the ratchet dogs 134 are biased into holding engagement with the piston 124 by the tapered surface 132 on the cylinder 100. As previously described, the teeth 136 are oriented in the downward direction so that they bite into the piston 124 preventing downward movement of the cylinder 100 relative to the piston 124. Thus, it can be appreciated that the packer assembly 10 is retained positively in the set position.

Frequently, packers set in well bores are subjected to a differential in pressure from either below or above and in some instances the packers are subjected to alternatively directed pressure differentials. The packer assembly 10 incorporates means for compensating for such pressure differentials so that the effect on the packer assembly 10 will be either nil or, at least, negligible.

Assuming that a higher pressure exists below the packing rings 102, the fluid pressure is present in the chamber 72 since fluid can pass through the lower bypass port 106, through the bypass passageway 90, through

the passageway 91 in the bypass valve 70 and then into the chamber 72. Such pressure exerts a force on the free piston 74 moving it upwardly into engagement with the expander housing 64. The upwardly directed force drives the segmented expanders 52 into tighter holding engagement with the upper slips 44 and forces the upper slips 44 into tighter holding engagement with the well casing 47. Thus, an upwardly directed pressure, which might tend to move the packer assembly 10 upwardly in the casing 47, is converted to a force that merely biases the upper slips 44 into a tighter holding engagement with the well casing 47, avoiding any movement of the packer assembly 10 in the well casing 47.

It should also be pointed out that, due to the differential surface areas of the bypass valve 70, there is produced a downward force on the valve 70 by the pressure in the chamber 72. Since the valve member 70 is attached to the mandrel 16, the force tends to move the mandrel 16 downwardly, pulling the upper slip cage and slips 44 into tighter holding engagement with the segmented expanders 52 and moving the upper slips 44 into tighter holding engagement with the casing 47. Thus, the higher pressure existing below the packing rings 102 is substantially balanced due to the action of the free piston 74 and the surface areas of the valve 70.

If a higher pressure exists in the well bore above the packing rings 102, such pressure acts through the port 76 that is in communication with the chamber 72 above the free piston 74. The pressure moves the free piston 74 downwardly into engagement with the valve 70, that is, into the position illustrated by dash lines in Fig. 4. When this condition exists, it can be seen that the fluid pressure also acts upwardly on the valve 70 through the port 88 over an area defined by the seal 82 and the seal 84, tending to force the mandrel 16 upwardly toward a position wherein the upper slips 44 would be unseated. However, it will also be noted that the fluid pressure in the chamber 72 is acting over an area defined by the seals 92 and 94, which area is larger than the area defined by the seals 82 and 84. Thus, the net force acts downwardly on the valve 70, mandrel 16, upper slips cage 38, and upper slips 44 through the free piston 74 again biasing the slips 44 into tighter holding engagement with the casing 47. Therefore, the higher pressure above the packing rings 102 also tends to set the packer assembly 10 more firmly.

To retrieve the packer assembly 10, the tubing string 14 is moved upwardly relative to the well casing 47. Since the mandrel 16 is attached to the tubing string 14, the mandrel 16 will move upwardly therewith.

As the upwardly directed force is applied, the shear pin 168 parts as illustrated in Fig. 5B, permitting the mandrel 16 to move upwardly relative to the remaining portion of the packer assembly 10. The bypass valve 70, which is attached to the mandrel 16, moves upwardly therewith until the seal 84 on the valve 70 clears the packing sleeve 86 (See Fig. 5A) reopening the bypass passageway 90. Opening the bypass passageway 90 equalizes pressures above and below the packing rings 102.

Continued upward movement of the mandrel 16 moves the setting sleeve 30 from under the segmented expanders 52, whereupon the garter spring 58 moves the segmented expanders 52 relatively inwardly and out of engagement with the upper slips 44. Simultaneously, the springs 50 bias the slips 44 inwardly and out of engagement with the well casing 47.

To permit initial movement of the mandrel 16 relative to the upper slips 44, the slot 34 in the setting sleeve 30 moves upwardly relative to the support pin 36 carried by the upper slip cage 38. When the sleeve 30 at the lower end of the slot 34 engages the support pin 36, the upper slip cage 38 is moved upwardly with the mandrel 16 moving the upper slips 44 to a position wherein they cannot engage the segmented expanders 52. Thus, the upper slips 44 cannot be inadvertently set during retrieval of the packer assembly 10.

As the mandrel 16 moves upwardly, the valve member 70 engages the free piston 74, carrying the free piston 74 upwardly into engagement with the expander housing 64. The segmented expanders 52 are moved upwardly with the expander housing 64 as the upward movement of the mandrel 16 continues.

Also, the packing sleeve 86, which is attached to the housing 64, is carried upwardly. The upward movement of the sleeve 86 relative to the cylinder 100 continues until the annular flange 96 thereon engages the inwardly extending shoulder 98 on the cylinder 100 (see Fig. 5B). The relative movement between the packing sleeve 86 and the cylinder 100 permits the resilient packing rings 102 to return substantially to their initial undeformed configuration and out of engagement with the well casing 47.

Engagement between the flange 96 and the shoulder 98 carries the cylinder 100 upwardly with the sleeve 86. The upwardly facing shoulder 131 located near the lower end of the cylinder 100 engages the annular enlargement 122 on the upper end of the piston 124, moving the piston 124 upwardly.

As the piston 124 moves upwardly, the expander 144 moves upwardly and out of engagement with the lower slips 152. The lower slips 152 are driven inwardly out of engagement with the casing 47 by the springs 162 contained in the lower slip cage 154.

Continued upward movement of the piston 124 as the mandrel 16 moves upwardly, brings

the upwardly facing surface 148 on the interior of the lower expander 144 into engagement with the shoulder 166 on the upper end of the retrieving sleeve 164 which, as previously described, is threadedly attached to the lower slip cage 154.

As can be appreciated from viewing Figs. 5A and 5B, a considerable extension in overall length occurs in the packer assembly 10 as the various parts move relative to each other during retrieval. The lower slip cage is located relatively near the bottom of the slip carrier 22 (See Fig. 5B). In this position, the teeth 176 on the lock members 174 move into engagement with the downwardly facing exterior teeth 178 on the slip carrier 22, retaining the lower slip cage 154 in the extended position and holding the lower slips 152 out of engagement with the lower expander 144. Since the lower slip cage 154 cannot move upwardly relative to the mandrel 16, the possibility of inadvertent setting of the lower slips 152 by engagement between the slips 152 and the lower expander 144 is positively avoided.

Thus, it can be appreciated that the packer assembly 10 requires only the upward movement of the mandrel 16 to place all of the components in position for retrieval. Furthermore, it can be appreciated that the upper slips 44 are positively prevented from engaging the upper segmented expanders 52 by the engagement of the support pins 36 with the setting sleeve 30 and that the lower slips 152 cannot inadvertently engage the lower expander 144 due to the engagement of the lock members 174 with the lower slip cage carrier 22.

Modified Embodiment of Figs. 6 and 7

When the packer assembly is to be used in small diameter casing, the packer assembly necessarily must be of relatively small outside diameter to fit within the casing. To accomplish this, the thickness of the various components of the packer assembly must be reduced to a minimum to provide a maximum flow passageway extending through the packer assembly.

The enlarged views of Figs. 6 and 7 illustrate a modified form of the packer assembly generally designated by the reference character 210 in which certain components, which will be described in detail, have been incorporated in the packer assembly 210 so that it can be used in small diameter casing. The reference characters utilized in the description of Figs. 6 and 7 correspond to the reference characters previously utilized in the description of the packer assembly 10 insofar as is possible and with the exception that each is in the 200 series. For example, the tubular mandrel, which was designated in the packer assembly 10 by the reference character 16, is designated in Figs. 6 and 7 by the character 216.

Referring now to Fig. 6, the packer assembly 210 includes the tubular mandrel 216 that extends therethrough and an expander housing 264 encircling the mandrel 216. The expander housing 264 includes an upper part 265 that carries the expander segments (not shown). An upper bypass port 288 extends through the upper part 265 into communication with a bypass passageway 290.

The upper part 265 is threadedly connected at its lower end with a lower part 267. As clearly shown, the lower part 267 is threadedly connected at its lower end to a packing sleeve 286 that is sized and arranged to carry packing rings 202.

The upper part 265 of the expander housing 264 has an annular recess 269 formed on the lower interior end thereof receiving the upper end of a valve seal 284.

The valve seal 284 is preferably constructed from a resilient material and is of sufficient thickness to project into the bypass passageway 290 located between the mandrel 216 and housing 264 when the seal 284 is in the relaxed condition. An annular flange 285 is formed on the lower exterior end of the seal 284. The flange 285 is located between the lower end of the upper part 265 of the expander housing 264 and an upwardly facing surface 287 formed on the lower part 267 of the expander housing 264. The flange 285 is of sufficient thickness to form a fluid-tight seal between the upper part 265 and the lower part 267 when they are threadedly connected.

The seal 284, by sealing the threaded connection joining the parts 265 and 267 of expander housing 264, eliminates the need for an additional seal to prevent fluid flow through the threaded connection. The clamping of the flange 285 between the parts 265 and 267 also aids in retaining the seal 284 in the annular recess 269.

The seal 284 also includes a pair of spaced reinforcing rings 289 and 291 that are preferably imbedded in the seal 284 when the seal is molded. The reinforcing rings 289 and 291 are preferably constructed from metal to provide the maximum reinforcing for the seal 284 and to provide the greatest force to aid in retaining the seal 284 in the recess 269.

The packer assembly 210 also includes a bypass valve 270 that is connected with the mandrel 216 by lock rings 278 and 280. It will be noted in Figs. 6 and 7 that the valve 270 is constructed of a relatively thin sleeve to reduce the wall thickness of the packer assembly 210 to the minimum, whereby the maximum flow passageway is provided therein. The valve 270 does not carry a seal member, such as the seal member 84 which was carried by the valve 70 due to the thin structure of the valve 270. Otherwise, the

structure of the valve 270 is identical to the structure of the valve 70 previously described.

Fig. 6 illustrates the valve 270 and seal 284 positioned wherein the bypass passageway 290 is open. During the setting of the packer assembly 210, which is accomplished as previously described for the packer assembly 10, the valve 270 engages the seal 284 as the expander housing 264 moves upwardly, closing the bypass passageway 290 as shown in Fig. 7. Thus, the valve 270 and seal 284 also are effective to provide the desired and required opening and closing of the bypass passageway 290 as did the valve 70 and seal 84 in the packer assembly 10. As previously pointed out, the packer assembly 210 can be constructed with a considerably smaller diameter since the seal 284 is located in the relatively thick expander housing 264 rather on the relatively thin valve 270.

It will be appreciated from the foregoing detailed description that the embodiments of the packer assembly described hereinbefore provide an improved fluid-pressure, actuated retrievable packer that can be retrieved upon the exertion of only an upward force on the mandrel. Further, a packer assembly constructed as hereinbefore described cannot be inadvertently set during the running of the packer assembly into the well bore, is positively locked in the set condition in the well bore, and cannot become inadvertently set while the packer is being retrieved from the well bore.

It will be understood that the foregoing detailed description is provided by way of example only and that many modifications and changes can be made thereto without departing from the scope of the annexed claims.

WHAT WE CLAIM IS:—

1. A fluid pressure-actuated, retrievable well packer assembly, comprising a tubular mandrel; first and second longitudinally spaced slip means encircling said mandrel; first and second longitudinally spaced expander means encircling said mandrel and each movable thereon by fluid pressure into engagement with a respective one of said slip means; and means operable in response to longitudinal movement only of the mandrel to disengage said slip means from their respective expander means to enable said packer assembly to be retrieved from a well.

2. A fluid pressure-actuated, retrievable packer assembly for use in a well bore, comprising a tubular mandrel; packing means encircling said mandrel and deformable into sealing engagement with the wall of said well bore; first and second longitudinally spaced slip means carried by said mandrel and located, respectively, on opposite sides of said packing means, said slip means being movable into holding engagement with the wall of the well bore; first and second longitudinally spaced expander means movable on said mandrel and engageable with a respective one of said slip means to move said slip means into holding engagement with the wall of the well bore, said expander means being movable into engagement with said slip means in response to fluid pressure in said tubular mandrel; an enlargement on said mandrel engageable with said first expander means to position said first expander means for engagement with said first slip means, said enlargement being moved out of engagement with said first expander means, upon upward movement of said mandrel, to release said first slip means from the wall of the well bore; and means engageable with said mandrel and second expander means, upon said upward movement of said mandrel, to move said second expander means out of engagement with said second slip means releasing said second slip means from holding engagement with the wall of the well bore to place said packer assembly in condition for retrieval upon only upward movement of said mandrel.

3. The packer assembly according to claims 1 or 2 and including first locking means retaining said expander means out of engagement with said slip means while said packer assembly is being lowered into the well bore; second locking means retaining said second expander means in engagement with said second slip means when said second slip means is in holding engagement with the wall of the well bore; and third locking means retaining said first and second expander means out of engagement with said first and second slip means when said slip means are released from engagement with the wall of the well bore during retrieval of said packer assembly.

4. The packer assembly according to claim 3 wherein said first locking means includes a shear pin releasably interconnecting said first and second expander means to prevent relative movement therebetween until a predetermined fluid pressure is applied thereon through said mandrel; and at least one lock dog engaging said first expander means and said tubular mandrel to prevent relative movement therebetween until said shear pin has been sheared.

5. The packer assembly according to claims 3 or 4 wherein said second locking means includes at least one ratchet member disposed between said first and second expander means and engageable therewith to permit relative movement between said first and second expander means during movement of said expander means into engagement with said first and second slip means and to prevent relative movement between said first and second expander means in a direction to release said expander means from said slip means; and resilient means biasing said ratchet member in a direction to maintain the engagement of said

structure of the valve 270 is identical to the structure of the valve 70 previously described.

Fig. 6 illustrates the valve 270 and seal 284 positioned wherein the bypass passageway 290 is open. During the setting of the packer assembly 210, which is accomplished as previously described for the packer assembly 10, the valve 270 engages the seal 284 as the expander housing 264 moves upwardly, closing the bypass passageway 290 as shown in Fig. 7. Thus, the valve 270 and seal 284 also are effective to provide the desired and required opening and closing of the bypass passageway 290 as did the valve 70 and seal 84 in the packer assembly 10. As previously pointed out, the packer assembly 210 can be constructed with a considerably smaller diameter since the seal 284 is located in the relatively thick expander housing 264 rather on the relatively thin valve 270.

It will be appreciated from the foregoing detailed description that the embodiments of the packer assembly described hereinbefore provide an improved fluid-pressure, actuated retrievable packer that can be retrieved upon the exertion of only an upward force on the mandrel. Further, a packer assembly constructed as hereinbefore described cannot be inadvertently set during the running of the packer assembly into the well bore, is positively locked in the set condition in the well bore, and cannot become inadvertently set while the packer is being retrieved from the well bore.

It will be understood that the foregoing detailed description is provided by way of example only and that many modifications and changes can be made thereto without departing from the scope of the annexed claims.

WHAT WE CLAIM IS:—

1. A fluid pressure-actuated, retrievable well packer assembly, comprising a tubular mandrel; first and second longitudinally spaced slip means encircling said mandrel; first and second longitudinally spaced expander means encircling said mandrel and each movable thereon by fluid pressure into engagement with a respective one of said slip means; and means operable in response to longitudinal movement only of the mandrel to disengage said slip means from their respective expander means to enable said packer assembly to be retrieved from a well.

2. A fluid pressure-actuated, retrievable packer assembly for use in a well bore, comprising a tubular mandrel; packing means encircling said mandrel and deformable into sealing engagement with the wall of said well bore; first and second longitudinally spaced slip means carried by said mandrel and located, respectively, on opposite sides of said packing means, said slip means being movable into holding engagement with the wall of the well bore; first and second longitudinally spaced expander means movable on said mandrel and engageable with a respective one of said slip means to move said slip means into holding engagement with the wall of the well bore, said expander means being movable into engagement with said slip means in response to fluid pressure in said tubular mandrel; an enlargement on said mandrel engageable with said first expander means to position said first expander means for engagement with said first slip means, said enlargement being moved out of engagement with said first expander means, upon upward movement of said mandrel, to release said first slip means from the wall of the well bore; and means engageable with said mandrel and second expander means, upon said upward movement of said mandrel, to move said second expander means out of engagement with said second slip means releasing said second slip means from holding engagement with the wall of the well bore to place said packer assembly in condition for retrieval upon only upward movement of said mandrel.

3. The packer assembly according to claims 1 or 2 and including first locking means retaining said expander means out of engagement with said slip means while said packer assembly is being lowered into the well bore; second locking means retaining said second expander means in engagement with said second slip means when said second slip means is in holding engagement with the wall of the well bore; and third locking means retaining said first and second expander means out of engagement with said first and second slip means when said slip means are released from engagement with the wall of the well bore during retrieval of said packer assembly.

4. The packer assembly according to claim 3 wherein said first locking means includes a shear pin releasably interconnecting said first and second expander means to prevent relative movement therebetween until a predetermined fluid pressure is applied thereon through said mandrel; and at least one lock dog engaging said first expander means and said tubular mandrel to prevent relative movement therebetween until said shear pin has been sheared.

5. The packer assembly according to claims 3 or 4 wherein said second locking means includes at least one ratchet member disposed between said first and second expander means and engageable therewith to permit relative movement between said first and second expander means during movement of said expander means into engagement with said first and second slip means and to prevent relative movement between said first and second expander means in a direction to release said expander means from said slip means; and resilient means biasing said ratchet member in a direction to maintain the engagement of said

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ratchet member with said first and second expander means.

6. The packer assembly according to any one of claims 3 to 5 as appendant to claim 2 wherein said third locking means includes a support pin carried by said first slip means and engageable with the enlargement on said mandrel to prevent engagement of said first slip means with said first expander means when said enlargement has been moved out of engagement with said first expander means; and a lock member disposed between said second slip means and said mandrel and engageable therewith to prevent relative upward movement of said slip means relative to said mandrel when said second slip means has been released for retrieval of said packer assembly.

7. The packer assembly according to claim 2 or any one of claims 3 to 6 as appendant to claim 2 wherein said packing means is carried by a portion of said first expander means; said first expander means defines an annular space with said mandrel along said portion and has a first port extending therethrough in communication with said annular space and a second port extending therethrough in communication with said annular space forming a bypass passageway extending longitudinally between opposite ends of said packing means, the first and second ports being located, when the packer assembly is positioned in a well, respectively above and below said packing means and said passageway extending from above to below said packing means; a second enlargement on said mandrel spaced from said first-mentioned enlargement carrying a first annular seal disposed in sliding and sealing engagement with said first expander means relatively above said first port; and a second annular seal member arranged to sealingly engage said first expander means and said second enlargement between said ports to close said by-pass passageway when said first expander means is moved upwardly into engagement with said first slip means.

8. The packer assembly according to claim 7 wherein the portion of said first expander means forming said by-pass passageway includes a sleeve carrying said packing means, and an expander cage threadedly connected at an end portion with said sleeve, said cage having a counterbore in an interior end thereof; and wherein said second annular seal is disposed in said counterbore and is engageable with said second enlargement to close said by-pass passageway, said second annular seal including a resilient seal body having an exterior flange engaging said sleeve and said end portion to seal the threaded connection between said sleeve and cage and to retain said seal in said counterbore.

9. The packer assembly according to claim 8 wherein said second annular seal also includes relatively rigid reinforcing means embedded therein to aid in retaining said second annular seal in said counterbore.

10. The packer assembly according to claim 9 wherein said reinforcing means includes a pair of spaced annular metal rings each disposed proximate a respective one of opposite ends of said seal body.

11. The packer assembly according to claim 7 or any one of claims 8 to 10 as appendant to claim 7 wherein said first expander means includes a third port located above said first port; said second enlargement provides a passageway extending parallel to the longitudinal axis of said tubular mandrel, said passageway having an end in communication with said second port in said first expander means; and wherein said packer assembly also includes an annular piston slidingly and selingly engaging said mandrel and said first expander means and positioned, when the packer assembly is in a well, above said second enlargement, one end of said piston being exposed to fluid pressure in the well bore through said second port and passageway and responsive to such pressure to move into engagement with said first expander means, whereby such pressure exerts a force on said mandrel and first expander means biasing said first slip means into tighter holding engagement with the wall of the well bore, and the other end of said piston being exposed to fluid pressure in the well bore through said third port and responsive to such pressure to move said piston into engagement with said second enlargement, whereby such pressure exerts a force on said mandrel biasing said first slip means into tighter holding engagement.

12. The packer assembly according to claim 2 or any one of claims 3 to 11 as appendant to claim 2 wherein said mandrel has a pressure port extending transversely therethrough; said first expander means includes a plurality of segmented expander members disposed around said mandrel, each of said expander members having an untapered inner surface engageable with said first mentioned enlargement for holding said expander members outwardly with respect to said mandrel to a position wherein said expander members are engageable with said first slip means, a sleeve member encircling said mandrel having an end operably connected with said segmented expander members and a shoulder engaging said packing means, and a cylinder member slidingly and sealingly engaging said mandrel encompassing said pressure port and having an end engaging said packing means in telescoping relationship with an end of said sleeve member; said second expander means includes a piston portion slidingly and sealingly engaging said mandrel and an interior end of said cylinder member and having one end exposed to fluid pressure through said port, an expander portion being engageable with

said second slip means to move said second slip means into holding engagement with the wall of the well bore, a lower interior flange portion engageable with said second slip means upon relative movement between said second expander means and said second slip means to pull said second slip means upwardly during retrieval of said packer assembly; and wherein said second expander means and first expander means are moved in relatively opposite directions on said mandrel in response to fluid pressure exerted through said port to move said slip means into holding engagement with the wall of the well bore and to deform said packing means into sealing engagement with the wall of said well bore.

13. The packer assembly according to claim 12 as appendant to claim 4 wherein said shear pin releasably interconnects said cylinder member and the piston portion of said second expander means, and a plurality of said lock dogs interconnects said cylinder member and tubular mandrel.

14. The packer assembly according to claim 12 as appendant to claim 5 wherein said one ratchet member is disposed between said cylinder member and the piston portion of said second expander means, and wherein said resilient means biasing said ratchet member in a direction to maintain the engagement of said ratchet member with said cylinder member and the piston portion of said lower expander means.

15. The packer assembly according to claim 12 as appendant to claim 6, wherein said support pin is operable to prevent engagement of said upper slip means with said segmented expander members when said enlargement has been moved out of engagement with said segmented expander members.

16. A packer assembly substantially as herein described with reference to, and as illustrated in, the accompanying drawings.

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