Aug. 12, 1969 A. J. TUCKER ET AL 3,460,616

RETRIEVABLE PACKER

Filed July 26, 1967 4 Sheets-Sheet 1

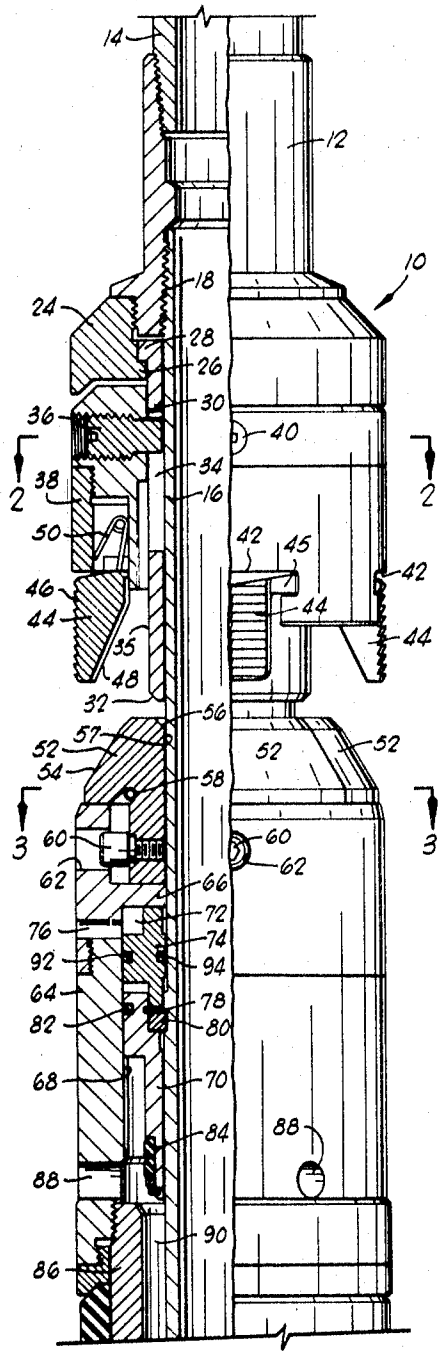


Fig. 1A

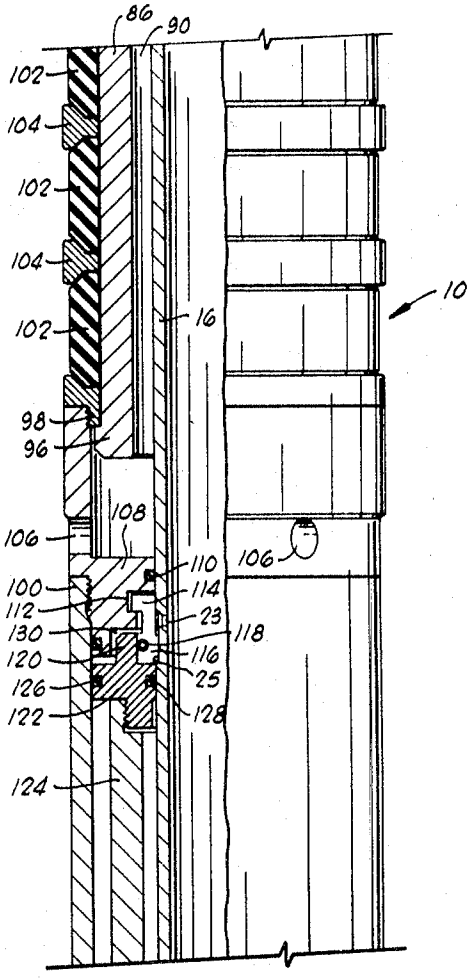


Fig. 1B

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RETRIEVABLE PACKER

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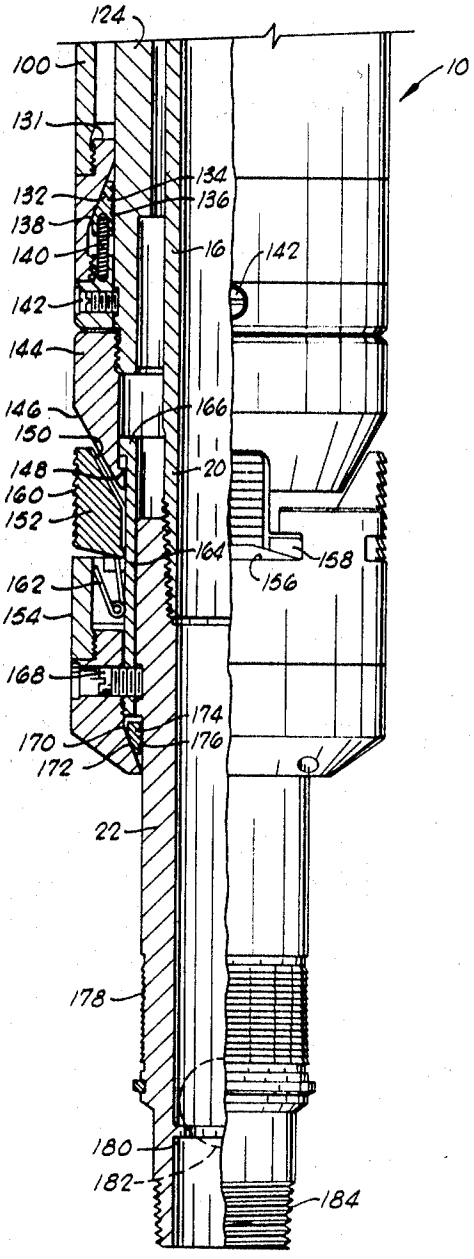


Fig. 1C

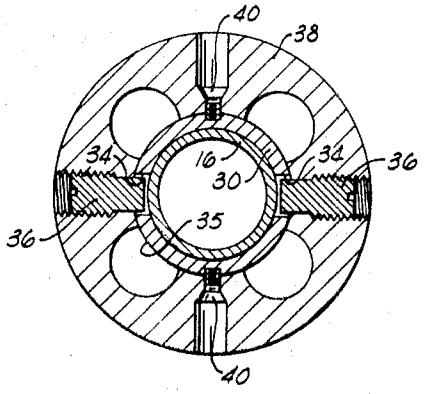


Fig. 2

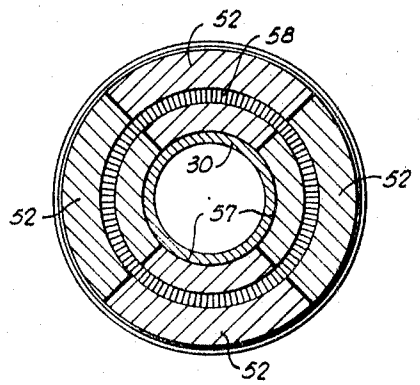


Fig. 3

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RETRIEVABLE PACKER

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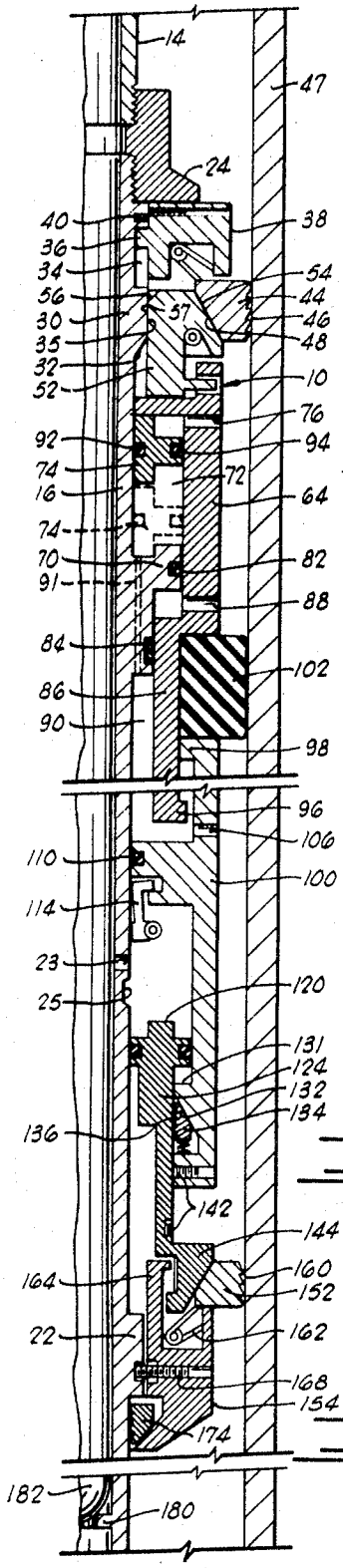


Fig. 4

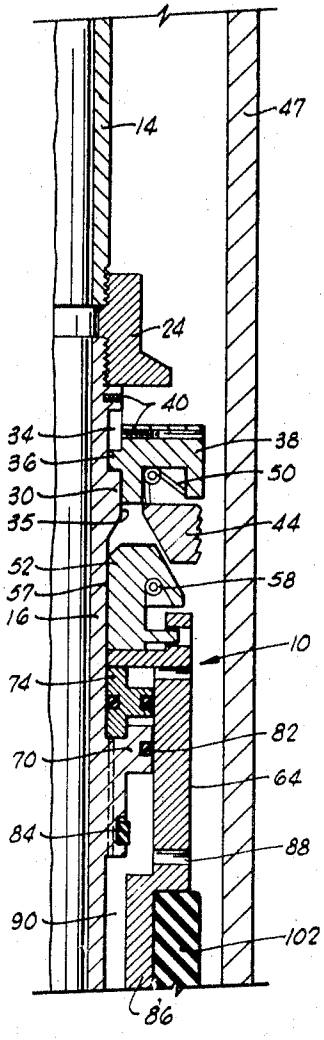


Fig. 5A

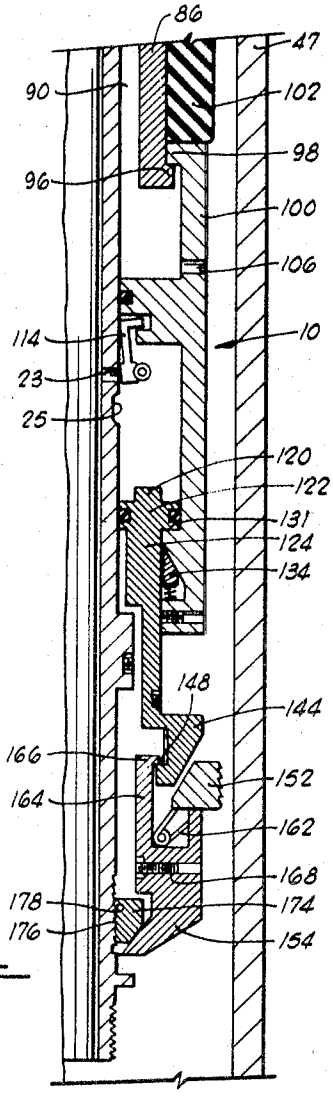


Fig. 5B

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RETRIEVABLE PACKER

Filed July 26, 1967 4 Sheets-Sheet 4

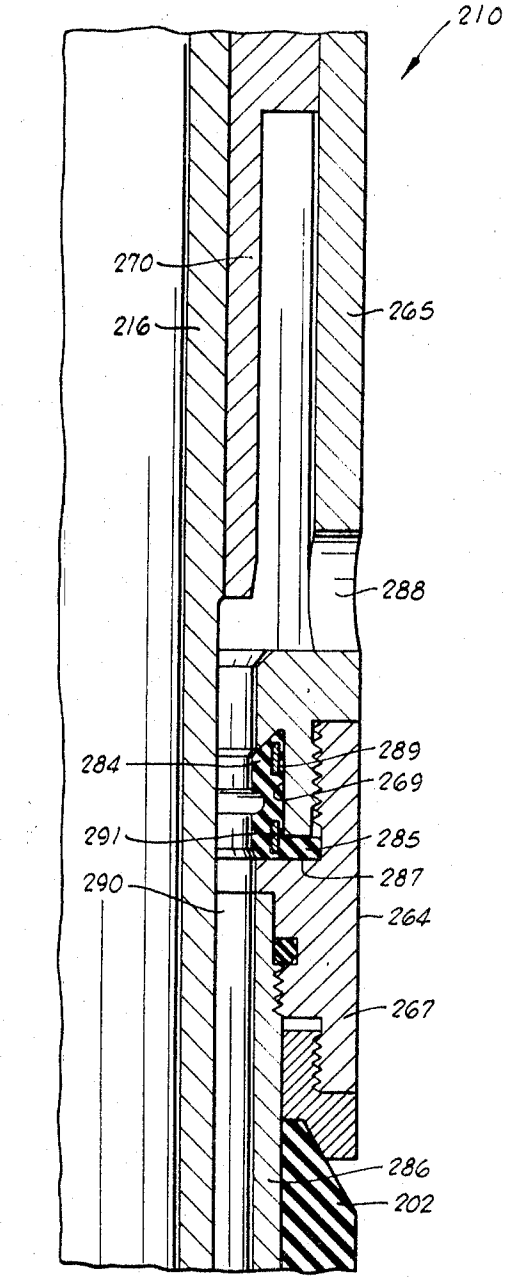


Fig. 6

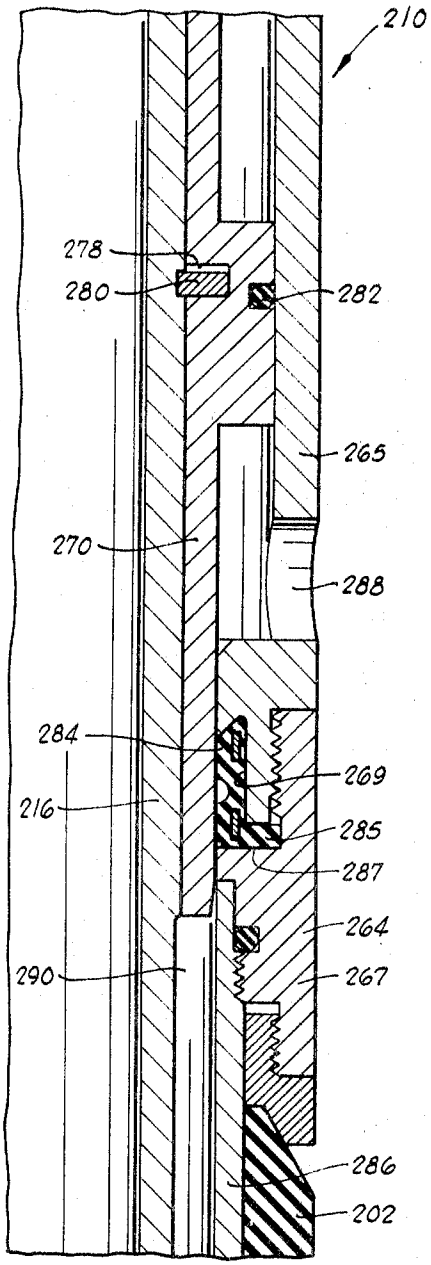


Fig. 7

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United States Patent Office 3,460,616 Patented Aug. 12, 1969

3,460,616

RETRIEVABLE PACKER

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Int. Cl. E21b 33/126, 33/129
U.S. Cl. 166—120 13 Claims

ABSTRACT OF THE DISCLOSURE

A fluid pressure-actuated, retrievable packer assembly including a tubular mandrel, upper and lower slips encircling the mandrel and upper and lower expanders movable along the tubular mandrel into engagement with the slips to move the slips into holding engagement with the wall of the well bore. A packing member that is deformable into sealing engagement with the wall of the well bore is carried by the upper expander. The upper and lower expanders being movable by fluid pressure in relatively opposite directions along the mandrel to engage the slips and to deform the packing member. The packer assembly also includes means for holding the slips and expanders out of engagement when the packer assembly is being run into the well bore, means for retaining the slips and expanders in engagement when the packer assembly is set and means for holding the slips and expanders out of engagement during retrieval of the packer assembly. The packer assembly is actuated; that is, moved into the set position in response to the pressure of fluid in the mandrel and is retrieved by the exertion of a straight upward pull on the mandrel.

Background of the invention

This invention relates generally to improved well tools. More particularly, but not by way of limitation, this invention relates to a fluid pressure-actuated, retrievable packer assembly for use in well bores and the like.

Many types of well packers have been constructed in the past for closing the annular space between two telescoped flow conductors, such as is formed between the casing of a well and a string of tubing disposed therein. Some of the packers have been of the permanent type; that is, a type constructed and arranged to be run into the well bore, set and left therein. Others have been of the retrievable type; that is, of a type constructed to be run into the well bore, set and, subsequently, retrieved from the well bore upon proper manipulation of the packer components.

Generally, the retrievable packers have been set either by a mechanical manipulation of the tubing string or by the application of a fluid pressure, usually hydraulic, to the packer components. Frequently, the fluid pressure-actuated packers have required manipulation of the tubing string, such as rotation and/or longitudinal movement to position the various components whereby the application of fluid pressure will set the packer. The tubing string is generally made up of a number of threadedly interconnected pipe sections which can be disengaged by rotation. Thus, it is highly desirable to avoid rotation of the tubing string during setting or retrieving of the packer.

While some of the previously constructed packers avoided the rotation of the tubing string during setting by the use of the fluid pressure for actuation, it has been necessary to rotate the tubing string to manipulate the various packer components to positions wherein the packer can be retrieved from the well bore.

Furthermore, it is highly desirable to provide the packer with some means for avoiding inadvertent setting of the packer both during insertion of the packer into the well bore and retrieval of the packer therefrom and with some means for avoiding inadvertent unsetting of the packer after it has been set in the well bore until the packer is to be retrieved. While previously constructed packers have incorporated one or more of these desirable features, it is not believed that all of the desirable features have been provided in a single packer.

Summary of the invention

This invention provides a fluid pressure-actuated retrievable packer assembly including a tubular mandrel; upper and lower slip means encircling the mandrel; upper and lower expander means encircling the mandrel and movable thereon by fluid pressure into engagement with the upper and lower slips, respectively; and, means responsive to longitudinal movement of the mandrel for disengaging the upper and lower slips from the upper and lower expanders to retrieve the packer assembly.

One object of the invention is to provide an improved fluid pressure-actuated retrievable packer that can be retrieved upon the exertion of only an upward force on the mandrel.

Another object of the invention is to provide an improved fluid pressure-actuated retrievable packer that includes means for preventing inadvertent setting of the packer during insertion of the packer into and removal of the packer from the well bore and means to positively retain the packer in the set condition until the packer is to be retrieved.

The foregoing and additional objects and advantages of the invention will become more apparent as the following detailed description is read in conjunction with the accompanying drawing wherein like reference characters denote like parts in all views.

Brief description of the drawing

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 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 bypas 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, an 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 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 outwardly and downwardly facing tapered surface 48. The slips 44 are each biased relatively inwardly by a spring 50 that is connected to the slips 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 providing 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 the 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 extreior 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 slip 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 the small diameter casing. The reference characters utilized in the description of FIGS. 6 and 7 correspond to the reference characters perviously 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 **268** 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 than 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, one that is positively locked in the set condition in the well bore, and one that 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 spirit of the invention or from the scope of the annexed claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a fluid pressure actuated retrievable packer assembly, the combination of:

a tubular mandrel;

upper and lower slip means encircling said mandrel;

upper and lower expander means encircling said mandrel and movable thereon by fluid pressure into engagement with said upper and lower slip means, respectively;

an enlargement on said mandrel engageable with said upper expander means to position said upper expander means for engagement with said upper slip means, said enlargement being moved out of engagement with said upper expander means, upon upward movement of said mandrel, to release said upper slip means from the wall of the well bore; and

means engageable with said mandrel and lower expander means, upon said upward movement of said mandrel, to move said lower expander means out of engagement with said lower slip means to place said packer assembly in condition for retrieval upon only upward movement of said mandrel.

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;

upper and lower slip means carried by said mandrel and located, respectively, above and below said packing means, said slip means being movable into holding engagement with the wall of the well bore;

upper and lower expander means movable on said mandrel and engageable with said upper and lower slip means, respectively, 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 upper expander means to position said upper expander means for engagement with said upper slip means, said enlargement being moved out of engagement with said upper expander means, upon upward movement of said mandrel, to release said upper slip means from the wall of the well bore; and

means engageable with said mandrel and lower expander means, upon said upward movement of said mandrel, to move said lower expander meaans out of engagement with said lower slip means releasing said lower 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 of claim **2** and also 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 lower expander means in engagement with said lower slip means when said lower slip means is in holding engagement with the wall of the well bore; and

third locking means retaining said upper and lower expander means out of engagement with said upper and lower 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 of claim **3** wherein said first locking means includes:

a shear pin releaseably interconnecting said upper and lower 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 upper expander means and said tubular mandrel to prevent relative movement therebetween until said shear pin has been sheared.

5. The packer assembly of claim **3** wherein said second locking means includes:

at least one ratchet member disposed between said upper and lower expander means and engageable therewith to permit relative movement between said upper and lower expander means during movement of said expander means into engagement with said upper and lower slip means and to prevent relative movement between said upper and lower 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 ratchet member with said upper and lower expander means.

6. The packer assembly of claim **3** wherein said third locking means includes:

a support pin carried by said upper slip means and engageable with the enlargement on said mandrel to prevent engagement of said upper slip means with said upper expander means when said enlargement has been moved out of engagement with said upper expander means; and,

a lock member disposed between said lower slip means and said mandrel and engageable therewith to prevent relative upward movement of said slip means relative to said mandrel when said lower slip means has been released for retrieval of said packer assembly.

7. The packer assembly of claim **2** wherein:

said packing means is carried by a portion of said upper expander means;

said upper expander means defines an annular space with said mandrel along said portion and has

a first port extending therethrough above said packing means in communication with said annular space, and

a second port extending therethrough below said packing means in communication with said annular space forming a bypass passageway extending from above said packing means 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 upper expander means relatively above said first port; and,

a second annular seal member arranged to sealingly engage said upper expander means and second enlargement between said ports to close said bypass passageway when said upper expander means is moved upwardly into engagement with said upper slip means.

8. The packer assembly of claim **7** wherein:

the portion of said upper expander means forming said bypass passageway includes

a sleeve carrying said packing means, and an upper expander cage threadedly connected at its lower end portion with said sleeve, said cage having a counterbore in the lower interior end thereof; and, wherein

said second annular seal is disposed in said counterbore and is engageable with said second enlargement to close said bypass passageway, said second annular seal including a resilient seal body having an exterior flange engaging said sleeve and lower portion to seal the threaded connection between said sleeve and cage and to retain said seal in said counterbore.

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

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

11. The packer assembly of claim **7** wherein:

said upper 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 a lower end in communication with said second port in said upper expander means; and, wherein

said packer assembly also includes an annular piston positioned above said second enlargement slidingly and sealingly engaging said mandrel and said upper expander means,

one end of said piston being exposed to fluid pressure in the well bore below said packing means through said second port and passageway and responsive to such pressure to move into engagement with said upper expander means, whereby such pressure exerts a force on said mandrel and upper expander means biasing said upper 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 above said packing means 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 upper slip means into tighter holding engagement.

12. The packer assembly of claim **2** wherein:

said mandrel has a pressure port extending transversely therethrough;

said upper 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 enlargement for holding said expander members outwardly with respect to said mandrel to a position wherein said expander members are engageable with said upper slip means,

a sleeve member encircling said mandrel having an upper end operably connected with said segmented expander members and a downwardly facing shoulder engaging said packing means, and

a cylinder member slidingly and sealingly engaging said mandrel encompassing said pressure port and having an upper end engaging said packing means in telescoping relationship with the lower end of said sleeve member;

said lower expander means includes

a piston portion slidingly and sealingly engaging said mandrel and the lower interior end of said cylinder member and having one end exposed to fluid pressure through said port

an expander portion being engageable with said lower slip means to move said lower slip means into holding engagement with the wall of the well bore,

a lower interior flange portion engageable with said lower slip means upon relative movement between said lower expander means and said lower slip means to pull said lower slip means upwardly during retrieval of said packer assembly; and, wherein

said lower expander means and upper 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 of claim **12** and also including:

first locking means retaining said expander means out of engagement with said slip means while said packer is being lowered into the well bore, said first locking means including

a shear pin releaseably interconnecting said cylinder member and the piston portion of said lower expander means to prevent relative movement therebetween until a predetermined fluid pressure is exerted through said pressure port, and

a plurality of lock dogs interconnecting said cylinder member and tubular mandrel to prevent relative movement therebetween until said shear pin has been sheared;

second locking means retaining said lower expander means in engagement with said lower slip means when said lower slip means is in holding engagement with the wall of the well bore, said second lock means including

at least one ratchet member disposed between said cylinder member and the piston portion of said lower expander means and engageable therewith to permit relative movement between said cylinder member and lower expander means during movement of said lower expander means into engagement with said lower slip means and to prevent relative movement between said upper and lower 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 ratchet member with said cylinder member and the piston portion of said lower expander means; and,

third locking means retaining said upper end lower expander means out of engagement with said upper and lower slip means when said slip means are released from engagement with the wall of the well bore during retrieval of said packer assembly, said third locking means including

a support pin carried by said upper slip means and engageable with the enlargement on said mandrel 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, and

a lock member disposed between said lower slip means and said mandrel and engageable therewith to prevent relative upward movement of said lower slip means relative to said mandrel when said lower slip means has been released for retrieval of said packer assembly.

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