May 7, 1968 T. L. ELLISTON 3,381,752

WELL TOOLS

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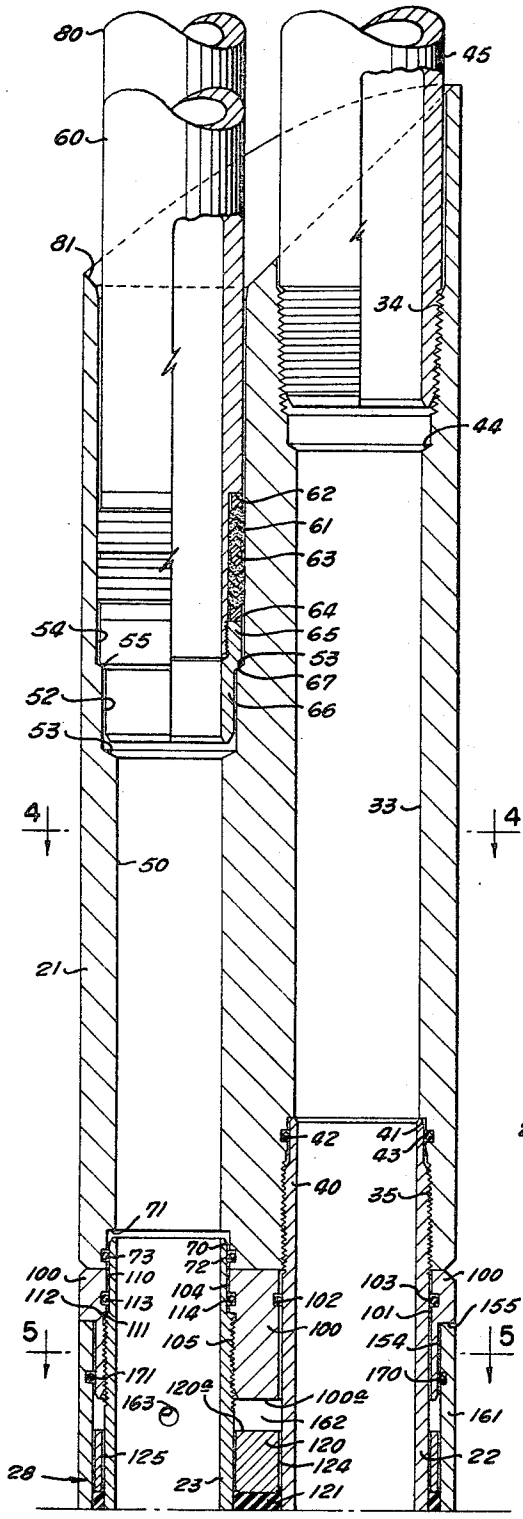


Fig. I-A

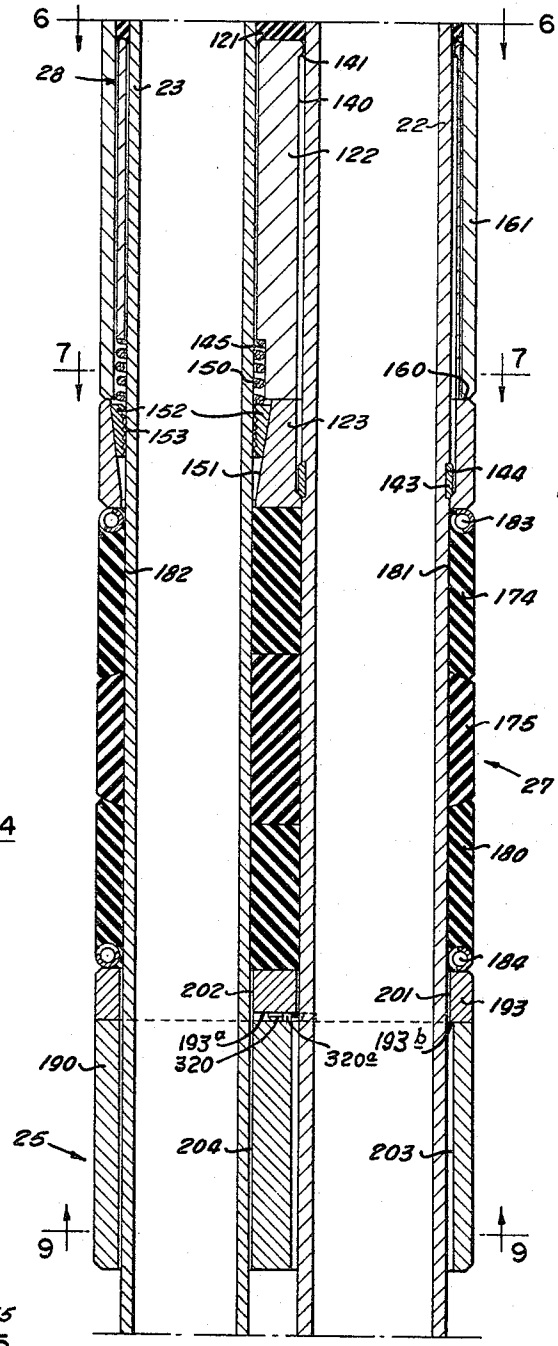


Fig. I-B

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WELL TOOLS

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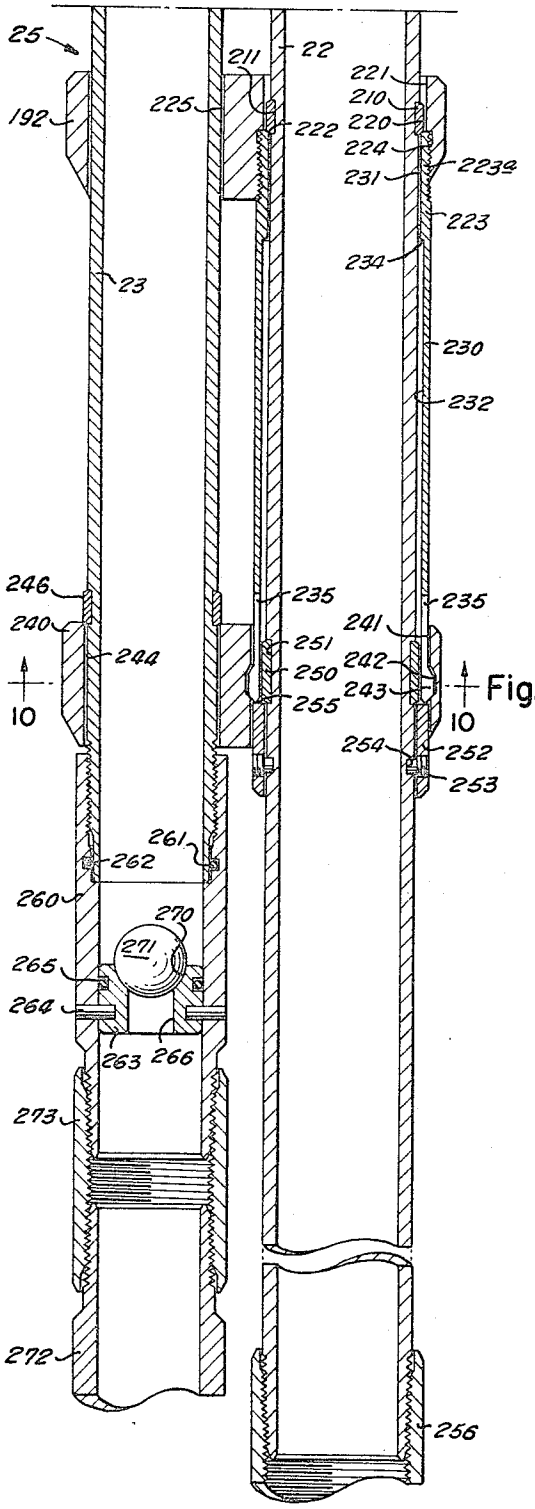


Fig. 1-C

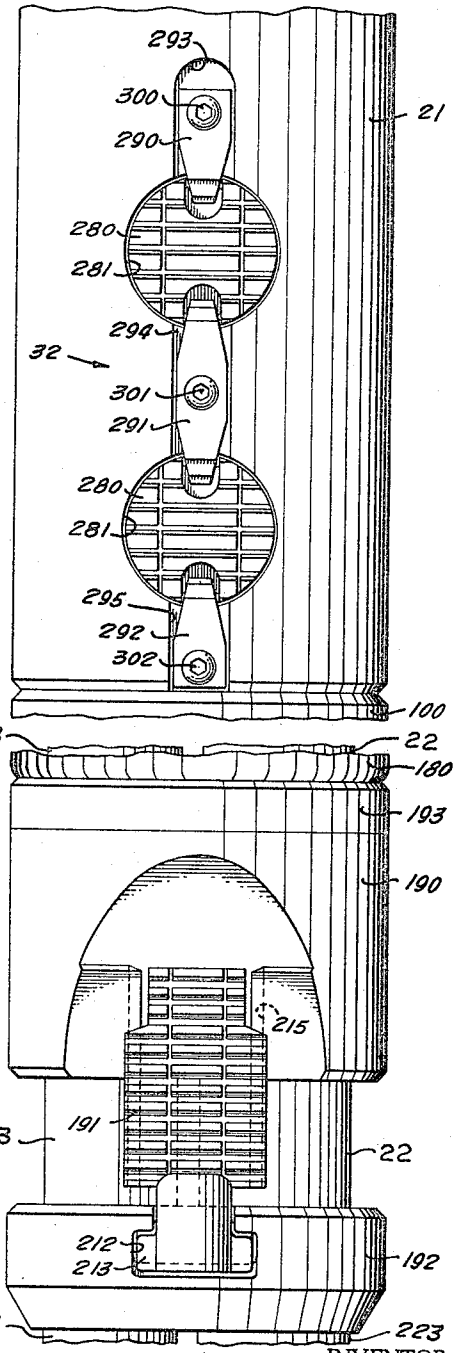


Fig. 2

Fig. 3

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WELL TOOLS

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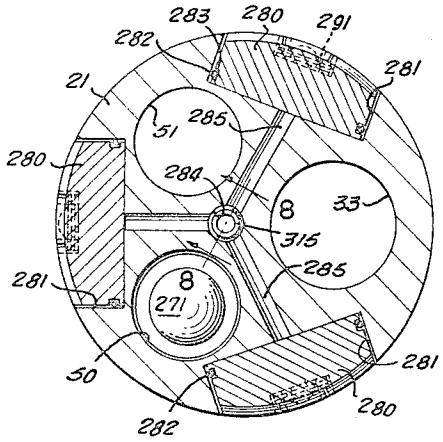


Fig. 4

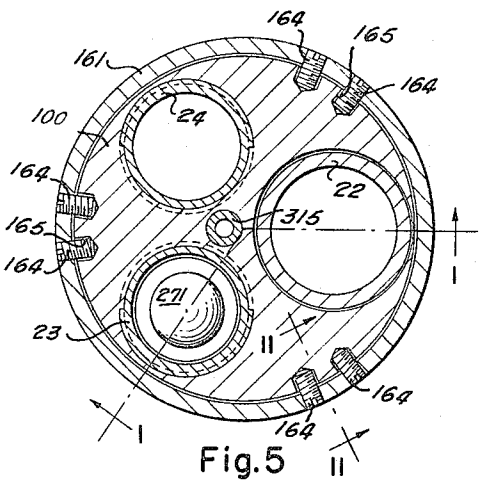


Fig. 5

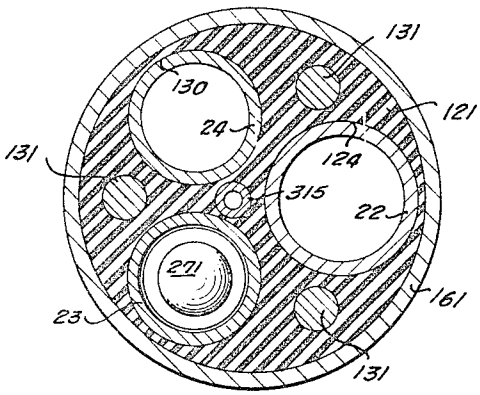


Fig. 6

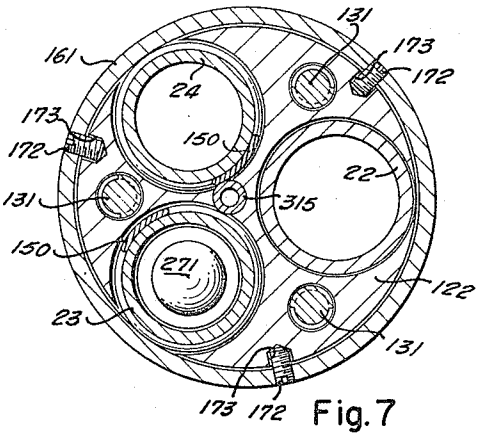


Fig. 7

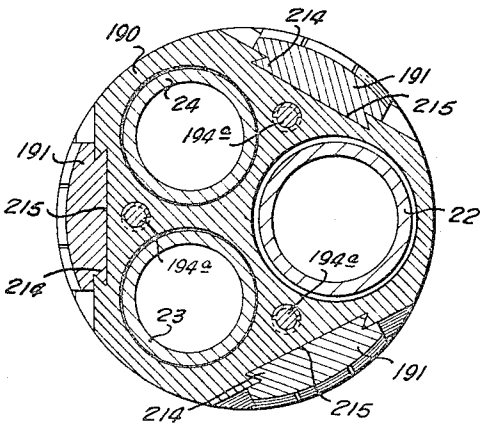


Fig. 9

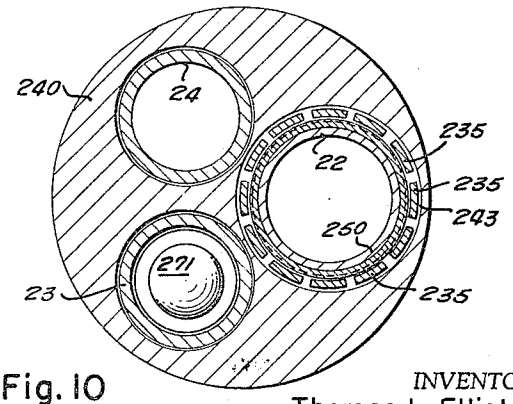


Fig. 10

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WELL TOOLS

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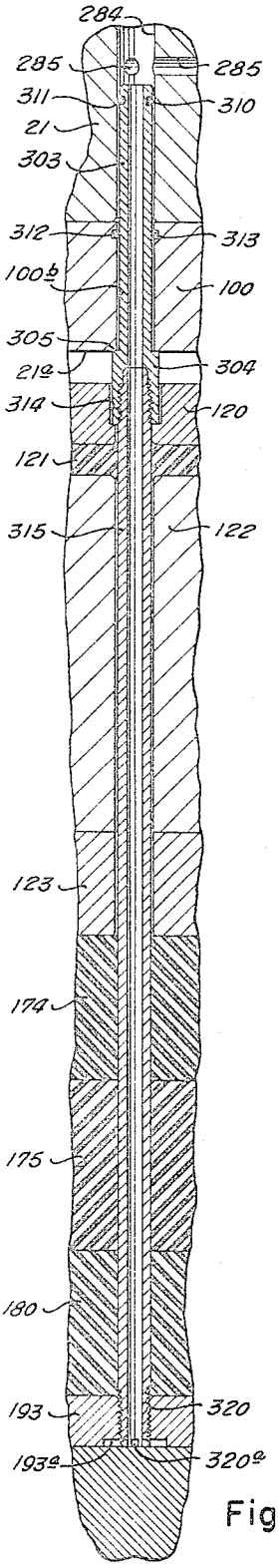


Fig. 8

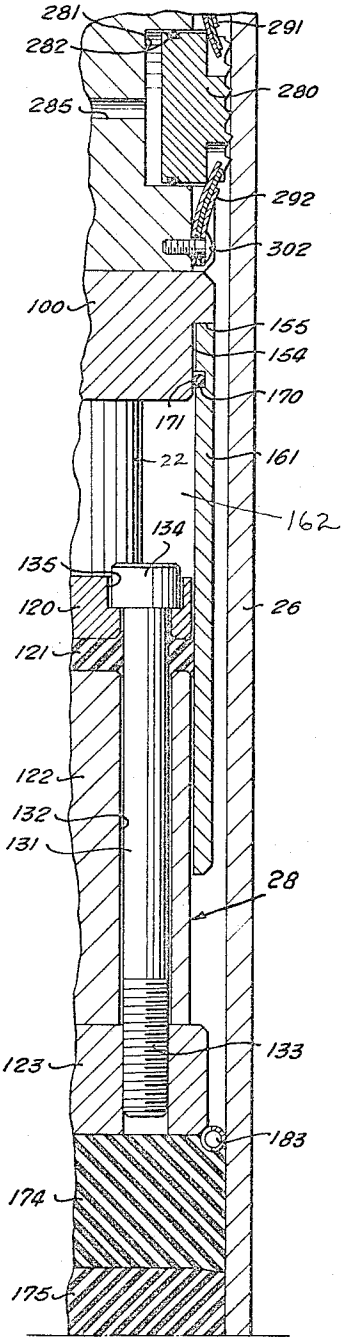


Fig. II-A

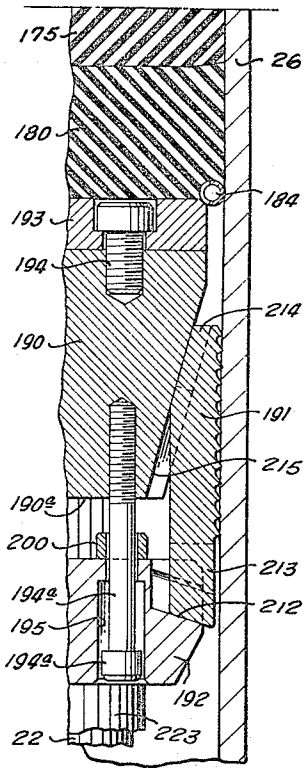


Fig. II-B

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United States Patent Office

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3,381,752

WELL TOOLS

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Filed Dec. 6, 1965, Ser. No. 511,697
11 Claims. (Cl. 166—120)

ABSTRACT OF THE DISCLOSURE

A multiple string hydraulic-set well packer having means for locking the same in anchored sealing position and means for releasing it from such position for removal from the well.

This invention relates to well tools and more particularly to plural tubing string packers.

One object of this invention is to provide a well packer.

Another object of the invention is to provide a well packer for use in well installations having a plurality of tubing strings.

A particularly important object of the invention is to provide a production packer for use with three tubing strings which can be set within a well casing or bore by means of hydraulic pressure without requiring movement of any of the three tubing strings relative to each other or to the packer.

Another object of the invention is to provide a triple string production packer for use in a well casing which permits circulation of fluids therepast after the well head and surface connections have been installed.

A further object is to provide a triple string production packer which can be moved into sealing engagement with a well casing and locked in such position after the well head and the surface connections have been installed.

Another object of the invention is to provide a triple string production packer having a flexible element which may be expanded by hydraulic pressure into sealing engagement with a casing and held locked in such position after the actuating hydraulic pressure is removed.

A further object is to provide a triple string production packer which may be hydraulically set and locked in sealing position within a well casing after the well head and surface connections have been installed and will withstand large pressure differentials in either longitudinal direction of the casing.

A still further object is to provide a packer for use with triple strings of tubing in a well casing which is responsive to fluid pressure in one of the tubing strings to lock the packer in sealing position within the well casing and which may be unlocked from the sealing position and readily removed from the casing by manipulation of another of the tubing strings.

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:

FIGURES 1A through 1C taken together constitute a longitudinal view in section along the line 1—1 of FIGURE 5 of a triple string packer embodying the invention;

FIGURE 2 is a fragmentary view in elevation showing a hold-down button unit of the packer utilized for restraining the packer against upward movement in a well casing;

FIGURE 3 is a fragmentary view in elevation of the packer illustrating a slip for supporting the packer against downward movement in a well casing;

FIGURE 4 is a sectional view taken along the line 4—4 of FIGURE 1A;

FIGURE 5 is sectional view taken along the line 5—5 of FIGURE 1A;

FIGURE 6 is a sectional view taken along the line 6—6 of FIGURE 1B;

FIGURE 7 is a sectional view taken along the line 7—7 of FIGURE 1B;

FIGURE 8 is a fragmentary longitudinal view in section taken along the line 8—8 of FIGURE 4 illustrating the means providing a flow passage from below the sealing assembly into the upper mandrel for applying pressure to the hold-down buttons;

FIGURE 9 is a view in section taken along the line 9—9 of FIGURE 1B;

FIGURE 10 is a view in section taken along the line 10—10 of FIGURE 1C; and

FIGURES 11A and 11B taken together constitute a fragmentary longitudinal view in section along the line 11—11 of FIGURE 5 showing a central portion of the packer with its sealing and slip assemblies expanded into sealing relationship with a well casing.

The invention thus has to do with a multiple string hydraulic set packer having hydraulic fluid pressure operating means for setting the anchoring means and the packing of the packer, and having means releasably locking the anchoring means and sealing means in locked sealing position. Hydraulic fluid pressure for actuating the anchoring and sealing means to anchoring and sealing position is supplied through one of the tubing strings, while another of the tubing strings is utilized to mechanically release the anchoring means and sealing means from anchored sealing position for removal of the packer from the well bore.

Referring to the drawings, a well tool or packer 20 embodying the invention includes an upper mandrel or head section 21, three lower mandrels 22, 23, and 24, supported from the upper mandrel and a slip assembly 25 for locking the packer against downward movement in a well casing 26. The packer also includes a laterally expansible sealing assembly 27 and a fluid actuated piston assembly 28 for expanding both the slip sealing assemblies. A plurality of hold-down button units 32 are mounted on the upper mandrel for lateral expansion into engagement with the inside wall of the casing responsive to a pressure differential across the seal assembly from below the packer to hold the packer against upward displacement relative to the well casing by the force of the pressure from below the packer.

The upper mandrel 21 is provided with a longitudinal bore 33 having internally threaded upper and lower end sections 34 and 35 respectively. The lower mandrel 22 is threaded along an upper end section 40 into the lower end section 35 of the upper mandrel. An internal downwardly facing annular shoulder 41 is provided in the upper mandrel around the bore 33 to engage the upper end of the lower mandrel 22 limiting its movement into the upper mandrel. Below the shoulder 41 an internal

annular recess 42 is formed in the upper mandrel around the bore 33 to receive a ring seal 43 for sealing around the lower mandrel 22 above its threaded section 40 within the bore 33. The bore 33 is enlarged below the threaded upper end section 34 to provide an internal annular upwardly facing shoulder 44 around the bore for engaging the lower end of a section of tubing, such as the tubing 45, to limit the downward movement of the tubing into the upper mandrel.

The upper mandrel is also provided with two longitudinal parallel bores 50 and 51 which are spaced apart from each other and from the bore 33 so that the three bores in the upper mandrel generally form a triangular configuration. As shown in FIGURE 1A the bore 50 is enlarged along an intermediate section 52 providing an upwardly facing internal annular shoulder 53 around the bore and is further enlarged upon an upper end section 54 providing an internal annular upwardly facing shoulder 55 around the bore.

A lower end section of a tubing string 60 extending between the surface and the packer 20 is received in the sections 52 and 54 of the bore 50 to provide fluid communication with the bore 50 and the lower mandrel 23. The tubing string 60 is reduced in diameter along a section 61 providing an external annular recess and a downwardly facing external annular shoulder 62 defining the upper end of the recess. An external annular packing 63 is received in the recess 61 where it is held against upward movement by the shoulder 62 and retained in the recess against downward movement by an upper end 64 of a retainer 65 threaded on the tubing string 60 below the packing. The retainer 65 is reduced in diameter along a lower end section 66 which is received within the section 52 of the bore 50. A downwardly and outwardly facing external annular shoulder 67 is provided on the retainer engaging the upwardly and inwardly facing shoulder 53 within the upper mandrel 21 to support the tubing string 60 against downward movement in the upper mandrel. The tubing string 60 is therefore insertable into and removable from the upper mandrel by longitudinal movement only without rotation of the tubing string in either direction.

The bore 50 is enlarged along a lower end section 70 providing a downwardly opening internal annular recess the upper end of which is defined by an internal annular shoulder 71. The enlarged bore section 70 receives in sliding relationship a short upper end section of the lower mandrel 23 when the packer is in its running-in operating condition as shown in FIGURES 1A–1C. An internal annular recess 72 is formed in the upper mandrel around the enlarged section 70 of the bore 50 to receive a ring seal 73 to seal within the upper mandrel around the lower mandrel 23. The lower mandrel 23 slides out of the enlarged bore section during the releasing of the packer as explained hereinafter.

The configuration of the upper mandrel around the bore 51, not shown, is the same as illustrated and described above with respect to the bore 50 to provide for the connection of a tubing string 80 and the lower mandrel 24 with the upper mandrel into the bore 51. The tubing 80 has an annular packing, not shown, held in the same manner as the packing 63 on the tubing 60 so that the tubing is slidably inserted into and removed from the bore 51 of the upper mandrel.

An upper end surface 81 of the upper mandrel 21 is flared upwardly and outwardly from the bores 33, 50, and 51, substantially as illustrated at page 3653 of the Composite Catalog of Oil Field Equipment and Service, 1964–65 edition, published by World Oil, Houston, Tex. The surface 81 aids in guiding the lower ends of the tubing strings into the bores of the upper mandrel.

As shown in FIGURES 1A and 5, a cylinder head 100 is connected around the lower mandrels 22, 23, and 24 below and engageable with the upper mandrel. The cylinder head has a bore 101 having a diameter providing a sliding fit around the lower mandrel 22. An internal annular recess 102 is formed in the cylinder head around the bore 101 for a ring seal 103 which seals around the lower mandrel 22 in the cylinder head. The cylinder head is additionally provided with a bore 104 extending in parallel spaced apart relationship with the bore 101 to receive the lower mandrel 23. The cylinder head is internally threaded along a major section 105 of the bore 104 extending from the lower end thereof for the threaded engagement of the lower mandrel 23. The bore 104 is reduced in diameter along an upper end section 110 providing a downwardly facing internal annular shoulder 111 above the threaded section 105 for engagement of an external annular shoulder 112 around the lower mandrel 23 limiting the extent to which the lower mandrel is threaded through the cylinder head. A ring seal 113 is positioned in an internal annular recess 114 formed in the cylinder head around the bore 104 to seal around the lower mandrel 23.

The cylinder head 100 is also provided with a longitudinal bore 115 extending parallel to and in spaced apart relationship from the bores 101 and 104 to receive the lower mandrel 24. The configuration of the cylinder head around the bore 115 and the provision of a ring seal, not shown, is the same as illustrated and described above with respect to the bore 104 for securing the lower mandrel 24 through the cylinder head so that it extends into the bore 51 of the upper mandrel.

The piston assembly 28 is slidably supported around the lower mandrels 22, 23, and 24 in spaced apart relationship below the cylinder head 100. The piston assembly includes a head section 120, a resilient seal section 121, a central section 122, and a bottom section 123. The piston assembly is provided with three longitudinal, parallel, spaced apart bores 124, 125, and 130 to receive the lower mandrels 22, 23, and 24, respectively.

As shown in FIGURES 11A and 6, the components of the piston assembly are secured together by three bolts 131 each positioned through a bore 132 in parallel spaced apart relationship circumferentially spaced around the piston assembly at 120 degree intervals between the bores 124, 125, and 130 through the assembly as illustrated in FIGURE 6. The bottom member 123 is internally threaded around each of the bores 132 to receive a threaded lower end section 133 of the bolts 131. Each bolt 131 has a head 134 which is partially countersunk into an enlarged upper end section 135 of its bore 132. Each of the heads 134 of the bolts extends above the upper end 120*a* of the head section 120 of the piston assembly.

The bore 124 through the piston assembly 28 is enlarged providing an internal annular recess 140 extending between an upper internal downwardly facing annular shoulder 141 in the section 122 to a lower upwardly facing internal annular shoulder 142 in the bottom section 123. A split ring 143 positioned within an external annular recess 144 formed in the lower mandrel 22 is engageable at an upper position with the shoulder 141 and at a lower position with the shoulder 142 limiting the longitudinal movement of the lower mandrel relative to the piston assembly.

The bore 125 through the piston assembly is enlarged along a lower end section of the central section 122 providing an internal annular recess 145 having an upper end surface 146 for a coil spring 150 positioned around the lower mandrel 23. The portion of the bore 125 extending through the bottom section 123 of the piston assembly comprises a frusto conical surface 151 which supports a plurality of tapered slip segments 152 circumferentially spaced around the mandrel 23. Each of the slips has internal upwardly facing teeth 153 which are engageable with the outer surface of the lower mandrel. The spring 150 is confined between the shoulder surface 146 and the upper ends of the slips 152 biasing them downwardly along the surface 151 against the outer surface of the

lower mandrel. The piston assembly may move downwardly relative to the mandrel 23 since the upwardly facing teeth 153 of the segments permit downward movement of the segments relative to the mandrel. The piston assembly is held against upward movement relative to the lower mandrel by the teeth of the segments and the engagement of the outer surfaces of the segments with the frusto-conical surface 151 which cams the slips inwardly with a greater force when an upward force is exerted on the bottom section 123. The bore 130 through the piston assembly around the lower mandrel 24 is similarly provided with an internal annular spring recess containing a spring around the mandrel 24, a frusto-conical surface, and a plurality of circumferentially spaced tapered slip segments identical to those illustrated and described above in the bore 125 for similarly allowing downward movement of the piston assembly along the lower mandrel and holding the piston assembly against upward movement relative to the lower mandrel.

The cylinder head 100 is reduced in outside diameter along a lower section 154 providing an external annular downwardly facing shoulder 155. The bottom section 123 of the piston assembly 28 is larger in outside diameter than the other components of the assembly providing an upwardly facing external annular shoulder 160. A sleeve 161 is positioned around the cylinder head and the piston assembly between the shoulders 155 and 160. At the retracted position in which the packer is lowered into the casing, the upper and lower shoulders 155 and 160 are engaged with the upper and lower ends, respectively, of the sleeve 161. Movement of the piston assembly 23 toward the cylinder head 100 is limited by the sleeve 161 thereby providing a chamber 162 within the sleeve around the lower mandrels between the upper end 120*a* of the piston assembly and the lower end 100*a* of the cylinder head to receive fluid under pressure for forcing the piston assembly downwardly away from the cylinder head to set the slip assembly 25 and expand the sealing assembly 27. Fluid communication into the chamber 162 is provided from within the lower mandrel 23 through one or more ports 163 in the mandrel.

As shown in FIGURE 5 the sleeve 161 is secured to the cylinder head 100 by a plurality of screws 164 each of which is threaded through the sleeve into a smooth walled blind bore 165 in the cylinder head thereby coupling the sleeve to the head. Below the screws 164 the sleeve 161 has an internal annular recess 170 for a ring seal 171 to seal within the sleeve around the reduced lower section 154 of the cylinder head 100.

As shown in FIGURE 7, the sleeve 161 is coupled with the central section 122 of the piston assembly 28 by three shear screws 172 circumferentially spaced apart at 120 degree intervals around the sleeve and threaded through the sleeve into a blind hole 173 in the central section. The shear screws are initially installed to retain the piston assembly at its upper end position until pressure is applied in the chamber 162 for severing the shear screws and setting the packer.

The sealing assembly 27 includes three expansible sealing elements 174, 175, and 180 slidably mounted in end-to-end array on the lower mandrels below the piston assembly. The sealing assembly is provided with longitudinally extending parallel spaced bores 181, 182, and a third bore, not shown, for receiving the lower mandrels 22, 23, and 24, respectively. An upper annular spring 183 and a lower annular spring 184 are molded into the upper and lower elements 174 and 180 respectively at the ends thereof to resist extrusion of the sealing element material when the sealing assembly is compressed and laterally expanded. The sealing elements are each a resilient expansible material such as rubber with the center element 175 being somewhat softer than the end elements. The center element performs the principal sealing function with a surrounding surface, such as a casing wall, while the end elements prevent extrusion of the center element.

Referring to FIGURES 1C, 3 and 11B, the slip assembly 25 includes a slip expander 190, a plurality of slips 191, and a slip carrier 192. The slip expander is connected at its upper end with a sealing element retainer 193 by a plurality of bolts 194 which are countersunk in the element retainer and threaded into the slip expander at circumferentially spaced locations around the retainer and slip expander between the lower mandrels 22, 23, and 24. The slip carrier 192 is movably supported from the slip expander by three bolts 194*a* which are circumferentially spaced around the expander between the lower mandrels as illustrated in FIGURE 10. Each of the bolts 194 is slidably received in countersunk relationship in a bore 195 in the slip carrier and threaded along its upper end section into the slip expander. The slidable relationship of the bolts and the slip carrier permits relative movement of the slip expander and slip carrier toward and away from each other. A spacer ring 200 is loosely fitted on each of the bolts 194 between the expander and carrier. The slip expander and slip carrier may move toward each other until the upper face of the spacer 200 engage the lower end of the expander. The expander end carrier may move apart until the heads of the bolts 194 are fully countersunk in the bores 195 of the carrier.

The sealing element retainer 193 is provided with two bores 201 and 202 and a third bore, not shown, to slidably receive the lower mandrels 22, 23, and 24, respectively. The slip expander 190 is similarly provided with three longitudinal, parallel, spaced bores 203, 204, and 205 to slidably receive the lower mandrels 22, 23, and 24, respectively. The diameter of the bore 203 is sufficiently larger than the outside diameter of the lower mandrel 22 that a split ring 210 in an external annular locking ring recess 211 around the lower mandrel may slide into the slip expander to engage the lower face 193*a* of the sealing element retainer 193 so that the retainer and slip expander are lifted by the split ring when releasing the packer from a well casing.

The slip carrier 192 is provided with upwardly opening T-slots 212 circumferentially spaced at 120 degree intervals and each receiving a T-handle 213 forming a lower end section of each of the slips 191. Each slip 191 has an internal longitudinally extending dovetail section 214 received in a mating dovetail slot 215 which is inclined downwardly and inwardly along the slip expander 190. Each slot 215 cooperates with a correspondingly positioned T-slot 212 so that each slip is supported by the slip carrier and is slidably coupled to the slip expander. Thus, relative motion of the slip expander and slip carrier toward each other effects lateral expansion of the slips for engagement with the inside wall of the well casing 30 while movement of the slip expander and carrier away from each other effects lateral retraction of the slips away from the casing.

The slip carrier 192 has a bore 220 having an upper section 221 which is large enough to permit the passage therethrough of the lower mandrel 22 with the split ring 210 attached. The split ring 210 is engageable with an upper end 222 of a collet member 223 which is positioned over the mandrel 22 and threaded along an upper end section 223*a* into a lower enlarged end section 224 of the bore 220 through the slip carrier. Engagement of the lock ring 210 with the upper end 222 of the collet member limits the downward movement of the lower mandrel 22 relative to the slip carrier. The slip carrier is also provided with a bore 224 for the lower mandrel 23 and another bore, not shown, for the lower mandrel 24. The collet member, including a central tubular section 230, has a bore 231 enlarged along a major section 232 below an internal shoulder 234 so that the central section is spaced apart around the lower mandrel 22. A plurality of collet fingers 235 are formed on and extend from the lower end of the tubular section of the collet member.

A circular releasing member 240 positioned around the lower mandrels is releasably held against longitudinal movement on the mandrel 22 by the collet fingers 235. The releasing member has a bore 241 for receiving the

lower mandrel 22 and the collet member. The member 240 is provided with an internal annular locking recess 242 around the bore 241 to receive an outer boss 243 on each of the collet fingers 235. The releasing member also has spaced parallel bores 244 and 245 to receive the lower mandrels 23 and 24, respectively. A split ring 246 is engaged around both of the lower mandrels 23 and 24 above the member 240 to hold it against upward movement on the mandrels. A split ring 250 is positioned around the lower mandrel 22 in an external annular recess 251. In the relative positions of the releasing member 240 and the lower mandrel 22 illustrated in FIGURE 1C, the split ring 250 holds the collet fingers 235 at a normal position at which the collet bosses 243 are in the locking recess 242 preventing relative movement between the collet member, the releasing member 240, and the lower mandrl 22. A lock ring 252 is releasably secured on the lower mandrel 22 by a plurality of circumferentially spaced shear screws 253 each of which is threaded through the lock ring into a blind hole or recess 254 in the lower mandrel 22. The upper end 255 of the lock ring 252 is engageable with the lower ends of the collet fingers 235 holding the lower mandrel 22 against upward movement relative to the releasing member 240 and the collet fingers so long as the shear screws 253 remain intact.

A coupling 256 is threaded on the lower mandrel 22 for connecting a tubing string, not shown, to the mandrel.

An adapter 260 is threaded on the lower end of the lower mandrel 23. A ring seal 261 in an internal annular recess 262 of the adapter seals around a lower end section of the lower mandrel. A ball seat member 263 is releasably secured within the adapter by a plurality of circumferentially spaced shear screws 264. A ring seal 265 seals around the seat member in the adapter. The ball seat member has a bore 266 surrounded by an upwardly facing annular seat surface 270 to receive a ball plug 271 for closing the bore to prevent flow from the mandrel 23 when the fluid pressure is being raised within the lower mandrel to set the packer, as explained hereinafter.

The hold-down units 32 are actuated responsive to pressure from below the sealing assembly 27 which biases a plurality of circular slips or hold-down buttons 280 radially outwardly to engage a well casing for restraining the packer against upward movement responsive to the force of pressure below the packer. Each of the hold-down buttons is positioned within a circular recess 281 formed in the upper mandrel 21 of the packer. The hold-down buttons are arranged in vertically aligned pairs circumferentially spaced around the upper mandrel at 120 degree intervals. A ring seal 282 fitted in an external annular recess 283 around the edge of each of the hold-down buttons seals around each button within its respective recess 281. A central longitudinally extending flow passage 284 in the upper mandrel is connected with radially extending flow passages 285 which open through the back face of each of the recesses 281 behind the hold-down button positioned in the recess for applying fluid pressure within each recess behind its hold-down button. Each pair of hold-down buttons is yieldably restrained in their recesses by upper, lower, and middle spring retainers 290, 291 and 292 positioned respectively, in upper, lower and middle recess sections 293, 294 and 295 respectively, which are formed in the upper mandrel opening through its outer surface and extending longitudinally to communicate with or intersect the recesses 281. The retainers 290, 291, and 292 are secured to the upper mandrel by the screws 300, 301 and 302, respectively.

The longitudinal flow passage 284, as seen in FIGURE 8, constitutes a blind bore opening through the lower end of the upper mandrel 21. The flow passage 284 slidably receives an upper tube 303 extending through a bore 100*b* in the cylinder head 100 and having an enlarged lower end section 304 providing an upwardly facing external annular shoulder 305 which engages the lower face 100*a* of the cylinder head. A ring seal 310 is positioned in an external annular recess 311 around the tube 303 to seal between the tube and the wall of the bore 284. The cylinder head 100 is provided with an internal annular recess 312 to receive a ring seal 313 for sealing around the tube 303 within the bore 100*a* of the cylinder head. A lower portion of the lower end section 304 of the tube 303 is received in an enlarged bore section 314 of the head member 120 of the pinton assembly. A tube 315 threaded at its upper end into the lower end section 304 of the tube 303 extends centrally downwardly through the components of the piston and sealing assemblies and is threaded into the retainer 193 along its lower end section 320.

The tube 315 has a plurality of laterally extending lower end slots 320*a* which communicate its bore with a downwardly opening generally circular recess 193*a* in the retainer 193. As seen in FIGURE 1B the recess 193*a* overlaps the upper end of the bore 203 in the slip expander 190 so fluid pressure from below the retainer around the mandrels is applied from the bore 203 through the recess 193*a* and the slots 320*a* into the tube 315 to expose the hold-down buttons to the casing annulus pressure below the packer.

The casing annulus pressure is applied from the tube 315 into the recesses 281 behind the hold down buttons. The tube 303 is slidable in the bores 284 and 100*b* whereby the tube may move longitudinally with the piston assembly to provide fluid communication into the bore 384 after the piston has moved downwardly relative to the upper mandrel to set the packer.

The packer 20 is set within the well casing 30 by supporting and lowering it on the tubing string 45 to the desired depth within the well casing. Preferably the tubing strings 60 and 80 are inserted into the bores 50 and 51 of the upper mandrel at the surface when the packer is being prepared for lowering into a well bore. The packer is connected with the tubing string 45 by threading the lower end of the tubing string into the threaded section 34 of the upper mandrel until its lower end engages the shoulder 44. By connecting all three tubing strings with the packer at the surface the three strings are run ino a well as the packer is lowered with the weight of the packer being supported from the string 45.

While the packer is being lowered into a well bore on the tubing string 45, it remains in a telescopically closed position as illustrated in the FIGURES 1A–1C. The lock ring 252 is held against longitudinal movement on the lower mandrel 22 by the shear screws 253. Downward movement of the collet member 223 is opposed by the lock ring 252 engaging the lower ends of the collet fingers 235 so that the collet fingers are held around the split ring 250 which retains the collet fingers at an outward position within the locking recess 242 of the member 240. The bosses 243 on the collet fingers thus hold the member 240 against longitudinal movement either upwardly or downwardly relative to the lower mandrel 22 and the collet member 223. The split rings 246 on the lower mandrels 23 and 24 engage the upper face of the member 240 to hold the lower mandrels against downward movement. Thus, weight imposed on the mandrels 23 and 24 is transferred through the split rings 246, the member 240, and the collet fingers 235 to the lock ring 252 which is held by the shear screws 253 on the lower mandrel 22. Since the lower mandrels 23 and 24 cannot move downwardly the cylinder head 100 into which the lower mandrels 23 and 24 are threaded is held at the upper end position against the lower end of the upper mandrel 21. The sleeve 161 is held against downward movement relative to the cylinder head by the screws 164. The piston assembly 28 is releasably secured to the sleeve 161 by the shear screws 172 holding the piston assembly against downward movement relative to the sleeve. The tube 315, as shown in FIGURE 8, is supported from the tube 304 which is received in the enlarged bore section 314 of the head section of the piston assembly thus preventing downward

movement of the tube 315 relative to the piston assembly. The element retainer 193 is threaded to the lower end of the tube 315 so that the retainer is thus held against downward movement. The connection of the slip expander 190 to the retainer 193 by the bolts 194 prevents the slip expander from moving downwardly within the slips. Thus, as the packer is lowered the seal assembly 27 remains contracted and the slip expander 190 is held in spaced apart relationship from the slip carrier 192 so that the slips 191 remain in a retracted position.

After the packer is at the desired depth in a well bore with the three tubing strings connected into it, fluids may be circulated in either direction around the packer through the well bore as desired to prepare the well for completion in accordance with standard practices. Since at this stage in the procedure of setting the packer the slip and sealing assemblies 27 and 28, respectively are still in the retracted position, drilling fluid may be displaced from the tubing after the surface well head equipment has been installed.

The packer is set in the casing 26 by engagement of the slips 191 with the inside wall of the casing and the lateral expansion of the sealing assembly 28 to seal within the casing around the packer. With the packer supported at the proper depth the locking and sealing steps are effected by fluid pressure applied through the tubing string 60 and the bore 50 of the upper mandrel into the lower mandrel 23. The lower mandrel is plugged at its lower end by the ball 271 which is inserted into the tubing string 60 at the surface and pumped downwardly through the tubing string, the upper mandrel, and the lower mandrel to the annular seat 270 of the member 263. When the ball is seated preventing flow from the lower mandrel 23 through the bore 265 of the seat member, the fluid pressure rises within the mandrel and through the ports 163 into the cylinder chamber 162.

The fluid pressure within the chamber 162 exerts an upward force on the lower face 100*a* of the cylinder head 100 and a downward force on the upper face 120*a* of the head section 120 of the piston assembly 28. The force against head holds it at an upper end position against the lower end of the upper mandrel 21. The force on the head action of the piston assembly urges it in a downward direction away from the cylinder head. Since the sleeve 161 and the piston assembly are coupled together by the shear screws 172 the piston assembly is movable downwardly only after the shear screws have been severed. The pressure within the chamber is raised until the force on the piston assembly exceeds the force necessary to shear the screws 172 and the piston assembly is released to move downwardly relative to the sleeve 161.

The piston assembly is forced downwardly relative to the sleeve 161 and the lower mandrels 22, 23 and 24. The lower mandrel 22 is held against downward movement since it is threaded into the upper mandrel which is supported at the desired depth by the tubing string 45. The lower mandrels 23 and 24 are against downward movement by the cylinder head 100 which is held against the lower end of the upper mandrel 21 by the force of the pressure within the chamber 162. The lower end of the bottom section 123 of the piston assembly is engaged with the upper end of the sealing assembly 27 whereby downward movement of the piston assembly causes the sealing assembly to slide downwardly on the mandrels. The sealing assembly components, while being expansible for serving a sealing function around the packer, are rigid enough that they will transmit downward force until the slip assembly 25 is engaged with the inside wall of the casing. The downward force applied to the upper end of the sealing assembly by the piston assembly is transmitted through the sealing assembly components to the upper end of the retainer member 193 forcing the slip expander 190 in a downward direction. As the slip expander moves downwardly the slips are held against downward movement by the slip carrier 192 which is rigidly secured on the releasing member 223 whose collet fingers 235 are held against downward movement by the engagement of their lower ends with the upper end of the lock ring 252. The lock ring is held against downward movement by the lower mandrel which is rigidly secured to the upper mandrel 21. The slips thus remain stationary as the slip expander moves downwardly within or behind them so that the downwardly and inwardly sloping surfaces defining the dovetail slots 215 effect lateral expansion of the slips into locking engagement with the inside wall of the well casing. The downward movement of the slip expander relative to the slip carrier is limited by the engagement of the lower end 190*a* of the slip expander with the upper faces of the spacer rings 200. As the slip expander moves downwardly, the bolts 194 slide downwardly relative to the slip carrier with the heads 194*a* of the bolts remaining countersunk but moving downwardly within the bores 195 of the slip carrier. The slips generally firmly engage the inside wall of the well casing prior to any contract between the slip expander and the spacer rings so that sufficient tolerance or safety factor is provided to allow further slip expansion responsive to additional forces on the packer.

When the slips are engaged with the well casing, as described above, the wedging of the slip expander within the slips holds the slip expander against additional downward movement preventing the lower end of the sealing assembly 27 from moving farther downwardly on the lower mandrels. Application of pressure within the chamber 162 is continued causing the piston assembly 28 to continue its downward movement relative to the lower mandrels forcing the upper end of the sealing assembly downwardly toward its lower end which is being held against downward movement. The sealing element is compressed and laterally expanded into fluid tight relationship with the inside wall of the well casing. The piston assembly is forced downwardly by the pressure in the chamber 162 until a predetermined compressive stress is established in the sealing assembly components, depending, of course, upon the pressure differential against which the sealing assembly is to function.

During the downward movement of the piston assembly relative to the lower mandrel while setting the slips and expanding the sealing element the slip segments 152 slide along the surfaces of the lower mandrels 23 and 24. As the member 123 of the piston assembly moves downwardly, the friction between the outside surfaces of the lower mandrels 23 and 24 and the toothed surfaces 153 of the slip segments biases the slip segments upwardly and outwardly against the springs 150 away from the mandrel surface along the frusto conical surfaces 151. The slip segments remain sufficiently disengaged from the lower mandrels to allow free downward movement of the piston assembly over the mandrels.

When the sealing assembly 27 is stressed to the desired degree, the pressure being applied into the chamber 162 is relaxed by reducing the pressure from the surface into the tubing string 60 subsequent to which the energy stored in the components of the sealing assembly tends to longitudinally expand the assembly biasing the member 123 of the piston assembly upwardly. Since the slip segments 152 are being held downwardly along their frusto conical surfaces 151 against the lower mandrels 23 and 24 by the springs 150, any upward movement of the member 123 causes the outside surfaces of the lower mandrels and the tapered surfaces 151 locking the member 123 and thus the piston assembly against upward movement on the mandrels 23 and 24. The piston assembly is held at a lower locked position maintaining the slips 191 in locking engagement with the side wall of the well casing and holding the seal assembly 27 in sealing relationship with the inside wall of the casing as illustrated in FIGURES 11A and 11B.

The downward movement of the piston assembly relative to the lower mandrel 22 displaces the bottom sec-

tion 123 and thus the shoulder 142 downwardly from the split ring 143 and moves the shoulder 141 closer to the split ring. Also, the retainer 193 moves downwardly toward the split ring 210 on the lower mandrel 22 since the slip expander 190 moves downwardly relative to the slip carrier during the setting of the slips 191. To set the slips the shoulder 141 within the head section 122 moves downwardly toward the split ring 143 substantially the same distance as the slip expander moves toward the slip carrier, the only difference in the distance being due to the compression in the sealing element 27 during the setting of the slips. The piston assembly then continues downward movement to expand the sealing assembly 27 and the internal shoulder 141 within the member 122 of the piston assembly moves downwardly after the slips 191 have been set and thus at its final position after expansion of the sealing assembly the shoulder 141 is closer to the split ring 143 than the distance between the lower end of the retainer 193 and the split ring 210. In releasing the packer, as explained hereinafter, the sealing element will therefore be permitted to relax prior to disengagement of the slips 191 from the inside wall of the casing.

The piston assembly is held at a lower end position by the slip segments 152 engaging the lower mandrels 23 and 24 and the lower mandrels are held against upward movement by the contact between the cylinder head 100 and the lower end of the upper mandrel 21. The packer thus remains locked within the well casing with the slips 191 holding it against downward movement relative to the casing. The slips 191 are tightly engaged with the inside wall of the casing while the slip expander is biased downwardly into wedging relationship within the slips by a downward force on the upper end of the retainer 193 by the lower end of the sealing element assembly resulting from the expanding force within the compressed sealing assembly.

Fluid pressure with the well casing below the sealing assembly 27 tending to lift the packer is transmitted upwardly through the bore 203 into the recess 193*a* and through the slots 320*a* into the tube 315. The pressure is applied through the tubes 315 and 303 into the longitudinal flow passage 284 in the upper mandrel. The fluid pressure is then applied through the radially extending flow passages 285 into the recesses 281 behind the hold-down buttons 280. The force of the pressure behind the hold-down buttons moves the buttons radially outwardly until the outer toothed surfaces of the buttons engage the inside wall of the well casing to hold the packer against upward movement within the casing responsive to fluid pressure below the packer.

When the fluid pressure differential across the packer from below drops below a predetermined value the pressure as applied from below the packer into the recesses 281 behind the hold-down buttons becomes insufficient to hold the buttons at their outward position at which time the spring sections 290, 291 and 292 retract the buttons away from the inside wall of the well casing into the recesses 281. The buttons remain so retracted until the pressure behind them as applied from below the packer again increases to a sufficient value to again force them outwardly to resist the upward movement of the packer.

The packer is released from the inside wall of the well casing and removed by lifting the tubing string 45. The upper mandrel and the lower mandrel 22 are lifted by the tubing string 45. The lifting force applied to the lower mandrel is transmitted through the shear screws 253 to the lock ring 252 which engages the lower end of the collet fingers 235. The collet fingers are held at their normal position within the locking recess 242 by the split ring 250 secured around the lower mandrel. The upward force applied to the lower ends of the collet fingers by the lock ring 252 is transmitted through the member 223 to the slip carrier 192. The slip carrier resists upward movement because the slips 191 supported by the carrier are in wedged relationship between the slip expander 190 and the inside wall of the well casing. Thus, the upward force applied to the lower mandrel 22 is opposed by the slips 191. When the upward force on the lower mandrel increases to a sufficient value, the screws 253 are sheared releasing the lower mandrel 22 for upward movement relative to the member 223 and the collet fingers 235.

After the shearing of the screws 253, the lifting of the tubing string 45 is continued with the upper mandrel being raised along with the lower mandrel 22 which slides upwardly through the various members around the mandrel including the cylinder head 100 at the upper end of the mandrel through the releasing member 240 near the lower end of the mandrel. The split ring 143 engages the annular shoulder 141 within the central section 122 of the piston assembly 28. Until the shoulder 141 is lifted by the split ring 143, the sealing assembly 27 and the slip assembly 25 remain engaged with the inside wall of the well casing. The upward movement of the lower mandrel to the positions at which the split ring 143 engages the shoulder 141 lifts the split ring 250 from within the collet fingers 235. The split ring 143 engages the shoulder 141 within the piston assembly prior to the engagement of the split ring 210 with the bottom edge 193*b* of the retainer 193, since, as previously explained, the shoulder 141 moved down farther than the lower edge of the retainer 193 in setting the packer so that the shoulder 141 is first to be engaged upon upward movement of the mandrel 22. Since the upper mandrel 21 is not directly connected with but fits in sliding sealed relationship over upper end sections of the mandrels 23 and 24, the upward movement of the upper mandrel while lifting the lower mandrel 22 does not lift the lower mandrels 23 and 24. The lower mandrels thus remain at the positions illustrated in FIGURES 1A–1C with the upper mandrel being lifted above their upper ends until the split ring 143 engages the shoulder 141 within the piston assembly.

When the split ring 143 engages the shoulder 141 within the piston assembly, further lifting of the upper mandrel by the tubing string 45 lifts the piston assembly 28 allowing the sealing assembly 27 to relax and contract from the casing wall and raising both of the lower mandrels 23 and 24. The bottom section 123 of the piston assembly is lifted upwardly from the upper end of the sealing assembly permitting the sealing element assembly to decompress and thus expand longitudinally while retracting laterally away from sealing engagement with the inside wall of the well casing. The upward movement of the lower section 123 with the piston assembly wedges the slip segments 152 between the tapered surfaces 151 and the outer walls of the lower mandrels 23 and 24 so that the mandrels are lifted by the piston assembly. Raising the lower mandrels 23 and 24 lifts the cylinder head 100 as the mandrels are threaded into the head. The sleeve 161 is lifted by the cylinder head. As the lower mandrels 23 and 24 are lifted the upper end of the adapter 260 engages the lower face of the releasing member 240. Raising the member 240 cams the collet fingers 235 inwardly releasing the member for upward movement over and relative to the member 223. The member 240 is thus raised above the collet fingers which are held against upward movement by the slip carrier until the slips are disengaged from the well casing after the sealing assembly is released.

The lifting of the upper mandrel 21 by the tubing string 45 is continued with the lower mandrel 22, the piston assembly, the lower mandrels 23 and 24, the cylinder head 100, and the sleeve 161 being raised. When the split ring 210 reaches the lower end 193*a* of the retainer 193, the split ring engages the retainer lifting it and the slip expander 190 which is secured to the retainer. As the slip retainer moves upwardly relative to the slip carrier 192 friction between the slips 191 and the casing holds the slips at their engaged position as the slip expander moves upwardly relative to the slips. The upward move-

ment of the expander disengages the slips from the inside wall of the well casing. The packer is lifted to the surface by means of the tubing string 45.

The packer is lifted to the surface in a somewhat pulled-apart or telescopically separated condition. The upper mandrel is spaced apart above the upper ends of the lower mandrels 23 and 24. Also, the cylinder head 100 is spaced above the piston assembly the distance moved by the piston assembly in setting the packer while the member 240 is telescoped upwardly over the member 223 above the collet fingers 235.

It will be obvious that while the packer 20 is a triple string packer, a packer embodying the invention may be designed for use with more than three strings of tubing by the use of additional lower mandrels of the type of the mandrels 23 and 24 with corresponding bores being provided in the upper mandrel. The principal limitation on the number of strings for which the packer may be designed resides in the space available in a particular installation.

It will now be seen that a new and improved well packer has been illustrated and described.

It will also be seen that a new and improved well packer for plural string well installations has been illustrated and described.

It will also be seen that a new and novel fluid actuated triple string well packer has been described and illustrated.

It will be further seen that a triple string production packer embodying the invention can be expanded and locked within a well casing or bore by means of hydraulic pressure without longitudinal movement of any of the tubing strings connected with the packer.

It will also be seen that the triple string packer permits circulation of fluids after the well head surface connections have been made before expanding and locking the packer.

It will also be seen that the well packer is locked in sealing relationship within a well bore hydraulically and held in such locked and sealing position subsequent to the removal of the hydraulic pressure.

It will be further seen that the well packer will withstand large pressure differentials in either longitudinal direction of the casing.

It will additionally be seen that the triple string packer is expanded and locked responsive to fluid pressure in one of the tubing strings and is released and removed from a casing by lifting another of the tubing strings.

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.

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

1. A well packer comprising: an upper mandrel having a plurality of longitudinally extending laterally spaced apart flow passages; a plurality of lower mandrels supported from said upper mandrel extending in laterally spaced apart parallel relationship, each of said lower mandrels communicating with one of the longitudinal flow passages through said upper mandrel; anchoring means on said lower mandrels movable between retracted and expanded positions engageable with a surface surrounding said packer to hold the packer against longitudinal movement relative to said surface; sealing means on said lower mandrels movable between contracted and expanded positions for sealing between said lower mandrels and said surrounding surface; fluid pressure actuated operating means for moving said anchoring means and said sealing means to anchored sealing position comprising piston slidably supported on said lower mandrels, a cylinder head slidably supported on said lower mandrels spaced from said piston means, a sleeve secured to said cylinder head extending in slidable sealing relationship around said piston means and providing a chamber within said sleeve between said piston means and said cylinder head for receiving fluid under pressure to move said piston means for moving said anchoring means and sealing means to anchored sealing position; one of said lower mandrels being secured at its upper end fixedly to said upper mandrel, the others of said lower mandrels being supported from said cylinder head and movable with respect to said upper mandrel, said other lower mandrels having means at their upper ends engageable with said upper mandrel in sealing relationship communicating with their respective flow passages in said upper mandrel when said packer is in said anchored sealing position; means for holding the anchoring means and sealing means in anchored sealing positions comprising slip means supported in said piston and cylinder means engageable with at least one of said lower mandrels for holding said piston means against longitudinal movement in one direction and permitting movement of said piston means in another direction relative to said lower mandrels, said slip means permitting said anchoring means and said sealing means to be moved to anchored sealing positions and being engageable with said at least one of said lower mandrels to hold said anchoring and sealing means in said anchored sealing positions; and means for releasing said anchoring means and said sealing means from anchored sealing positions.

2. A multiple string well packer as defined in claim 1 including means for temporarily closing one of said other lower mandrels, said mandrel being provided with port means providing fluid communication from said mandrel above the location of temporarily closing said mandrel into said chamber between said cylinder head and said piston means applying fluid pressure through said mandrel into said chamber to actuate said piston means for expanding said anchoring and said sealing means.

3. A multiple string well packer as defined in claim 2 wherein said piston means includes means for forming a slidable sealing relationship with the inside wall of said sleeve.

4. A multiple string well packer as defined in claim 3 wherein said piston means includes an enlarged bottom section providing an upwardly facing external annular shoulder engageable with the lower end of said sleeve to limit the upward movement of said piston means relative to said sleeve for maintaining the upper end of said piston means spaced apart below the lower end of said cylinder head.

5. A multiple string well packer as defined in claim 4 including a bore in said piston receiving said first lower mandrel having a wall section spaced apart from said first lower mandrel along a major portion of the length of said piston means providing a lower internal annular shoulder and an upper internal annular shoulder within said piston means around said first lower mandrel, and a first snap ring secured around said first lower mandrel and movable with said mandrel within said piston means between said upper and lower shoulders, said snap ring being engageable with said upper shoulder upon upward movement of said first lower mandrel relative to said piston means for lifting said piston means upwardly from said sealing means to release said sealing means from said surrounding surface.

6. A multiple string well packer as defined in claim 5 including a second snap ring secured on said first lower mandrel and engageble with said anchoring means for releasing said anchoring means from said surrounding surface, said first snap ring being engageable with said upper shoulder in said piston means prior to engagement of said second snap ring with said anchoring means whereby said piston means is lifted to release said sealing means prior to release of said anchoring means by said second snap ring.

7. A multiple string well packer as defined in claim 6 including a tubular collet member supported from said anchoring means, means releasable interconnecting said

collet member and said first lower mandrel and releasably operatively interconnecting said collet member with the other lower mandrels whereby said first lower mandrel is releasable from said collet means and then said other mandrels are releasable from said collet means.

8. A multiple string well packer as defined in claim 7 wherein said anchoring means includes a slip expander supported from said piston means and a slip carrier supported on said collet means.

9. A well packer as defined in claim 8 wherein said piston means is secured with said sleeve by means adapted to shear responsive to fluid pressure within said chamber for releasing said piston to expand said sealing means and said anchoring means, a lock ring is secured to said first lower mandrel and engageable with said collet means for holding said lower mandrel against movement toward said collet means, and means is connected between said lock ring and said first lower mandrel adapted to shear responsive to a force on said first lower mandrel toward said collet means for releasing said first lower mandrel to disengage said sealing means and said anchoring means from said surrounding surface.

10. A multiple string well packer as defined in claim 9 including fluid actuated hold-down button units in said upper mandrel operable responsive to fluid pressure below said sealing means of said packer for holding said packer against upward movement and means in said packer providing a fluid flow passage extending from said hold-down button units through said packer to below said sealing means for applying said fluid pressure from below said sealing means into said hold down button units.

11. A triple string well packer comprising: an upper mandrel having three spaced apart longitudinally extending flow passages; a first lower mandrel secured along an upper end section thereof into said upper mandrel in communication with a first of said flow passages; second and third lower mandrels supported in parallel spaced apart relationship relative to said first lower mandrel, said second and third lower mandrels being slidably engageable along upper end sections thereof into second and third flow passages, respectively, through said upper mandrel; a cylinder head supported on said lower mandrels below the lower end of said upper mandrel, said cylinder head being slidable on said first lower mandrel and being secured with and supporting said second and third lower mandrels whereby said mandrels and said cylinder head are movable as a unit; a sleeve supported and extending from said cylinder head downwardly around said lower mandrels; a piston assembly slidably supported on said lower mandrels within said sleeve, said piston assembly including sealing means for sealing around said assembly within said sleeve and a bottom section providing an external upwardly facing annular shoulder engageable with a lower end surface on said sleeve for holding said piston assembly against upward movement relative to said sleeve and providing a spaced-apart relationship between a lower face on said cylinder head and an upper face on said piston assembly forming a chamber within said sleeve between said cylinder head and said piston assembly around said lower mandrels; at least one of said second and third mandrels having a port therethrough into said chamber for supplying fluid under pressure from said mandrel into said chamber for displacing said piston assembly downwardly away from said cylinder head for setting said packer in a well bore; a plurality of slip segments supported wtihin a frusto-conical seat surface of said piston assembly around at least one of said second and third lower mandrels for engaging said mandrel to prevent upward movement of said piston assembly relative to said mandrel for locking said packer in a well bore and to permit downward movement of said piston assembly along said lower mandrels; said first lower mandrel extending through a bore of said piston assembly enlarged along a major portion of the length of said piston assembly providing an upper internal annular shoulder and a lower internal annular shoulder around said first lower mandrel; a split ring secured around said first lower mandrel movable with said lower mandrel within said piston assembly between said upper and lower shoulders for engaging and lifting said assembly in releasing said packer from a well bore; an expansible sealing assembly supported on said mandrels below said piston assembly adapted to be longitudinally compressed to effect lateral expansion for sealing around said mandrels within a surrounding surface; a sealing assembly retainer supported on said lower mandrels below said sealing assembly; a slip expander supported on said lower mandrels below and secured to said sealing assembly retainer, said slip expander having a bore receiving said first lower mandrel and being greater in diameter than said mandrel whereby a lower face of said sealing assembly retainer forms an internal annular shoulder at the upper end of said bore around said first lower mandrel for lifting said slip expanded to release said slips; a plurality of slips secured in longitudinally slidable relationship around said slip expander; a slip carrier supported in spaced-apart relationship from said slip expander on said lower mandrels below and longitudinally movable relative to said slip expander; said slip carrier and said slips being interconnected whereby said slips are laterally movable relative to and longitudinally supported by said slip carrier; said slip carrier being provided with an internal annular upwardly facing shoulder around a bore through said carrier receiving said first lower mandrel; a split ring secured around said first lower mandrel movable with said mandrel between said annular shoulder within said slip carrier and the lower face of said sealing assembly retainer at the upper end of said slip expander for releasing said slips responsive to longitudinal movement of said first lower mandrel; a tubular collet member secured within and extending downwardly from said slip carrier around said first lower mandrel, said collet member having a plurality of circumferentially spaced collet fingers along a lower end section thereof; a releasing member positioned around said lower mandrels, said releasing member having an internal annular locking recess around a bore of said member receiving said first lower mandrel to receive external bosses on said collet fingers for releasably locking said releasing member against longitudinal movement relative to said collet member; a split ring secured around said first lower mandrel positionable within said collet fingers for holding said collet fingers in said locking recess of said releasing member; a locking ring on said first lower mandrel below said collet fingers for engaging said collet fingers to hold said lower mandrel against upward movement relative to said collet member; shearable means connected between said locking ring and said first lower mandrel; means connected on each of said second and third mandrels below said releasing member for holding said mandrels against upward movement relative to said releasing member; a split ring on each of said second and third lower mandrels above said releasing member for holding said mandrels against downward movement relative to said releasing member; means releasably secured within said lower mandrel having a port leading to said chamber between said piston assembly and said cylinder head for temporarily closing said mandrel against fluid flow therethrough below said port; means connecting said piston assembly with said sealing assembly retainer; hold-down means supported by said upper mandrel for restraining said packer against upward movement responsive to pressure from below said packer, said means being actuatable by pressure below said sealing assembly; means providing fluid communication between said hold-down means through said packer to below said sealing assembly for applying fluid pressure from below said assembly into said hold-down means; and shearable means connectable between said piston assembly and said sleeve around said piston assembly for holding said piston assembly against downward movement relative to said

sleeve until a predetermined fluid pressure is applied into said chamber above said piston assembly for releasing said piston assembly from said sleeve to expand said sealing assembly and set said slips on said slip expander.

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