

March 1, 1966

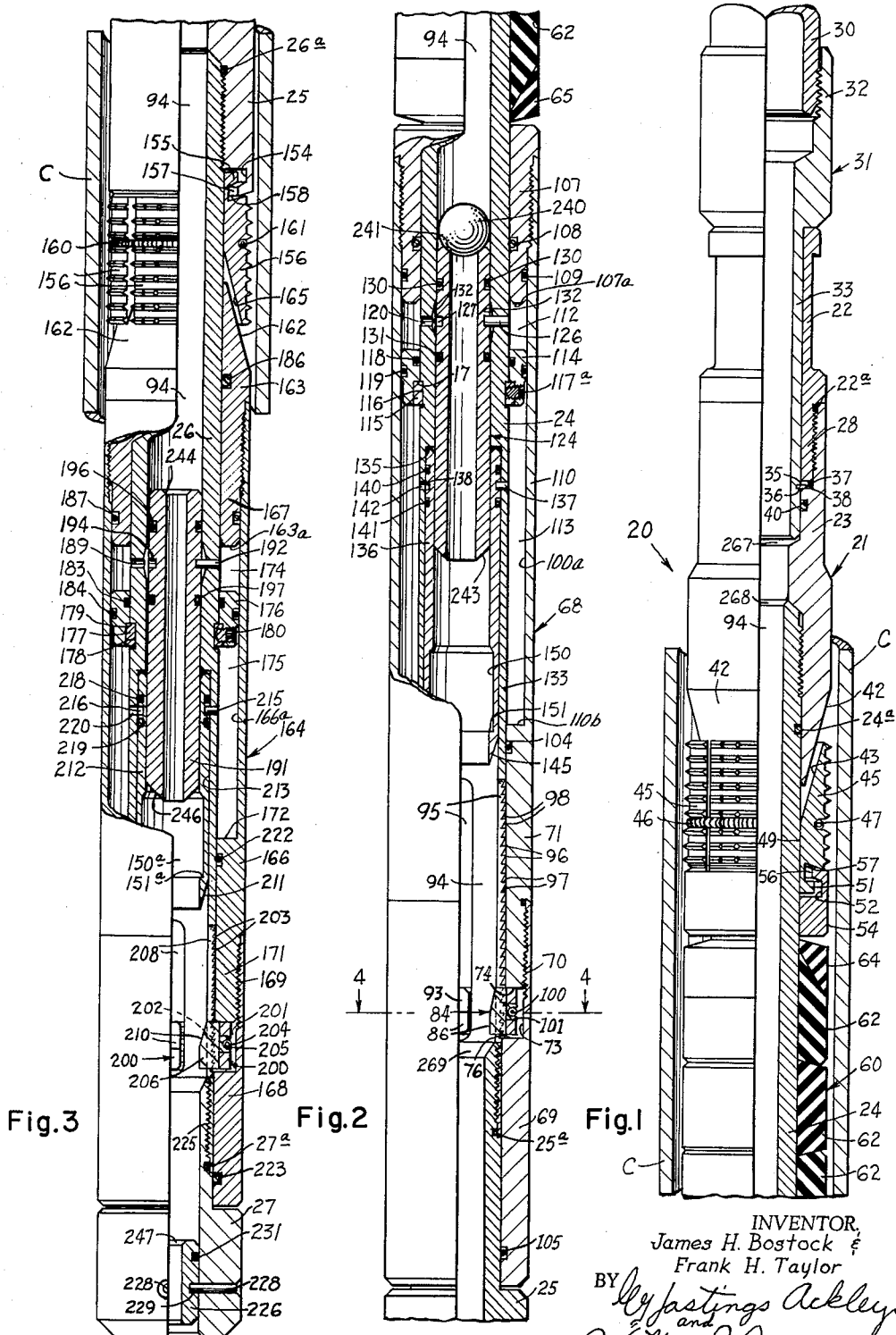
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3,237,695

HYDRAULICALLY SET WELL PACKER

Filed Nov. 30, 1962

3 Sheets-Sheet 1



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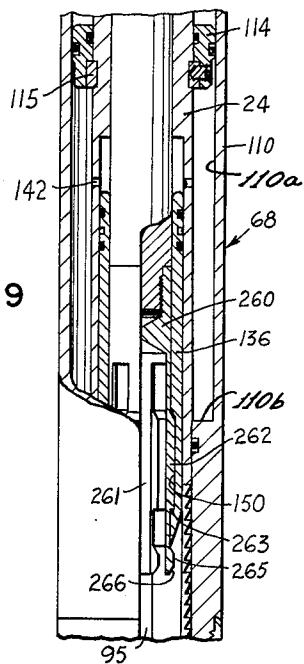
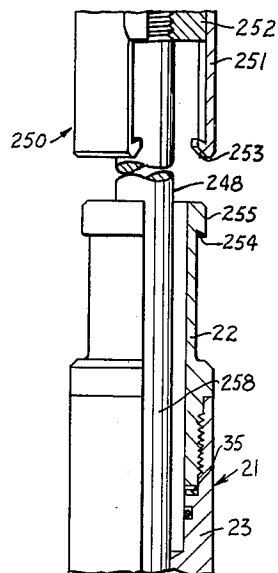


Fig. 9

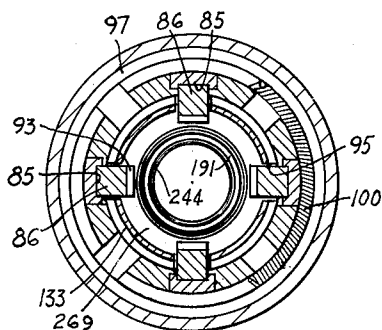
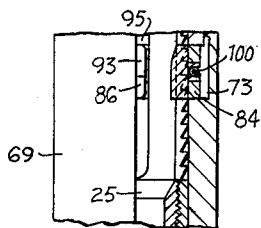


Fig. 4

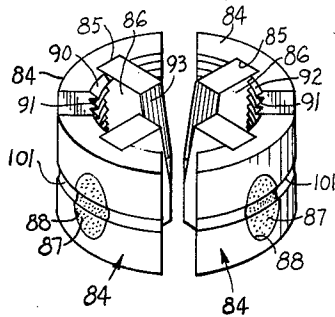


Fig. 5

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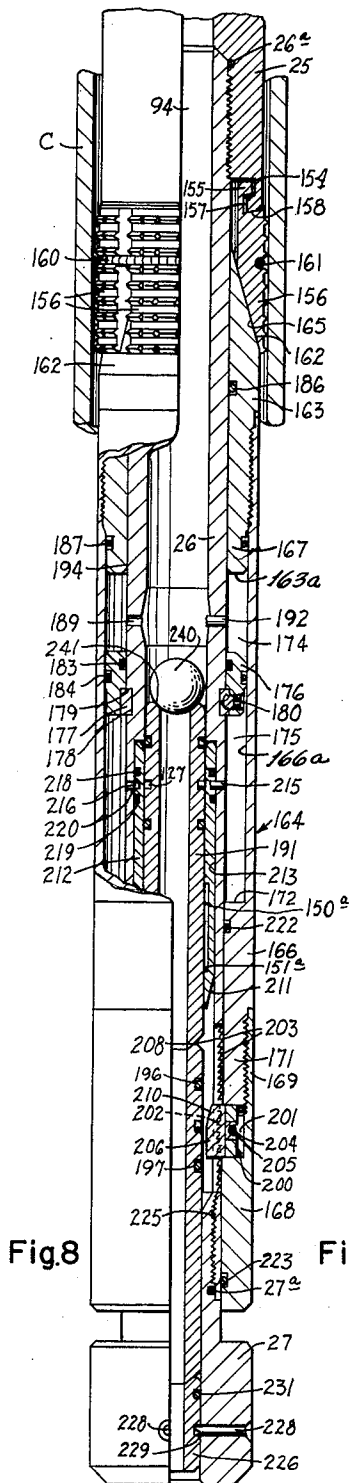


Fig. 7

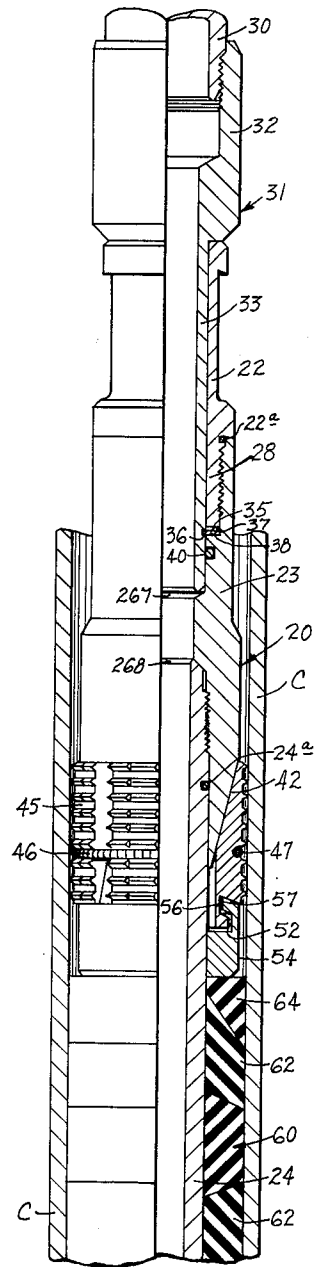
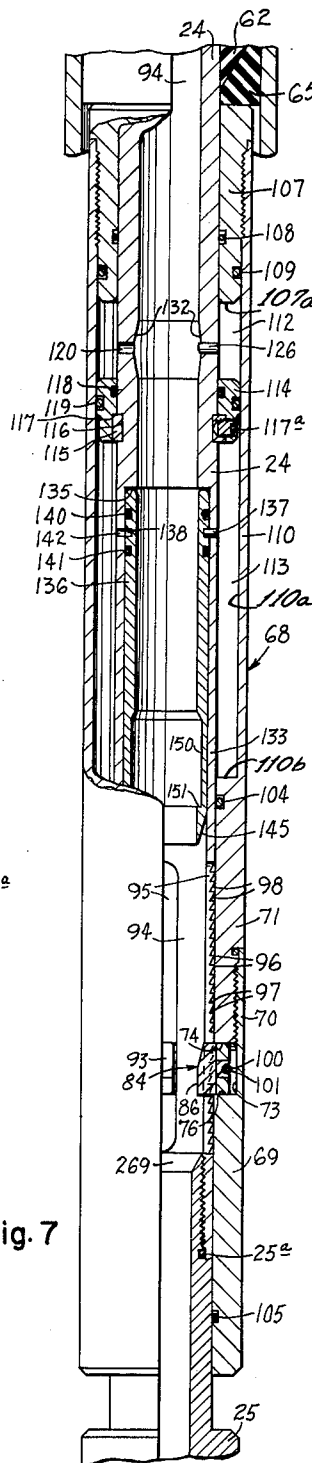


Fig. 6

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HYDRAULICALLY SET WELL PACKER

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11 Claims. (Cl. 166—120)

This invention relates to well tools and more particularly to a packer for closing the annulus between two telescoped spaced flow conductors, such as a well casing and a string of tubing disposed therein.

An object of this invention is to provide a new and improved packer for sealing the annulus between an inner flow conductor, such as string of tubing, and an outer flow conductor, such as a well casing through which the string of tubing extends, the packer being connectable to the inner flow conductor to constitute a section thereof and releasably securable in operative position in the outer flow conductor without the necessity of imparting any longitudinal or rotational movement to the inner flow conductor.

Another object is to provide a packer which is releasably connectable to the lower end of an inner flow conductor such as the string of tubing whereby the string of tubing may be retrieved from the outer flow conductor in the event that the packer becomes lodged therein.

Another object of the invention is to provide a packer having anchoring means for releasably securing the packer against movement in the outer flow conductor and sealing means expandable to engage and seal between the inner flow conductor and the outer flow conductor wherein the anchoring means and the sealing means may be moved to their operative anchoring and sealing positions by either the environmental pressure within the outer flow conductor or by fluid pressure introduced into the interior of the inner flow conductor above the packer.

Still another object is to provide a packer having two anchoring means, one of the anchoring means being engageable with the outer flow conductor to prevent longitudinal movement of the inner flow conductor in one direction in the outer flow conductor and the other anchoring means being engageable with the outer flow conductor to prevent longitudinal movement of the inner flow conductor in the opposite longitudinal direction, wherein each anchoring means has means for individually and sequentially moving the two anchoring means into anchoring position.

A further object is to provide a first fluid pressure operated means for moving one of the anchoring means into position engaging the outer flow conductor and then causing the sealing means to be moved into sealing engagement with the outer flow conductor and having another fluid pressure operated means for subsequently moving the other anchoring means into anchoring engagement with the outer flow conductor.

A still further object is to provide a packer having locking means for releasably locking the fluid pressure operated means in position holding the anchoring means and the seal means in position engaging the outer flow conductor.

A still further object is to provide a packer having means engageable by a pulling tool lowered into the packer for releasing the anchoring means and the sealing means for movement from positions in engagement with the outer flow conductor whereby the packer may be readily removed from the outer flow conductor by upward movement of the inner flow conductor or if the inner flow conductor has been previously removed from the outer flow conductor by a suitable pulling tool.

Another object is to provide a well packer having a

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tubular mandrel, connectable to the lower end of a string of tubing, having upper and lower sets of anchoring means and a seal means mounted on the exterior thereof, a first piston means movable longitudinally on the mandrel for moving the upper anchor means into expanded position and engagement with a well casing and then expanding the sealing means, and a second piston means longitudinally movable on the mandrel for moving the lower anchor means into expanded position engaging the well packer, the piston means having areas thereof exposable to the pressure from within the interior of the mandrel through ports of the mandrel initially closed by upper and lower valves releasably secured in their port closing positions whereby the upper port may be opened by fluid pressure introduced into the tubing string when the upper sleeve is moved downwardly to open the upper port of the mandrel and then the lower port may be opened by movement of the lower sleeve downwardly in the mandrel.

Still another object is to provide a well packer wherein the valves are movable from their initial port closing positions by fluid pressure introduced into the string of tubing above the packer.

A further object is to provide a well packer wherein the piston means and the mandrel are provided with coengageable means for releasably locking the piston means in positions holding the anchoring means and the sealing means in expanded positions and wherein the mandrel is provided with longitudinally movable release means for releasing the locking means to permit movement of the anchoring means and the sealing means forward to retracted positions from their expanded positions.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIGURE 1 is a vertical partly sectional view of the top portion of a well packer embodying the invention showing it connected to the lower end of a string of tubing and positioned in a well casing and showing the anchoring means and the sealing means in their retracted positions;

FIGURE 2 is a continuation of FIGURE 1 and is a view, partly in section, with some parts broken away, of an intermediate portion of the well packer;

FIGURE 3 is a view, similar to FIGURE 2 being a continuation thereof, of the lower portion of the well packer;

FIGURE 4 is a sectional view taken on line 4—4 of FIGURE 2;

FIGURE 5 is a perspective view of locking means of the well packer;

FIGURE 6 is a vertical partly sectional view showing the upper portions of the well packer, the well packer being shown in anchored and sealing position in a well casing;

FIGURE 7 is a continuation of FIGURE 6 and is a vertical partly sectional view, with some parts broken away, of an intermediate portion of the well packer;

FIGURE 8 is a view, similar to FIGURE 7 being a continuation thereof, of the lower portion of the well packer; and,

FIGURE 9 is a fragmentary, vertical partly sectional view, with some parts broken away, showing a releasing tool in position in the well packer.

Referring now to the drawings, the well packer 20 embodying the invention includes a mandrel 21 formed of a top section 22, an upper slip expander section 23, a seal section 24, a slip carrier section 25, an expander carrier section 26 and a bottom sub 27 threadably con-

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nected to one another. The lower reduced end of the top section is threaded into the upper end of the expander section 23 whose lower section in turn is threaded on the upper end portion of the seal section of the mandrel. The lower end of a string of tubing 30 is releasably connected to the mandrel by a top sub 31 into whose enlarged upper end portion 32 is threaded the lower end of the string of tubing. The lower tubular reduced portion 33 of the sub 31 extends through the top section into the expander section and is releasably secured to the mandrel by a split shear washer 35 whose inner end portions are receiver in an external annular recess 36 of the top sub and whose outer portions are disposed between the lower annular end surface 37 of the top section and the annular upwardly facing shoulder 38 of the expander section. An O-ring 40 disposed in an internal annular recess of the expander section seals between the sub and the expander section of the mandrel.

The lower end portion of the expander section has a downwardly and inwardly beveled or frusto-conical surface 42 engageable with the arcuate upwardly and outwardly extending surfaces 43 of the slips 45 disposed about the seal section 24 and biased toward the retracted position illustrated in FIGURE 1 by a garter spring 46 which extends through suitable external recesses 47 of the slips. The vertical arcuate surfaces 49 of the slips 45 engage the annular or cylindrical surface of the seal section of the mandrel. The lower ends of the slips are provided with hooks or external flanges 51 which are receivable in the annular internal recess 52 of the slip carrier 54 slidably mounted on the slip carrier section. The upper internal flange 56 of the slip carrier is received in the external recesses 57 of the slips. The flanges of the slips and the flange of the slip carrier limit longitudinal movement of the slips relative to the carrier and permit limited outward movement of the slips relative to the carrier.

It will be apparent that when the slip carrier is moved upwardly on the slip carrier mandrel, the cam surfaces 43 of the slips 45 engage the expander or cam surface 42 of the expander section 23 of the mandrel and the slips are moved outwardly toward expanded position and into engagement with the internal surfaces of the well casing C.

A seal or packer assembly 60 is mounted on the seal section below the upper slip carrier 54 and may include a plurality of annular resilient packer elements 62 formed of such material as synthetic rubber and the like and a pair of back-up rings 64 and 65. The back-up rings are formed of a material such as nylon, Teflon, Delrin or the like, which is less extrudable than the resilient material of which the packer elements are formed so that the back-up rings, when the seal assembly is moved to expanded position, bridge the annulus or gap between the mandrel and the casing on opposite ends of the packer elements and thus prevent extrusion of the packer elements therethrough.

The packer assembly is movable upwardly on the seal section by a piston sleeve 68 disposed on the mandrel for longitudinal movement relative thereto. The piston sleeve has a bottom section 69 whose upper portion 70 of enlarged internal diameter is threaded on the lower end portion of the intermediate section 71 of the piston sleeve. An internal annular recess 73 is formed by these two sections of the piston sleeve and is defined by the annular downwardly facing end shoulder or surface 74 of the intermediate section and the upwardly facing annular shoulder 76 of the bottom section.

The lock members 84 for releasably locking the piston sleeve against downward movement on the mandrel are disposed in the recess 73 of the piston sleeve. Each lock member has an internal longitudinal slot 85 in which is received the outer portion of a cam lug 86 which is rigidly secured to the lock member in any suitable manner, as by the weld 87 in the externally opening bore 88 of the

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lock member which communicates with the longitudinal recess 85. The lock members are provided with internal arcuate teeth 90 having lower downwardly facing abrupt or horizontal shoulders 91 and upwardly and outwardly beveled shoulders 92.

The cam lugs have upper cam surfaces or shoulders 93 which extend downwardly and inwardly for a purpose to be explained below. The cam lugs extend inwardly into the flow passage 94 of the mandrel through the peripherally spaced longitudinal slots 95 of the seal section 24 of the mandrel. The external surface of the portion of the seal section having the longitudinal slots is provided with external teeth 96 having upper abrupt horizontal shoulders 97 and lower shoulders 98 which extend upwardly and outwardly whereby upward movement of the piston sleeve on the mandrel results in camming engagement between the beveled upper shoulders 92 of the teeth 90 of the lock members and the lower shoulders 98 of the teeth 96 of the seal section of the mandrel and causes outward movement of the lock members in the recess 73 against the resistance offered by the garter spring 100 disposed in the external recesses 101 of the lock members. Downward movement of the piston sleeve relative to the mandrel is prevented, however, by the engagement of the abrupt downwardly facing shoulders of the teeth of the lock members with the abrupt upwardly facing shoulders 97 of the teeth of the mandrel. The lock members are forced to move with the piston sleeve since their upper end surfaces are engageable with the downwardly facing end shoulder or surface 74 of the intermediate section of the piston sleeve and their lower end surfaces are engageable with the upwardly facing annular shoulder 76 of the bottom section 69 of the piston sleeve.

The intermediate and bottom sections of the piston sleeve 68 are provided with internal annular recesses in which are disposed the O-rings 104 and 105 which seal between the piston sleeve and the mandrel above and below the longitudinal slots 95. The top annular section 107 of the piston sleeve has a reduced lower portion threaded in the upper end of the intermediate section of the piston sleeve. The top section has an internal annular recess in which is disposed the O-ring 108 which seals between the top section of the piston sleeve and the seal section 24 of the mandrel and an external annular recess in which is disposed an O-ring 109 which seals between the top and intermediate sections of the piston sleeve. The intermediate section of the piston sleeve has an upper portion 110 of enlarged internal diameter which defines with the seal section an annular space divided into an upper annular chamber 112 and a lower annular chamber 113 by a seal ring 114 rigidly secured to the seal section by means of a split ring 115 whose inner portions are received in an annular external recess 116 of the seal section and whose outer portions are received in the downwardly opening internal recess 117 of the seal ring. A set screw 117a rigidly secures the split ring to the seal ring. O-rings 118 and 119 disposed in annular internal and external recesses of the seal ring seal between the seal ring and the seal section of the mandrel and between the seal ring and the intermediate section of the piston sleeve. It will be apparent that the downwardly facing annular surface 107a of the top annular section 107 of the piston sleeve defined by the line of sealing engagement of the O-ring 108 with the mandrel and the line of sealing engagement of the O-ring 109 with the interior surface 110a of the upper portion 110 of the intermediate section of the piston sleeve is exposed to the pressure within the upper chamber 112 and that the annular upwardly facing shoulder 110b of the intermediate section between the line of sealing engagement of the O-ring 104 with the mandrel and the line of sealing engagement of the O-ring 119 with the internal surface 110a of the intermediate section is exposed to the pressure within the lower cham-

ber 113. The opposed surfaces 107a and 110b of the piston sleeve may thus be regarded as opposed pressure actuable surfaces which are exposed to the pressures within the upper and lower chambers 112 and 113, respectively.

The seal section of the mandrel has one or more lateral ports 120 which communicate the interior or the flow passage 94 of the mandrel with the upper chamber 112. A tubular valve 124 is releasably secured in the flow passage of the mandrel by a shear pin 126 which extends through a suitable lateral bore of the seal section of the mandrel into the external annular recess 127 of the valve. The valve has an upper external annular recess in which is received an O-ring 130 which seals between the valve and the seal section above the port 120 and with a similar lower external annular recess in which is received an O-ring 131 which seals between the valve and the seal section below the port whereby the upper valve 124 closes the upper chamber 112 when the valve is held in the upper position illustrated in FIGURE 2 by the shear pin. The seal section may be provided with an internal annular recess 132 into which the port 120 opens and which has beveled upper and lower shoulders to facilitate passage of the O-rings 130 and 131 therepast without injury or damage to the O-rings.

The lower portion 133 of the seal section of the mandrel is of enlarged internal diameter to provide a downwardly facing internal annular shoulder 135 which limits upward movement of a release sleeve 136 in the mandrel held in the upper position illustrated in FIGURE 2 by a shear pin 137 which extends through a suitable lateral bore of the seal section into the external annular recess 138 of the release sleeve. The release sleeve has upper and lower O-rings 140 and 141 disposed in suitable external recesses of the release sleeve which seal between the release sleeve and the seal section above and below the lateral port 142 of the mandrel which port opens into the lower chamber 113. The valve 124 is movable downwardly through the release sleeve 136 when its shear pin 126 is sheared.

The lower end of the release sleeve has a downwardly and inwardly extending or beveled annular shoulder 145 engageable with the cam surfaces or shoulders 93 of the cam lugs to move the lock members outwardly to permit upward movement of the mandrel relative to the piston sleeve when the release sleeve is moved downwardly to a lower position in the mandrel as will be explained below. The release sleeve has an internal annular recess 150 which provides an upwardly facing abrupt shoulder 151 engageable by a suitable release tool lowered through the flow passage 94 of the mandrel whereby the release sleeve may be moved downwardly to open the port 142 communicating with the lower chamber 113 and subsequently to move the teeth of the lock members out of locking engagement with the teeth 96 of the mandrel.

The slip carrier section 25 of the mandrel has a lower portion of enlarged internal diameter threaded on the expander carrier section 26 of the mandrel and is provided with an internal annular recess 154 in which are receivable the upper external flanges or hooks 155 of the lower slips 156. The internal flange 157 of the slip carrier section extends into the external recesses 158 of the slips. It will be apparent that the engagement of the flanges 155 and 157 permits movement of the slips between the retracted positions illustrated in FIGURE 3 and the expanded positions illustrated in FIGURE 8.

The slips are resiliently held in the retracted positions illustrated in FIGURE 3 by a garter spring 160 which extends through suitable external recesses 161 of the slips. The slips are movable to their expanded positions by the camming engagement of the upwardly and inwardly beveled or frusto-conical cam surface 162 of the top expander section 163 of the lower piston sleeve 164 with the arcuate downwardly and outwardly extend-

ing lower surfaces 165 of the slips when the lower piston sleeve is moved upwardly from its lower position illustrated in FIGURE 3 to the position illustrated in FIGURE 8. The lower piston sleeve is substantially similar in structure to the upper piston sleeve 68, having an intermediate section 166 into which the reduced lower portion 167 of the top expander section is threaded and a bottom section 168 into whose upper portion 169 of enlarged internal diameter is threaded the lower reduced portion 171 of the intermediate section.

The annular space above the internal annular shoulder 172 of the intermediate section of the piston sleeve and between the intermediate section and the mandrel is divided into upper and lower annular chambers 174 and 175 by a seal ring 176 secured to the expander carrier section 26 of the mandrel by a split ring 177 whose inner portions extend into a suitable annular recess 178 of the expander carrier section and whose outer portions extend into a downwardly opening recess 179 of the seal ring 176. The seal ring is secured to the split ring by a suitable set screw 180 threaded in a suitable bore of the seal ring.

The seal ring has internal and external annular recesses in which are disposed the O-rings 183 and 184 which seal between the seal ring and the mandrel and between the seal ring and the lower piston sleeve 164, respectively. The top section of the piston sleeve is provided with internal and external annular recesses in which are disposed the O-rings 186 and 187 which seal between the top section of the piston sleeve and the mandrel and between the top and intermediate sections of the piston sleeve, respectively.

The expander carrier section 26 of the mandrel has a lateral port 189 communicating the upper chamber 174 with the flow passage 94 of the mandrel which is closed by the tubular valve 191 releasably secured to the expander carrier section by a shear pin 192 which extends through a suitable bore or aperture of the mandrel into the external annular recess 194 of the valve 91. O-rings 196 and 197 disposed in external annular recesses of the valve seal between the valve and the expander carrier section above and below the port 189 whereby the valve prevents any flow of fluid into or out of the upper chamber 174 when the valve is held in the upper position illustrated in FIGURE 3.

The lower piston sleeve is provided with a plurality of lock members 200, identical in structure to the lock members 84, which are disposed in the internal annular recess 201 of the lower piston sleeve and whose teeth 202 engage the teeth 203 of the expander carrier section of the mandrel to permit upward movement of the piston sleeve on the mandrel and prevent downward movement of the piston sleeve on the mandrel. The teeth 202 and 203 are of the same configuration and function in the same manner as the teeth 90 and 96 of the lock members 84 and seal section 24 of the mandrel. The lock members 200 are resiliently biased toward engagement with the mandrel by the garter spring 204 which extends through the external recesses 205 of the lock members. The cam lugs 206 of the lower piston sleeve extend through the longitudinally extending slots 208 of the expander carrier section of the mandrel so that their downwardly and inwardly extending cam surfaces or shoulders 210 are disposed within the flow passage of the mandrel and in position to be engaged by the downwardly and inwardly beveled cam shoulder or surface 211 of the lower release sleeve 212 disposed in the lower portion 213 of enlarged internal diameter of the expander carrier section of the mandrel.

The lower release sleeve is held in the upper position illustrated in FIGURE 3 by a shear pin 215 which extends through a suitable lateral bore of the expander carrier section into the external annular recess 216 of the lower release sleeve. The release sleeve is provided with upper and lower O-rings 218 and 219 disposed in

suitable external annular recesses of the release sleeve which seal between the release sleeve and the expander carrier section above and below the lateral port 220 of the mandrel which provides communication between the lower chamber 175 and the flow passage of the mandrel when the release sleeve is moved downwardly in the mandrel. The O-rings 222 and 223 disposed in suitable internal annular recesses of the intermediate and bottom sections 166 and 168 of the lower piston sleeve seal between the piston sleeve and the mandrel above and below the elongate slots 208 of the mandrel. The annular downwardly facing surface 163a of the top expander section 163 between the line of sealing engagement of the O-ring 186 with the mandrel and the line of sealing engagement of the O-ring 187 with the internal surface 166a of the intermediate section 166 above its annular shoulder 172 is exposed to the fluid pressure within the upper chamber 174. The upwardly facing annular surface or shoulder 172 between the line of sealing engagement of the O-ring 222 with the mandrel and the line of sealing engagement of the O-ring 184 with the internal surface 169a is exposed to the pressure within the lower chamber 175. The opposed annular surfaces 163a and 172 of the piston sleeve may be regarded as pressure actuable surfaces which are exposed to the pressures within the upper and lower chambers 174 and 175, respectively.

The bottom section 27 of the mandrel has an upper reduced end portion 225 threaded in the lower end of the expander carrier section of the mandrel. A stop ring 226 is releasably secured in the bottom section by means of the shear pins 228 which extend through suitable lateral bores of the bottom section into an external annular recess 229 of the stop ring. The stop ring has an external annular recess in which is disposed an O-ring 231 which seals between the stop ring and the bottom sub.

If desired, the O-rings 22a, 24a, 25a, 26a, and 27a may be provided in suitable recesses of the mandrel sections to seal between telescoped sections of the mandrel.

In use, when it is desired to close the annulus between the string of tubing 30 and the well casing C, the lower end of the string of tubing is connected to the mandrel by means of the shear washer 35. At this time the upper valve 124 and the upper release sleeve 136 close the ports 120 and 142 and the chambers 112 and 113 are maintained at atmospheric pressure. The lower valve 191 now closes the port 189 and the lower release sleeve 212 closes the port 220 so that the upper and lower chambers 174 and 175 are also at atmospheric pressure. Since the chambers above and below the seal rings 114 and 176 are now at atmospheric pressure, the upper and lower piston sleeves 68 and 164 are held against upward movement on the mandrel since upward movement would tend to cause an increase in the pressure in the lower chambers 113 and 175 and simultaneously tend to cause a decrease in the pressure in the upper annular chambers 112 and 174. Downward movement of the piston sleeves on the mandrel is now prevented by the engagement of the teeth of the lock members 84 and 200 with the teeth 96 and 203, respectively, of the mandrel.

The tubing with the packer thus connected to its lower end is then lowered into the well casing to a desired position therein. The string of tubing is then hung from the surface in the conventional manner and the wellhead connections set in place. The well packer is now in the position illustrated in FIGURES 1 through 3 and, if desired, fluids may be circulated down through the string of tubing, out the lower end of the packer mandrel and thence upwardly through the annulus between the string of tubing and the well casing C to the surface.

When it is desired to close the annulus between the string of tubing and the well casing, a ball 240 is introduced into the string of tubing at the surface and allowed to drop therethrough until it engages the seat 241 on the

upper end of the upper tubular valve 124. If desired, fluid may be pumped into the string of tubing at the surface to accelerate the downward movement of the ball valve 240 through the string of tubing to its position closing the bore of the upper tubular valve 124. When the ball 240 sealingly engages the top seat 241 of the upper valve, fluid under pressure is introduced into the string of tubing to cause a downward force to be exerted on the upper tubular valve which, when it exceeds a predetermined value, causes the shear pin 126 to shear whereupon the upper valve is moved downwardly by such fluid pressure. The upper valve is moved downwardly by such fluid pressure until its bottom annular seat 243 sealingly engages the top annular seat 244 of the lower valve 191. The shear pin 192 which holds the lower valve in its upper position requires a force to shear it which approximates that required to shear the pin 126. As a result downward movement of the upper valve is now stopped and the bore of the mandrel is maintained closed since the ball closes the bore of the upper valve and the O-rings of the upper valve sealingly engage the internal surfaces of the mandrel.

When the port 120 is opened by the downward movement of the upper valve 124, the fluid pressure from the bore 94 of the packer mandrel above the ball is communicated to the upper chamber 112 and causes upward movement of the upper piston sleeve 68 on the mandrel since such fluid pressure is greater than atmospheric pressure within the lower chamber 113. As the upper piston sleeve 68 moves upwardly, it moves the packer assembly 60, the slip carrier 54 and the upper slips 45 upwardly on the mandrel. During such upward movement, the camming engagement of the frusto-conical expander surface 42 of the expander section 23 of the packer mandrel 21 causes the slips to move outwardly into gripping engagement with the internal surfaces of the well casing. When the upward movement of the slips and the slip carrier 54 is stopped and outward movement of the slip is arrested, continued upward movement of the upper piston sleeve causes the packer assembly to expand and move into sealing engagement between the seal section of the mandrel and the well casing as illustrated in FIGURES 6 and 7 of the drawing. The fluid pressure in the bore 94 of the mandrel above the ball and the upper valve now tends to hold the piston sleeve in its upper position and thus tends to hold the upper slips 45 in casing engaging and packer anchoring position and also tends to hold the packer assembly in its expanded sealing position. The lock members 84, which move outwardly due to the camming engagement of their teeth with the teeth 96 of the packer mandrel during upward movement of the upper piston sleeve, now prevent downward movement of the upper piston sleeve on the mandrel, lock the piston sleeve in any position to which it has been moved upwardly, and thus hold the upper slips 45 and the packer assembly in expanded casing engaging positions should the pressure within the bore 94 of the mandrel decrease for any reason.

When the slips have been moved to their expanded anchoring positions and the packer assembly 60 has been moved to its expanded sealing position, the fluid pressure introduced into the string of tubing is increased to a second predetermined value, which may be higher than the first predetermined value at which the shear pin 126 sheared, to cause the shear pin 192 to shear and permit downward movement of the upper valve, the lower valve and the ball valve until the lower seat 246 of the lower tubular valve engages the seat 247 of the stop ring 226. The shear pins 228 now hold the two tubular valves and the ball against continued downward movement. Since the engagement of the seat 246 with the seat 247 of the stop ring now prevents fluid flow therebetween, since the O-ring 231 seals between the stop ring and the mandrel and since the ball 240 closes the bore of the upper valve, the lower end of the mandrel is still held closed against flow of fluid. When the lower tubular valve 191 is

moved downwardly in the packer mandrel and the port 189 is opened, the fluid pressure in the bore 94 of the mandrel is communicated to the upper chamber 174 and since the lower chamber 175 is still at atmospheric pressure, the lower piston sleeve 164 is moved upwardly by such fluid pressure and the camming engagement between the expander surface 162 thereof with the cam surfaces 165 of the lower slips 156 moves the lower slips outwardly into gripping or anchoring engagement with the well casing. The camming engagement between the teeth of the lug members 200 and the teeth 203 of the mandrel move the lug members outwardly to permit such upward movement of the lower piston sleeve to a position wherein the lower slips are moved into their expanded anchoring positions and then lock the lower piston sleeve in such upper position and thus prevent the lower slips from moving from their expanded towards their retracted positions.

After the lower slips have been moved to their expanded positions, a further increase in the pressure of the fluid introduced into the string of tubing causes the shear pins 228 to shear whereupon the stop ring, the lower and upper tubular valves and the ball are ejected through the lower end of the packer mandrel and fall to the bottom of the well. The lower end of the packer mandrel is thus opened and flow of well fluids upwardly through the bore of the string of tubing may now take place, the packer now preventing any flow between the string of tubing and the well casing.

The well packer is now held against movement in the well casing in either longitudinal direction. Any force tending to move the well mandrel upwardly also tends to move the expander surface 162 upwardly relative to the slips 156, since the slips are mounted for limited longitudinal movement relative to the mandrel, and to move them outwardly into more firm anchoring or gripping engagement with the well casing. Any force tending to move the well packer mandrel downwardly causes the expander surface 42 to move the upper slips 45 outwardly into firmer anchoring or gripping engagement with the well casing.

It will also be apparent that the pressure within the bore 94 of the packer mandrel is now at all times communicated to the upper chambers 112 and 174 so that any increase in the pressure within the string of tubing tends to move the piston sleeves upwardly and thus tends to hold the upper and lower slips with greater force in anchoring or gripping engagement with the well casing and the packer assembly 60 in sealing engagement with the well casing.

It will thus be apparent that the well packer 20 is set by introducing a fluid pressure into the string of tubing at the surface above the packer after the ball valve of the mandrel of the packer has been closed by the ball valve 240 dropped or pumped into the tubing string through the tubing string into sealing engagement with the supper seat 241 of the upper tubular valve, and that the upper slips, the packer assembly and the lower slips are sequentially moved to their expanded or operative positions in engagement with the well casing as the fluid pressure in the string of tubing above the packer mandrel is increased to first cause the upper tubular valve to be released and moved downwardly, then the lower tubular valve to be released for downward movement and finally the stop ring 226 to be released for downward movement to permit the expulsion of the ball, the tubular valves and the stop ring from the mandrel.

When it is desired to remove the well packer 20 from the well casing, an upward force is exerted on the string of tubing 30 to cause the shear washer 35 to shear whereupon the string of tubing and the top sub 31 are removed upwardly from the well leaving the well packer in the well casing. A releasing tool 248 is then lowered into the well casing by means of a conventional string of flexible line tools by means of the usual flexible line.

Such flexible line tools may include stems, jars and a suitable fishing or pulling tool 250 such as the Type B Otis Pulling Tool illustrated on Page 3933 of the Composite Catalog of Oil Field Equipment and Services, 1962-63 edition, having dogs 251 pivotally mounted on a core 252 whose hooks 253 are engageable with the undercut shoulder 254 provided by the external annular flange 255 on the upper end of the top section 22 of the mandrel 21 of the well packer.

The releasing tool 248 includes a prong or rod 258 whose upper end is threaded in a suitable downwardly opening bore of the core 252 of the pulling tool 250. A collet 260 is threaded on the lower reduced end of the rod 258 and is provided with a plurality of resilient fingers 261 having external bosses 262 intermediate their ends which are receivable in the recesses 150 and 150a of the upper and lower release sleeves 136 and 212, respectively. The bosses of the collet fingers are provided with abrupt downwardly facing shoulders 263 which are engageable with the upwardly facing lower shoulders 151 and 151a, respectively, of the upper and lower release sleeves, respectively, when the intermediate bosses of the collet fingers are positioned in the internal recesses 150 and 150a, respectively.

The collet fingers also have end bosses 265 spaced below and intermediate bosses which have upwardly and outwardly extending lower cam shoulders 266 engageable with such upwardly facing obstructions as the inwardly and downwardly beveled upper shoulders 267, 268 and 269 of the top section and the slip carrier section, respectively, of the packer mandrel for camming the fingers inwardly toward one another to permit movement of the collet fingers and of the collet past such obstructions.

As the string of flexible line tools is lowered through the string of tubing, the releasing tool 248 moves downwardly into the bore 94 of the packer mandrel, the lower cam shoulders 266 of the end bosses 265 upon engaging the upwardly facing shoulders 267 and 268 cam the resilient collet fingers inwardly to permit the movement of the collect past such shoulders and through the seal section whose bore is of smaller diameter than the distance between outer surfaces of the oppositely facing bosses of the collet fingers. The releasing tool is moved downwardly through the bore of the packer mandrel until the intermediate bosses are aligned with the internal recess 150 of the upper release sleeve 136 whereupon the collet fingers move resiliently outwardly to position the intermediate bosses in the internal recess 150 of the upper release sleeve. Further downward movement of the releasing tool relative to the upper release sleeve is then prevented by the engagement of the abrupt downwardly facing shoulder 263 of the intermediate bosses with the upwardly facing lower shoulder 151 of the upper release sleeve. Downward jars now imparted to the releasing tool by means of the flexible line tools now causes the shear pin 137 to shear and further downward jars imparted to the releasing tool move the releasing tool and the upper release sleeve downwardly in the mandrel. As the upper sleeve is moved downwardly the lateral port 142 is opened to permit the lower chamber to communicate with the bore 94 of the mandrel so that the pressure in the upper and lower chambers 112 and 113 is equalized and the fluid pressure from within the bore 94 no longer tends to move or bias the piston sleeve upwardly relative to the mandrel. The beveled lower shoulder 146 of the upper release sleeve engages the upper shoulders 93 of the cam lugs 86 of the lock members 84 as downward movement of the release sleeve is continued and the camming engagement between the shoulder 145 and the shoulders 93 of the cam lugs causes the lock members to be moved outwardly in the annular recess 73 until the teeth 90 of the lock members move out of engagement with the teeth 96 of the mandrel and the upper piston sleeve 68 is thus released for

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downward movement on the mandrel. Outward movement of the lock members is then stopped by the engagement of their outer surfaces with the internal surface of the bottom section of the piston sleeve defining the recess 73 and continued downward movement of the upper release sleeve causes downward movement of the upper piston sleeve on the packer mandrel since the cam lugs of the lock members still protrude into the bore 94 and are engaged by the shoulder 145 of the upper release sleeve. As the piston sleeve is moved downwardly the packer elements of the packer assembly 60 are freed to decompress and disengaged from the internal surfaces of the well casing C.

As the upper piston sleeve is moved to its lowermost position on the mandrel illustrated in FIGURE 2, the cam shoulders 266 of the end bosses of the collet fingers move into engagement with the beveled shoulder 269 of the slip carrier section 25 and the camming engagement therebetween moves the collet fingers inwardly as downward movement of the releasing tool is continued. Such inward movement of the collet fingers moves the intermediate bosses 262 out of the internal recess 150 of the upper release sleeve thus freeing the collet for downward movement relative to the upper release sleeve which is left in its lower position holding the lock members 84 in their outer inoperative positions.

Continued downward movement of the releasing tool then causes the collet fingers to move into the lower release sleeve 212 until the intermediate bosses thereof move into alignment with the internal recess 150a of the lower release sleeve whereupon the collet fingers move resiliently outwardly and the intermediate bosses 262 move into the recess so that their downwardly facing lower shoulders 263 engage the lower upwardly facing shoulder 151a of the lower release sleeve. The shear pin 215 holding the lower release sleeve in its upper position is sheared by the downward jars and the lower release sleeve is moved downwardly in the mandrel. The lateral port 220 is thus opened to the bore 94 so that the pressure in the upper and lower chambers 174 and 175 is now equalized and the pressure within the bore of the mandrel no longer tends to hold or bias the lower piston sleeve 164 upwardly on the mandrel. As the lower release sleeve is moved downwardly in the mandrel, the beveled cam shoulder 211 thereof engages the upper cam shoulders 210 of the cam lugs 206 and moves the lock members 200 outwardly so that their teeth move out of engagement with the teeth 203 of the mandrel and the lower piston sleeve is freed for downward movement on the mandrel. The outer surfaces of the lock members 200 engage the inner surface of the bottom section 168 of the lower piston sleeve defining the recess 201 so that further outward movement of the lock members is stopped before the cam lugs 206 thereof are fully retracted from the bore of the mandrel. The lower release sleeve continues to engage the cam lugs of the lock members and further downward jars imparted to the releasing tool, which cause further downward movement of the lower release sleeve, now also cause downward movement of the lower piston sleeve 164. The expander surface 162 of the lower piston sleeve is thus moved downwardly relative to the lower slips 156 which are moved to their retracted position out of engagement with the well casing by the force exerted thereon by the garter spring 160.

The prong or rod is of such length that as the lower piston sleeve 164 is moved back to its lowermost position on the mandrel illustrated in FIGURE 3, the hooks 253 of the dogs 251 of the pulling tool 250 move below the flange 255 of the mandrel into position to engage the undercut shoulder 254. An upward pull then exerted on the releasing tool through the set of flexible line tools and the flexible line to which they are secured, then causes the mandrel to be moved upwardly through the well casing since the lower slips and the resilient elements of

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the packing assembly are now in their retracted position out of engagement with the well casing and since upward movement of the mandrel causes the upper expander surface 42 to move out of engagement with the upper slips which are then moved to their retracted position and out of engagement with the well casing by the garter spring 46.

It will now be seen that the two piston sleeves are successively moved to their lowermost positions by their respective release sleeves as the release sleeves are successively moved downwardly in the bore of the packer mandrel to permit the slips and the packer assembly 60 to move out of engagement with the well casing.

If the bore of the tubing string and of the packer mandrel is sufficiently large, the releasing tool 248 may be lowered into the packer mandrel through the string of tubing by means of a set of flexible line tools which includes stems and jars, but no pulling tool such as the pulling tool 250, to move the upper and lower release sleeves sequentially downwardly in the manner described above. The string of tubing with the packer secured to the lower end thereof may then be removed upwardly from the well casing. Should the well packer for some reason be fouled in the well casing, as by sand or debris lodging on top thereof, the upward force imparted to the string of tubing will cause the shear washer 35 to fail. The string of tubing is then removed from the well after which a suitable fishing tool would be lowered into the well casing to engage the flange 255 of the mandrel whereupon a greater force can be applied to the packer through suitable jarring or pulling equipment to remove it upwardly from the well casing.

It will also be apparent that the releasing tool could be moved down by fluid pressure through the tubing string and through the bore of the mandrel to move the release sleeves downwardly therein by fluid pressure introduced into the string of tubing above the releasing tool if releasing tool instead of a flexible line. In this case, the releasing tool would be provided with suitable seal means for sealing between the string of tubing and the rod 258 to permit fluid pressure introduced into the string of tubing at the surface to cause such downward movement of the releasing tool through the string of tubing and the bore of the mandrel to move the upper and lower release sleeves.

It will now be seen that a new and improved well packer has been illustrated and described which includes a mandrel provided with upper and lower sets of slips for anchoring the packer mandrel in a well casing and with a packer or sealing assembly for sealing between the mandrel and the well casing.

It will further be seen that one set of slips and the packer assembly are movable into their expanded casing engaging positions by a pressure responsive means such as the upper piston sleeve 68, when a selected area of the pressure responsive means is exposed to fluid pressure introduced into the mandrel after a valve, such as the upper tubular valve 124, is moved by such fluid pressure to expose such area of the pressure responsive means to the fluid under pressure.

It will further be seen that the other set of slips is similarly movable into expanded casing engaging position by a second pressure responsive means, such as the lower piston sleeve 168, when a selected area of the second pressure responsive means is exposed to fluid pressure introduced into the bore of the mandrel after a second valve means, such as the lower tubular valve 191, is moved in the bore of the mandrel to expose such selected area of the second pressure responsive means to the pressure of the fluid within the bore of the mandrel.

It will further be seen that the forces exerted by the fluid pressure acting on such selected areas of and biasing the two pressure responsive means toward their operative positions wherein they tend to hold the packer assembly and the slips in their expanded casing engaging positions

may be counterbalanced by similar forces exerted thereby on the pressure responsive means when other areas of the two pressure responsive means are exposed to the pressure of the fluid from within the bore of the mandrel upon the movement of the release sleeves or valves 136 and 212 5 to lower positions wherein the ports 142 and 220 are open to the bore of the mandrel.

It will further be seen that the upper piston sleeve has an annular downwardly facing surface, between the lines of contact of the O-rings 108 and 109 with the mandrel and with the intermediate section 110 of the piston sleeve, 10 exposed to the pressure of the fluid within the bore 94 when the port 120 is open so that the fluid pressure within the bore 94 of the mandrel biases the upper piston sleeve upwardly on the mandrel to position moving and holding 15 the packing assembly and the upper slips to and in their expanded casing engaging positions and that the upper piston sleeve has an upwardly facing surface of the same area as the upwardly facing surface, between the lines of contact of the O-rings 104 and 119 with the mandrel and the intermediate section 110 of the upper piston sleeve, 20 which is also exposed to the pressure of the fluid within the bore 94 of the mandrel when the upper release sleeve is moved downwardly to open the port 142 so that the force of the pressure is balanced and does not tend to move the piston sleeve in either longitudinal direction on the mandrel when both ports 120 and 142 are open. 25

It will further be seen that the lower piston sleeve similarly has a downwardly facing surface defined by the line of contact of the O-rings 136 and 187 with the mandrel and with the intermediate section 166 of the lower piston sleeve which is exposed to the pressure within the bore 94 of the mandrel when the lower tubular valve 191 is moved to its lower position and the port 139 30 is open so that the fluid pressure biases the lower piston sleeve upwardly and that such force is counterbalanced when the upwardly facing surface of the lower piston sleeve between the lines of contact of the O-rings 222 and 184 with the mandrel and the intermediate section 40 of the mandrel, which has the same area as the upwardly facing surface, is also exposed to the pressure of the fluid in the bore of the mandrel when the lower release sleeve 212 is moved to its lower position and the port 216 is open. 45

It will further be seen that such areas of each of the two piston sleeves constitute surfaces defining initially closed longitudinally spaced chambers which are filled with a compressible fluid, as air at atmospheric pressure, whereby the fluid trapped in such chambers holds the piston sleeves against movement on the mandrel until one 50 of the chambers is opened to the bore of the mandrel.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention. 55

What is claimed and desired to be secured by Letters Patent is:

1. A well packer including: a tubular mandrel; first and second longitudinally spaced anchoring means movably mounted on said mandrel; first expander means on said mandrel for moving said first anchoring means outwardly upon relative longitudinal movement between said first expander means and said first anchoring means; sealing means on said mandrel; first pressure responsive means movably mounted on said mandrel for causing relative longitudinal movement between said first anchoring means and said first expander means for moving said first anchoring means outwardly to expanded position and into anchoring engagement with a flow conductor when said mandrel is telescoped in said flow conductor, said first pressure responsive means and said anchoring means engaging said sealing means for expanding said sealing means into sealing engagement with the flow conductor after said first anchoring means is moved to 75

anchoring engagement with the flow conductor; second expander means on said mandrel for moving said second anchoring means outwardly upon relative longitudinal movement between said second expander means and said second anchoring means; second pressure responsive means movably mounted on the mandrel for causing relative longitudinal movement between said second anchoring means and said second expander means to move said second anchoring means laterally outwardly of said mandrel to expanded position to engage the well flow conductor, each of said pressure responsive means including piston means having opposed facing pressure actuable surfaces, said mandrel having a plurality of longitudinally spaced port means communicating with the interior of said mandrel for separately exposing said opposed surfaces of each of pressure responsive means to pressure within the interior of said mandrel; valve means movably mounted in said mandrel closing said port means of said mandrel, said valve means being movable to open a first one of said port means to cause one of said surfaces of said piston means of said first pressure responsive means to be exposed to fluid pressure from within said mandrel to cause said first pressure responsive means to move longitudinally on said mandrel to move said first anchoring means and said sealing means to expanded position and subsequently to open a second one of said port means to cause one of said surfaces of said piston means of said second pressure responsive means to be exposed to pressure from within said mandrel to move said second anchoring means to expanded position. 30

2. The well packer of claim 1; and second valve means in said mandrel movable by means introduced into said mandrel after said one pressure actuable surface of said piston means of said first and second pressure responsive means have been exposed to pressure from within said mandrel for opening a third one of said port means to expose the other of said pressure actuable surfaces of said piston means of said first pressure responsive means to the pressure from the interior of the mandrel and subsequently for opening a fourth one of said port means to expose the other of said pressure actuable surfaces of said piston means of said second pressure responsive means to the pressure from the interior of said mandrel whereby the pressures acting on said opposed pressure actuable surfaces of said piston means of each of said first and second pressure responsive means are equalized. 40

3. The well packer of claim 2; and first coengageable lock means on said first pressure responsive means and said mandrel and second co-engageable lock means on said second pressure responsive means and said mandrel permitting movement of said pressure responsive means on said mandrel to move said anchoring and sealing means to expanded positions, said lock means preventing movement of the one of said pressure responsive means with which it is associated relative to the mandrel to prevent movement of said anchoring and sealing means from said expanded positions toward retracted positions. 50

4. A well packer of the character set forth in claim 3 wherein: said second valve means mounted in said mandrel includes means movable to engage said first lock means and then said second lock means to move said first lock means and then said second lock means to inoperative positions upon movement of said second valve means to positions opening said second and fourth ones of said port means. 65

5. A well packer including: a tubular mandrel having an expander means; first anchoring means movably mounted on said mandrel and engageable with said expander means on longitudinal movement in one longitudinal direction relative to said mandrel for moving said anchoring means laterally outwardly of said mandrel to expanded position; sealing means on said mandrel; first piston means movably mounted on said mandrel for moving said sealing means and said first anchoring means 75

in said one longitudinal direction for first moving said first anchoring means to expanded gripping position and then moving said sealing means to expanded sealing position; said mandrel and said first piston means having means providing first and second longitudinally spaced chambers about said mandrel, said first piston means having a first surface exposed to pressure within said first chamber and having a second surface exposed to fluid pressure within said second chamber, said mandrel having a first port means communicating the interior of said mandrel with said first chamber and a second port means communicating the interior of said mandrel with said second chamber; first valve means in said mandrel closing said first port means; second valve means in said mandrel closing said second port means; means releasably securing said first valve means and said second valve means in port closing positions in said mandrel; second anchoring means movably mounted on said mandrel; second piston means movably mounted on said mandrel and having expander means engageable with said second anchoring means for moving said second anchoring means laterally outwardly of said mandrel to expanded anchoring position upon longitudinal movement of said second piston means in said one direction on said mandrel; said mandrel and said second piston means having means providing longitudinally spaced third and fourth chambers about said mandrel; said second piston means having opposed third and fourth surfaces exposed within said third and fourth chambers respectively; third port means communicating the interior of said mandrel with said third chamber; fourth port means communicating the interior of said mandrel with said fourth chamber; third valve means in said mandrel releasably secured in a position therein closing said third port means against flow from the interior of said mandrel to said third chamber; fourth valve means in said mandrel releasably secured in a position therein closing said fourth port means against flow from the interior of the mandrel to said fourth chamber; said mandrel and said first piston means having co-engageable first lock means; said mandrel and said second piston means having co-engageable second lock means, each of said lock means permitting movement of its associated piston means on said mandrel in said one direction and preventing movement of such associated piston means in a second opposite direction; said first valve means being movable to open said first port means to permit fluid pressure from within the interior of the mandrel to enter said first chamber to move said first anchoring means and said sealing means to their expanded gripping and sealing positions; said first valve means then engaging said third valve means to open said third port means to permit fluid pressure from within the interior of said mandrel to enter said third chamber to move said second expander means and said second gripping means to expanded gripping position; said second valve means and said fourth valve means remaining closed during movement of said first valve means and said third valve means, whereby said well packer is anchored in sealing position.

6. A well packer of the character set forth in claim 5 wherein: said second valve means and said fourth valve means are longitudinally spaced from each other in said mandrel and have longitudinal flow passages therethrough of a size through which said first valve means and said third valve means may move longitudinally; said second valve means having means thereon engageable with said first lock means of said first piston means for releasing said first lock means upon movement of said second valve means in said second direction to free said first piston means for movement in said second direction; said fourth valve means having means thereon engageable with said second lock means of said second piston means for releasing said second lock means to free said second piston

means for movement in said second direction; movement of said first piston means in said second direction moving said first expander means with respect to said first anchoring means and said sealing means to permit said first anchoring means and said sealing means to move to retracted positions relative to said mandrel; and movement of said second piston means in said second direction moving said second expander means with respect to said second anchoring means to release said second anchoring means from gripping position to free said packer for movement.

7. The well packer of claim 5 wherein: said second and fourth valve means have means engageable with a releasing means movable through said mandrel for moving said second valve means and said fourth valve means in said second direction to open said second and fourth port means of said second and fourth chambers.

8. The well packer of claim 7 wherein: said first and third valve means have flow passages, said first valve means having seat means engageable by a closure means movable through said mandrel in said second direction for closing said flow passage of said first valve means whereby fluid pressure introduced into said mandrel after said closure means has been introduced into said mandrel and into engagement with said seat means causes movement of said first valve means and subsequently said third valve means in said second direction upon engagement of said coengageable means of said first and third valve means.

9. The well packer of claim 8, and releasable stop means carried by said mandrel and engageable by said third valve means upon movement of said third valve means in said second direction, said first valve means having means sealingly engageable with said mandrel preventing flow of fluids therebetween whereby fluid pressure introduced into said mandrel after a closure means has been introduced into said mandrel and positioned in engagement with said seat means moves said first valve means in said second direction until its movement is arrested by the engagement of said coengageable means of said first and third valve means, said first and third valve means being movable in said second direction by said fluid pressure until said third valve means engages said stop means, said first and third means and said stop means being movable in said second direction and out one end of said mandrel when the fluid pressure in said mandrel is increased to a second predetermined value higher than said first predetermined value.

10. The well packer of claim 5 wherein: said second and fourth valve means have stop means engageable by a retrieving tool movable in said second direction through said mandrel for moving said second and fourth valve means sequentially in said second direction.

11. The well packer of claim 10 wherein: said mandrel is provided with release means engageable by a retrieving tool for moving said retrieving tool out of engagement with said stop means of said second valve means to permit the retrieving tool to move in said second direction relative to said second valve means to engage said stop means of said fourth valve means when said second valve means has been moved to a predetermined position in said second direction.

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