

July 7, 1970

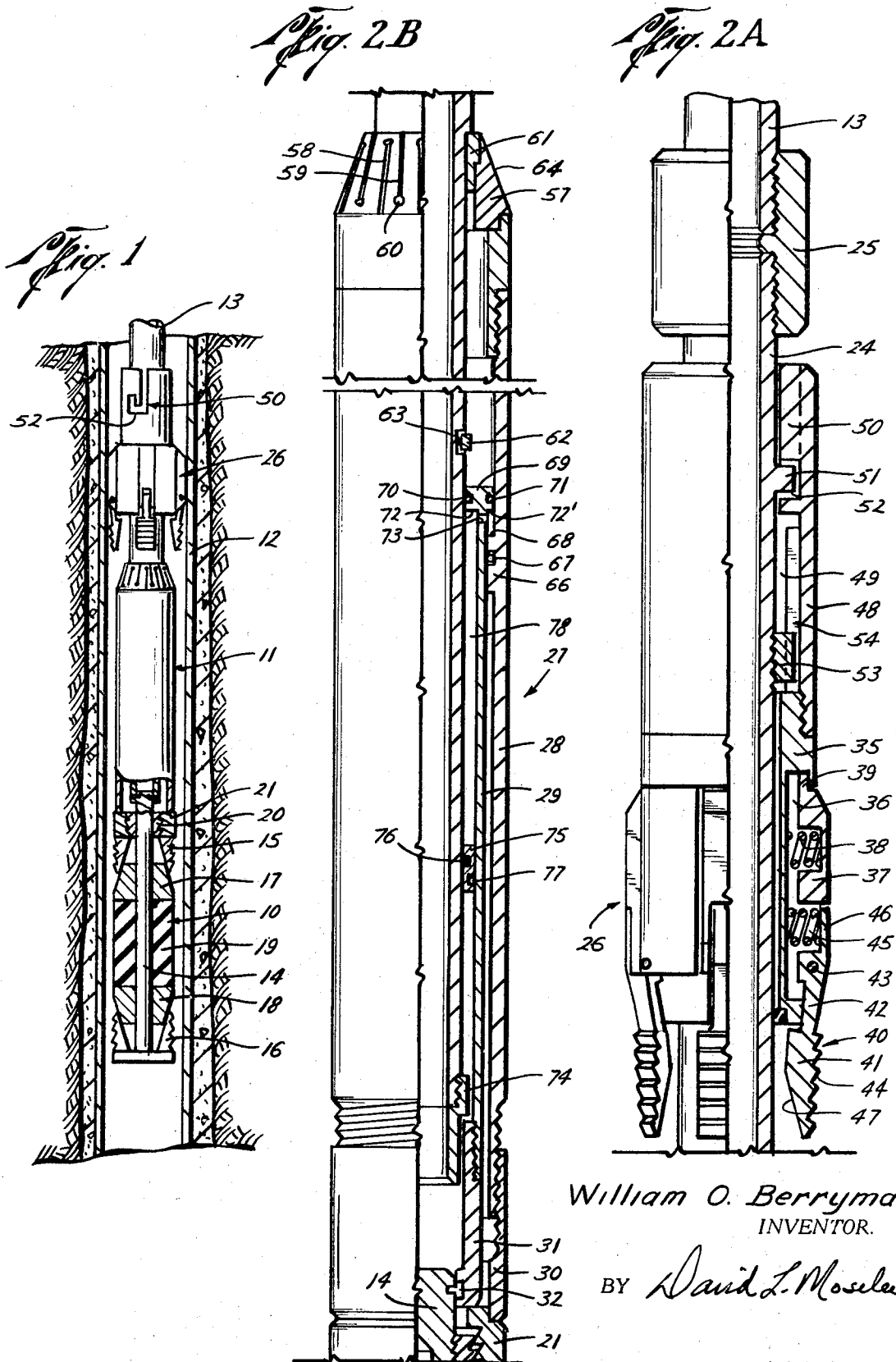
W. O. BERRYMAN

3,519,074

SETTING TOOL APPARATUS

Filed Oct. 28, 1968

2 Sheets-Sheet 1



William O. Berryman
INVENTOR.

BY *David L. Mosley*

ATTORNEY

July 7, 1970

W. O. BERRYMAN

3,519,074

SETTING TOOL APPARATUS

Filed Oct. 28, 1968

2 Sheets-Sheet 2

Fig. 3B

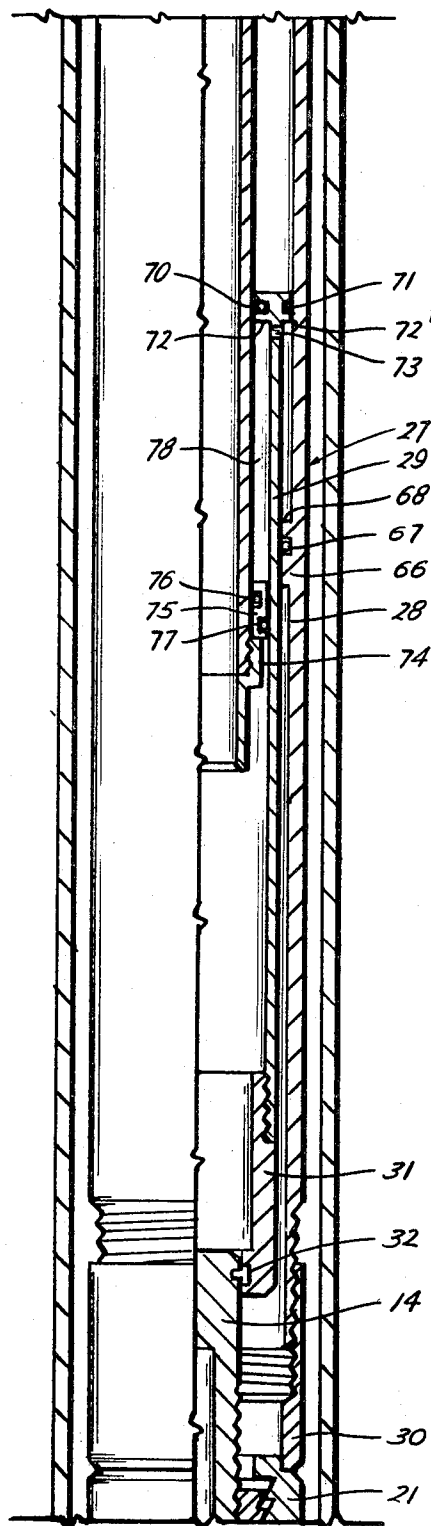
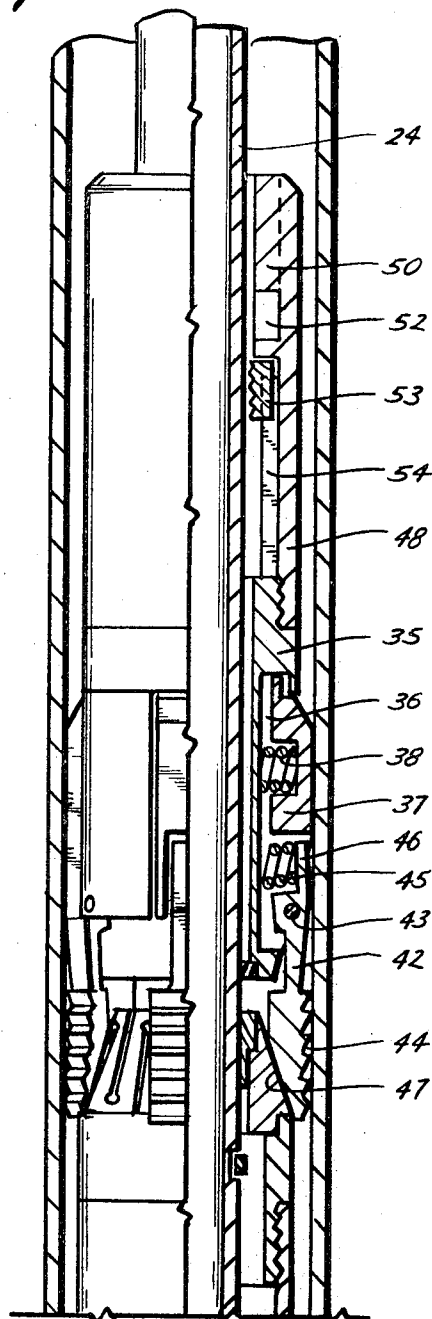


Fig. 3A



William O. Berryman
INVENTOR.

BY *David L. Mosley*

ATTORNEY

1

3,519,074

SETTING TOOL APPARATUS

William O. Berryman, Houston, Tex., assignor to Schlumberger Technology Corporation, New York, N.Y., a corporation of Texas

Filed Oct. 28, 1968, Ser. No. 771,076

Int. Cl. E21b 23/06

U.S. Cl. 166—123

8 Claims

ABSTRACT OF THE DISCLOSURE

A setting tool apparatus for use in setting well tools in well bores includes inner and outer members movable in opposite directions relative to one another for applying oppositely directed forces to the well tool. The outer member can be selectively and releasably anchored against upward movement, and has an upwardly facing pressure surface. The inner member has a downwardly facing pressure surface, said pressure surfaces forming movable walls of a fluid-filled hydraulic chamber. An operator member connected to the lower end of a pipe string can be manipulated to effect anchoring of the outer member and then moved upwardly by the pipe string into engagement with a piston ring, whereupon upward strain on the pipe string and piston ring will generate a fluid pressure in the chamber which acts on the pressure surfaces of the members to cause relative movement in opposite directions, thereby setting the well tool. The area of the pressure surface on said inner member is larger than the area of said piston ring, whereby the upward force on said inner member tending to cause relative movement is a multiple of the upward strain on the pipe string. When the well tool is set, the setting tool is automatically released from the well tool, and the anchoring of the outer member is released without any further manipulation of the pipe string.

This invention relates generally to well tools used in well bores, and more specifically to mechanical setting tools operable by manipulation of a pipe string for setting well tools such as packers, plugs and retainers in a well conduit.

The aforementioned well tools which can be lowered into a well conduit on a pipe string and then set by manipulation of the pipe string to pack off the well bore, generally include a mandrel which carries upper and lower normally retracted slips and a packing element arranged to be expanded into contact with the well conduit wall. Expansion of the slips and packing element can be effected by the application of oppositely directed forces, usually a downward force on the upper slip together with an upward force on the mandrel. In response to such forces, the slips are shifted outwardly by cooperatively arranged expander cones, and the packing element is compressed and expanded into sealing engagement with the well conduit.

The application of such oppositely directed forces may be accomplished through use of a mechanical setting tool which is coupled between the well tool and the pipe string. A typical mechanical setting tool includes an inner member having its lower end connected to the packer mandrel by a shear stud or the like, and its upper end

2

connected to the pipe string, and an outer member which is coupled in force transmitting relationship with the upper slips. By appropriate manipulation of the pipe string, the upper slip can be shifted into gripping contact with the conduit, after which an upward strain on the pipe string at the earth's surface will effect expansion of the lower slip and packing element.

In the past, mechanical setting tools have not been usable at very great depths because the total upward strain which can be applied to the pipe string at the surface to operate the setting tool and set the packer is limited by the tensile strength of the pipe string. The deeper the setting depth, the greater the weight of pipe in the well, so that a lesser amount of strain, over and above the weight of the pipe string, can be applied at the surface to operate the setting tool. However, in recent times, wells are being drilled deeper and deeper below the earth's surface requiring setting of packers corresponding greater depths. Thus, the foregoing limitations in using conventional mechanical setting tools are becoming more critical.

A general object of the present invention is to provide a new and improved setting tool for packers or the like, which is constructed and arranged for setting a well tool on a pipe string, and which incorporates a structure for releasably anchoring the outer member in the well bore, and a hydraulic force multiplying means enabling a reduction in the total strain applied to the pipe string at the surface to produce an adequate setting force to the tools. Although the present invention may be used at any depth in a well bore, it has a particular utility in setting tools at great depths below the surface.

With this and other objects in view, apparatus in accordance with the concepts of the present invention includes an operating member coupled to the pipe string and carrying an anchoring assembly and a hydraulically operable setting assembly. The setting assembly includes telescopically arranged inner and outer members coupled in force transmitting relationship to relatively movable parts of a well tool. The anchoring assembly includes slip and expander means for anchoring the outer member against upward movement in the well conduit, and the setting assembly further includes piston means on said members having transverse pressure surfaces providing moving walls of a fluid-filled hydraulic chamber. A pressure generating means can be activated by upward movement of said operating member and generates a fluid pressure in said chamber which acts on said surfaces as longitudinal force in opposite directions. The transverse area of said piston means is greater than the transverse area of said generating means, so that the upward force on said inner member is a multiple of the force applied to said generating means by the pipe string. Accordingly, a lesser total strain can be applied to the pipe string at the top of the well bore to obtain the required setting force for the well tool, which enables setting of well tools at greater depths without exceeding the strength of the pipe string. The anchor assembly is arranged to be automatically released after the well tool is set, to enable withdrawal of the setting tool from the well bore without further manipulation of the pipe string.

The present invention has other concepts and advantages which will become more apparent in connection

3

with the following detailed description of an exemplary embodiment. Such embodiment is shown in the accompanying drawings in which:

FIG. 1 is a somewhat schematic view of a well packer and setting tool disposed in a well bore on a pipe string; FIGS. 2A and 2B are longitudinal sectional views, with portions in side elevation, of the setting tool of the present invention with parts in their relative positions before setting of the well packer, FIG. 2B forming a lower continuation of FIG. 2A; and

FIGS. 3A and 3B are views similar to FIGS. 2A and 2B, but with parts in their relative positions after the well tool has been set in the well bore.

Referring initially to FIG. 1, a schematic representation of a well tool 10 such as a packer, plug or retainer, is coupled to a mechanical setting tool 11, which incorporates the principles of the present invention, and is suspended in a well casing 12 on a pipe string 13 of tubing or drill pipe. The well tool 10 includes a central mandrel 14 carrying normally retracted upper and lower slips 15 and 16 which can be shifted outwardly by upper and lower companion expander cones 17 and 18. A packing element 19 is disposed between the expander cones and is arranged to be expanded outwardly when subjected to longitudinal compression force. A conventional body lock ring 20 is cooperable within a setting head 21 to grip the mandrel 14 and trap the slips 15 and 18 and the packing element 19 in expanded positions.

Turning now to FIGS. 2A and 2B for details of the setting tool apparatus 11, a tubular operating member 24 is coupled at its upper end to the pipe string 13 by a collar 25, and extends substantially throughout the length of the setting tool. An anchor assembly 26 is mounted on an upper portion of the operating member 24, and a hydraulically operable setting assembly 27 is mounted around a lower portion of the operating member. The setting assembly 27 is constituted by an outer tubular member 28 and an inner tubular member 29 which are telescopically disposed for relative movement in opposite longitudinal directions relative to one another. The lower end portion of the outer member 28 can be formed by a threadedly attached setting sleeve 30 which abuts against an upper surface of the setting head 21. The lower end portion of the inner member can be formed by a threadedly attached adapter sleeve 31 which extends over the upper end portion of the mandrel 14 and which is releasably coupled thereto by a conventional shear ring 32. Thus, the inner member 29 is coupled to the mandrel 14 for transmitting upward force thereto until the shear value of the ring 32 is reached, at which point the ring can shear and release the inner member 29 from the well tool 10. Although the use of an annular shear ring as shown enables a full-opening bore through the setting tool, it will be equally appreciated that a conventional tension stud could be used to connect the inner member 29 to the mandrel 14.

The anchoring assembly 26 includes a tubular cage 35 slidably received on the operating member 24. The cage 35 has a plurality of circumferentially spaced, longitudinally extending recesses 36, each of which receives a drag block 37. Coil springs 38 are positioned between each drag block 37 and the cage 35 and function to urge the blocks radially outwardly into frictional engagement with a well casing. Each drag block 37 also has end portions or flanges 39 (only one end shown) to limit outward movement of the blocks relative to the cage 35.

Operatively associated with each drag block 37 is a slip element 40 which has a head 41 and a stem 42. To accommodate a respective slip element, each drag block can have a slot in which a stem is received. Pins 43 pivotally connect respective stems of each slip 40 to the drag blocks 37. Each slip head 41 has external wickers or teeth 44 which are formed to face upwardly, and an inner surface 47 which inclines inwardly and upwardly relative to the operating member 24. Springs 45 are inserted into each

4

recess 36 to urge tangs 46 on the end of each stem 42 outwardly, thereby pivoting the slip head 41 inwardly toward the operating member 24 when the various parts of the setting tool 11 are in relative positions for longitudinal movement in a well bore as shown in FIGS. 2A and 2B.

A control sleeve 48 is threadedly attached to the upper end of the cage 35 and has an internal splined recess 49 and an upwardly opening J-slot 50. During lowering into a well bore, relative longitudinal movement between the various members is prevented by engagement of a lug 51 within the closed segment 52 (FIG. 1) of the J-slot 50. As a further control over relative longitudinal movement, a stop nut 53 threadedly engages the operating member 24 and is corotatively secured to the sleeve 48 by splines 54. After the lug 51 is released from the J-slot 50 by appropriate manipulation, the operating member 24 can be reciprocated upwardly until the stop nut 53 engages the top of the recess 49, at which point the operating member 24 must be rotated by the pipe string 13 to the right to unthread the nut and enable further upward movement of the operating member.

A slip expander cone 57 is mounted on the upper end of the outer member 28 and is initially spaced downwardly below the slip elements 40. The expander cone 57 is radially expansible and contractible due to the provision of slots 58 and 59 extending alternately from one end of the cone to points 60 adjacent opposite ends thereof. The expander cone 57 is supported in expanded condition by an annular support ring 61 which can have stepped outer surfaces engageable with companion inner surfaces of the expander cone 57. Removal of the support ring 61 from underneath the expander cone 57 will enable the cone to contract inwardly toward the operating member 24. The support ring can be removed by upward movement of the operating member 24 relative to the expander cone 57, whereupon a release ring 62 engaging in a groove 63 can abut the support ring and shift it out from underneath the cone 57. The expander cone 57, when expanded as shown in FIG. 2B, has outer inclined surfaces 64 cooperable with the inner surfaces 47 on the slip elements 40 for shifting the slip elements outwardly into gripping contact with a well casing, thereby anchoring the outer member 28 against upward movement in the casing.

The outer member 28 has a shouldered piston section 66 extending inwardly toward the inner member 29 and sealed against the outer periphery of the inner member by a seal ring 67. The shoulder configuration of the piston section 66 provides an upwardly facing transverse pressure surface 68. The upper end of the inner member 29 is formed by an annular piston head 69 which is sealed against the inner periphery of the outer member by a seal ring 70, and against the outer periphery of the operating member 24 by a seal ring 71. The piston head 69 has downwardly facing pressure surfaces 72 and 72' which are communicated via a radial port 73, the pressure surfaces on the piston head 69 and the outer member being disposed so as to face one another. The operating member is telescopically disposed within the inner member 29 and has an annular shoulder 74 formed near its lower end. An annular, floating piston ring 75 is disposed between the operating member 24 and the inner member 29, and suitable seal rings 76 and 77 prevent fluid leakage past the ring 75. The annular spaces between the inner member 29 and the operating member 24, and between the inner and outer members, provides a chamber 78 which is filled with a suitable hydraulic fluid. As shown in FIG. 2B, the piston ring 75 is initially spaced upwardly from the shoulder 74 a distance to permit the operating member 24 to be moved upwardly to the extent necessary to unthread the stop nut 53 before the shoulder 74 picks up the piston ring 75.

In operation, the parts assembled as shown in FIGS. 2A and 2B are coupled to the well tool 10 to be lowered and set in the well bore. During lowering, the lug 51 on

the operating member 24 is positioned within the closed segment 52 of the J-slot 50, and the drag blocks 37 engage the casing wall and are pushed downwardly in the casing by the weight of the pipe string 13. At setting depth, the assembly is halted, the pipe string 13 is torqued a part turn to the left and then lifted to disengage the lug 52 from the J-slot 50, and then the pipe string is rotated several turns to the right to unthread the stop nut 53 from the operating member 24, the drag blocks 37 preventing rotation of the cage 35 and the stop nut. After the stop nut 53 is disengaged, the operating member 24 is free to be moved upwardly by the pipe string relative to the anchor assembly 26 and the setting assembly 27.

Elevation of the pipe string 13 at the top of the well bore will raise the setting assembly 27 relative to the anchor assembly 26 until the expander cone 57 engages the slip elements 40 and shifts them outwardly into contact with the casing as shown in FIG. 3A. Now the outer member 28 cannot move any further upwardly, nor can the setting head 21 on the well tool 10. Continued upward movement of the pipe string 13 will cause the shoulder 74 to pick up the piston ring 75. Due to the fact that the outer member 28 cannot move upwardly, upward force on the piston ring 75 generates a fluid pressure in the chamber 78 which acts upwardly on the lower surfaces 72 and 72' of the piston head 69, and downwardly on the surface 68 of the outer member 28. The respective upward and downward forces developed on the members 29 and 28 causes lifting of the mandrel 14 relative to the setting head 21 sufficiently to set the upper slips 15 against the well casing wall and then expansion of the packing 19 and setting of the lower slips 16. Of course, the upper and lower slips can be of any conventional design. The body lock 20 traps the mandrel 14 in the highest relative position to which it is moved, thus locking the well tool 10 permanently set in the casing 12.

The upward setting force applied to the mandrel 14 is fully developed in the following manner. As previously described, upward strain on the pipe string 13 will generate a fluid pressure in the chamber 78 which is a function of the upward force and the transverse area of the piston ring 75. This pressure acts upwardly on the downwardly facing transverse surfaces 72 and 72' of the piston head 69, and downward on the upwardly facing transverse surface 68 of the outer member 28. Inasmuch as the downwardly facing surfaces 72 and 72' provide a cumulative area which is considerably larger than the transverse area of the piston ring 75, the upward force on the inner member 29 is considerably greater than the upward force being applied to the pipe string 13 at the surface. As an illustrative example, the area of the piston ring 75 may be one square inch, while the sum of the areas of the surfaces 72 and 72' may be two square inches. Therefore, an upward pull on the operating member 24 of 20,000 lbs. will develop 20,000 p.s.i. fluid pressure in the chamber 78 which acts on the inner member 29 as an upward force of 40,000 lbs., which force is applied to the mandrel 14. The area of the surface 68 on the outer member 28 may be, for example, one square inch, so that a downward force of 20,000 lbs. is also developed on the outer member 28, which force is applied to the setting head 21 and the upper slips 15. The anchor assembly 26 will prevent movement of the upper slips 15 until such a time as the upper slips are set against the casing. Thereafter, there is a net result of 40,000 lbs. upward force on the mandrel 14 and a restraining force of 20,000 lbs. exerted by the casing on the upper slips, which, together with the downward force of 20,000 lbs. being exerted by the outer member 28 on the upper slips 15 firmly sets the packing element 19 and the lower slips 16 against the casing. The lock ring 20 will trap the setting load in the tool in a conventional manner, and when a predetermined force is applied to the shear ring 32, it will fail and release the setting tool 11 from the packer 10.

The release ring 62 is spaced on the operating member 24 relative to the anchoring assembly 26 in such a manner that the release ring is closely adjacent, but preferably not engaging, the support ring 61 when the parts are telescoped and the well tool 10 is fully set. Thus, when the shear ring 32 fails, the operating member 24 can move quickly upwardly and cause the release ring 62 to displace the support ring 61 out from underneath the expander cone 57. When this occurs, the expander cone 57 will collapse or contract inwardly and release the slip elements 40 from engagement with the casing. Then the setting tool 11 is free to be withdrawn from the well bore, leaving the well tool 10 permanently set therein.

It will now be apparent that a new and improved setting tool operable by a pipe string to set well tools in well bores has been disclosed. Since certain changes and modifications will occur to those skilled in the art in view of the present disclosure without departing from the concepts of the present invention, it is the aim of the appended claims to cover all such changes and modifications falling within the true spirit and scope of the present invention.

I claim:

1. Apparatus for use in setting well tools in well bores, comprising: inner and outer tubular members telescopically mounted for movement in opposite longitudinal directions relative to one another; means for releasably anchoring said outer member against upward movement; piston means on said members having opposed transverse pressure surfaces and providing movable walls of a fluid-filled hydraulic chamber; pressure generating means including an operating member adapted for connection to a pipe string extending to the top of the well bore, said generating means being movable upwardly relative to said members for generating fluid pressure in said chamber, said pressure acting to force said inner member upwardly relative to said outer member; and means responsive to further upward movement of said pressure generating means for releasing said anchor means to enable withdrawal of said apparatus from the well bore.

2. The apparatus of claim 1 wherein said piston means includes an annular head on said inner member sealingly slidable on said operating member and said outer member, said head having inner and outer surface areas, and port means for communicating said surface areas.

3. The apparatus of claim 1 wherein said pressure generating means includes a piston element having a transverse pressure surface of smaller area than the area of the pressure surface on said inner member.

4. The apparatus of claim 3 wherein said anchoring means includes normally retracted slip means, expansible and contractible expander means adapted, when expanded, to shift said slip means outwardly, and support means behind said expander means for holding said expander means in expanded condition, said support means being adapted to be removed from behind said expander means to enable contraction of said expander means and release of said slip means.

5. The apparatus of claim 4 wherein said releasing means includes an element on said pressure generating means engageable with said support means.

6. Apparatus for use in setting a well tool in a well bore, said well tool having first and second members movable in opposite longitudinal directions during setting, comprising: inner and outer telescopically movable members, said outer member engaging one of said first and second members; means for releasably coupling said inner member to the other of said first and second second members; slip and expander means for releasably anchoring said outer member against upward movement; hydraulic means including opposed transverse pressure surfaces on said inner and outer members forming movable walls of a fluid-filled hydraulic chamber, fluid pressure in said chamber acting on said surfaces to force said inner member up-

7

wardly relative to said outer means; and means adapted for connection to a pipe string extending to the top of the well bore for generating a fluid pressure in said chamber which is a function of an upward force applied to the pipe string at the top of the well bore.

7. The apparatus of claim 6 wherein said generating means includes a transverse pressure surface sized relative to said surfaces of said hydraulic means whereby the upward force on said liner member is greater than the upward force applied to the pipe string at the top of the well bore.

8. The apparatus of claim 7 further including means for releasing said slip and expander means from anchoring positions, said releasing means being operable only after release of said coupling means.

5

10

15

8

References Cited

UNITED STATES PATENTS

1,529,409	3/1925	Condra	166—224
3,024,845	3/1962	Conrad	166—123
3,057,406	10/1962	Patterson et al.	166—123
3,125,162	3/1964	Briggs et al.	166—123
3,294,171	12/1966	Kelley	166—123 X
3,298,437	1/1967	Conrad	166—123 X
3,360,049	12/1967	Kisling	166—123

DAVID H. BROWN, Primary Examiner

U.S. Cl. X.R.

166—217