Sept. 21, 1971 W. O. BERRYMAN 3,606,923

SUBSURFACE WELL APPARATUS

Filed Nov. 22, 1968 2 Sheets-Sheet 1

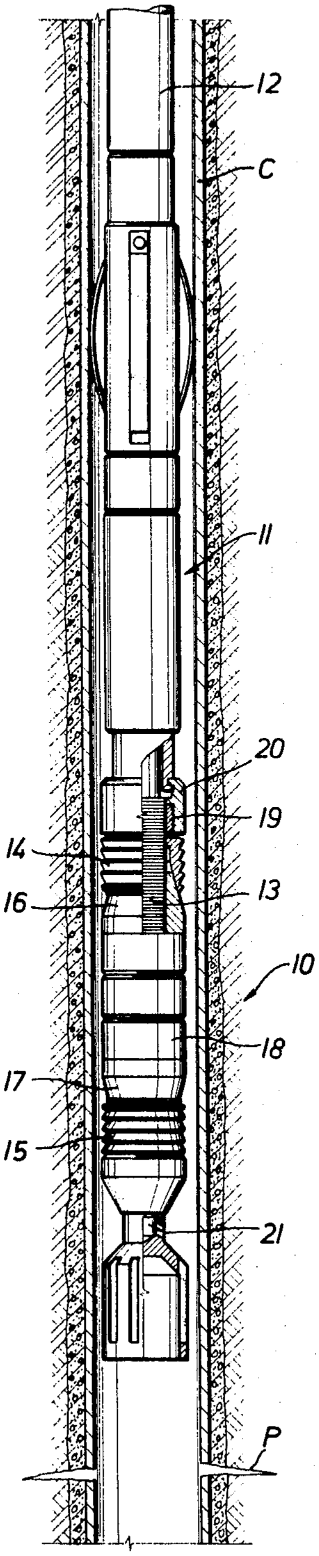

FIG. 1

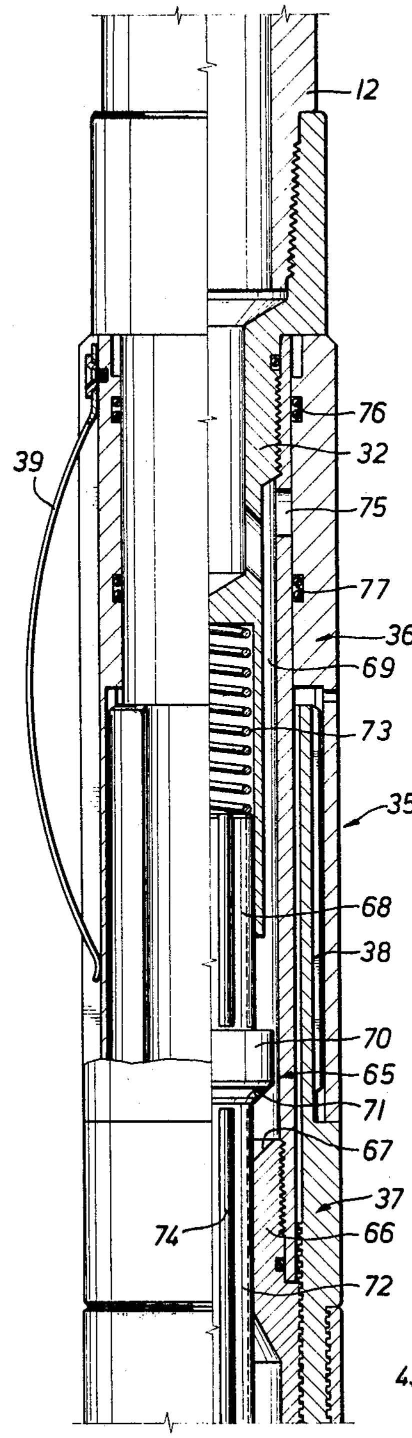

FIG. 2A

FIG. 2B

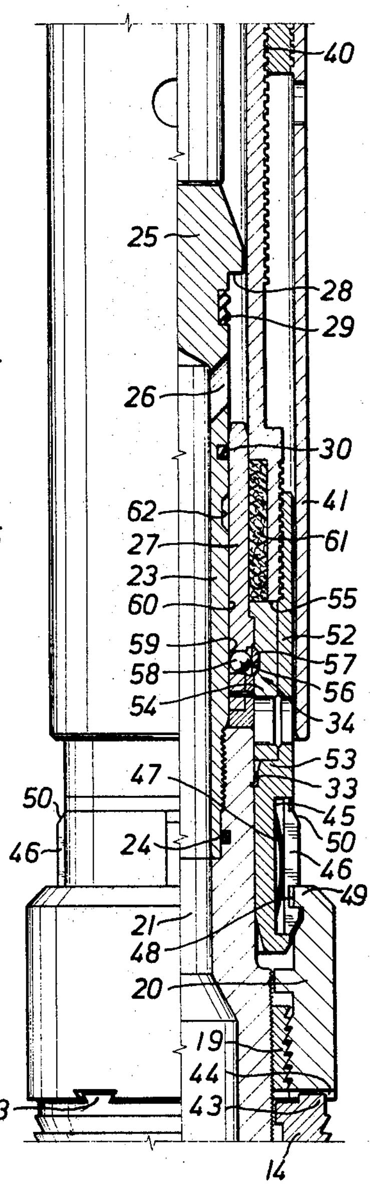

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FIG. 3A

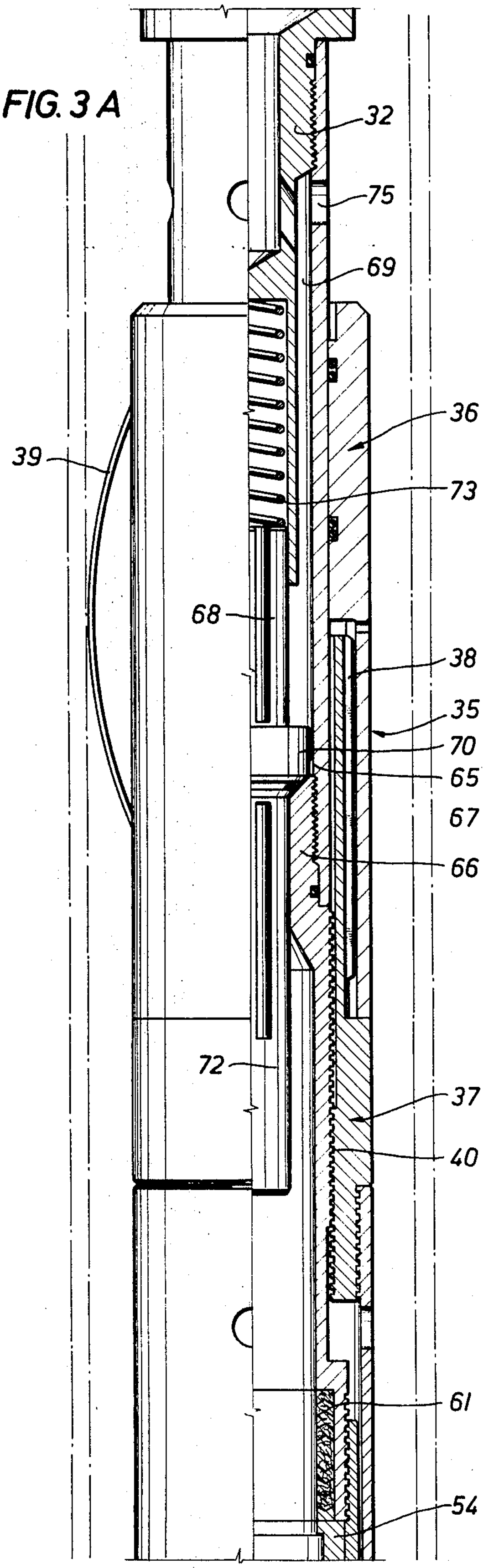
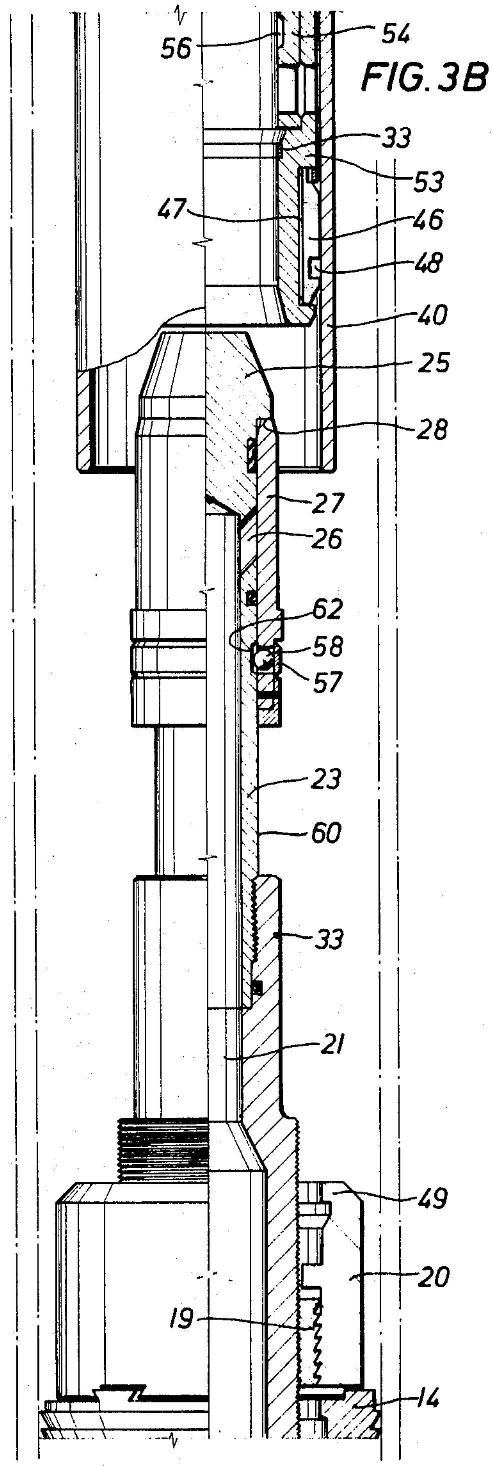


FIG. 3B



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3,606,923
SUBSURFACE WELL APPARATUS

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Int. Cl. E21b *23/06, 33/128*
U.S. Cl. 166—125 **7 Claims**

ABSTRACT OF THE DISCLOSURE

A setting tool apparatus for use in setting well packers in well bores includes inner and outer body structures coupled to the well packer and having means responsive to manipulation of the pipe string for causing relative longitudinal movement to set the well packer, releasable latch means for preventing setting of the packer during lowering into the well bore, and valve means in said inner and outer body structures for enabling testing of the pipe string for leaks at any time after the packer is set and drainage of fluid from the pipe string during withdrawal of the apparatus from the well bore.

This invention relates generally to subsurface well tools, and more particularly to a new and improved mechanical setting tool for setting well packers such as cement retainers in cased well bores.

In order to conduct a pressure operation such as squeeze cementing, fracturing or acidizing in a zone in a well bore, it is common practice to set a permanent retainer packer at the upper end of the zone. Fluid under pressure can be forced through the packer and into regions behind the casing via casing perforations, and the packer is provided with suitable valving to trap the fluid below the packer at developed pressures.

To conduct a pressure operation during only one trip of the pipe string into the well bore, it is necessary to lower the packer together with a setting tool on a pipe string, the setting tool being responsive to manipulation of the pipe string to effect setting of the packer. The setting tool also includes instrumentalities to operate the well packer valve. Prior art setting tools of this type have been sometimes complicated and complex in operation, causing either failures in setting the packer properly or necessitating a complex series of surface manipulations of the pipe string in order to operate the tools. Accordingly, one feature of the present invention relates to the provision of a new and improved setting apparatus for a valved well packer which is reliable and simple in operation and which can be operated by minimum surface manipualtions of the pipe string.

Before conducting a pressure operation in which fluid pressure may reach considerable magnitudes, it may be desirable to apply fluid pressure to the inside of the string to see whether or not any leaks are present. If there are, of course the string should be withdrawn and the leaking joint or pipe section laid down. Once a leak is detected, the precise location thereof may be determined by repeated testing as the entire string is withdrawn from the well. Another feature of the present invention resides in the provision of a new and improved setting tool which incorporates a tester valve which enables repeated leak testing of the pipe string at any time after the packer has been set.

When a pressure operation has been completed and the setting tool and pipe string are being removed from the well bore, it is desirable not to pull a "wet" string of pipe, that is to say, the pipe string should be drained of fluids during removal so as not to unnecessarily remove drilling fluids from the well bore. Moreover, spillage of

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fluids on the rig floor is an inconvenience to the operators and may create a hazard to personnel and equipment. Yet another feature of the present invention resides in the provision of a means to automatically drain the pipe string as it is elevated in the well bore.

With the foregoing features in mind, the present invention may be summarized as an apparatus including a body structure having its upper end adapted for connection to a pipe string and its lower end adapted to be releasably coupled to a well packer having normally retracted means which can be expanded by the application of longitudinal force in opposite directions. Upper and lower relatively movable members are mounted on said body structure, said upper member having friction drag means for resisting movement in a well bore, said lower member being coupled to said body structure by means responsive to relative rotation for causing downward feeding of said lower member along said body structure and corresponding application of oppositely directed force to said normally retracted means. Latch means are provided to positively prevent the application of said longitudinal force during lowering into a well casing, said latch means being released by downward feeding of said lower member.

Apparatus in accordance with the present invention further includes a valve structure including a downwardly closing valve element engageable with a valve seat in said body structure for closing the lower end of the pipe string to enable pressure testing for leaks. Drain ports are provided in the wall of said body structure above said valve seat, said ports being opened and closed by said upper member in response to upward and downward movement of the pipe string to enable selective and repetitive pressure testing for leakage without having to withdraw a fluid-filled pipe string from the well bore.

The present invention has other features and advantages which will become more clearly apparent in connection with the following detailed description, taken in conjunction with the appended drawings in which:

FIG. 1 is a somewhat schematic view of a well packer and setting tool suspended in a cased well bore on a pipe string;

FIGS. 2A and 2B are longitudinal sectional views, with portions in side elevation, of a setting tool apparatus in accordance with the principles of the present invention with parts in their relative positions before the well packer is set; and

FIGS. 3A and 3B are views similar to FIGS. 2A and 2B, but showing the setting tool apparatus after setting the packer and disengaged therefrom.

Referring initially to FIG. 1, the well bore is lined with casing C which is normally cemented in place. Perforations P extend laterally to the wall of the casing C and through the cement to provide fluid communication paths between the well bore and the region behind the casing. In order to force cement, acid or hydraulic fracturing fluids or the like under pressure through the perforations, a well packer **10** and its setting tool **11** are lowered into the well bore on a running-in string of tubing or drill pipe **12** and the packer is set above the perforations. The packer **10** isolates the casing interval adjacent the perforations P from the rest of the well bore and confines the high fluid pressures which are normally developed to the pipe string **12**.

The packer **10**, sometimes called a cement retainer, includes a central mandrel **13** carrying normally retracted upper and lower slips **14** and **15** which can be shifted outwardly by upper and lower companion expander cones **16** and **17**. An elastomeric packing element **18** is disposed between the expander cones **16** and **17** and is arranged to be expanded outwardly when subjected to longitudinal compression force. A conventional ratchet lock ring **19** is cooperable within a setting head **20** to grip the mandrel **13** and trap the slips and packing element in expanded positions. Other conventional elements of a well packer such as shear pins and anti-extrusion rings are not shown but, of course, may be used.

The mandrel **13** has a central bore **21** open to the well bore at its lower end. A tubular member **23** (FIG. 2B) is threaded into the upper end of the mandrel **13** with a seal element **24** fluidly sealing the threaded connection. A blunt nose portion **25** closes the upper end of the tubular member **23**, and a plurality of ports **26** extend laterally through the wall of the tubular member to communicate with its bore. A valve sleeve **27** is slidably received on the tubular member **23** for movement between a lower open position, as shown, and an upper closed position wherein the upper end of the valve sleeve **27** engages a downwardly facing shoulder **28** on the nose portion **25**. In the upper position, the valve sleeve **27** spans the ports **26** and suitable seals **29** and **30** fluidly seal between the valve sleeve and the tubular member above and below the ports. For further constructional details of the retainer packer **10**, reference may be had to U.S. Patent No. 3,387,660, issued June 11, 1968 and assigned to the assignee of the present invention.

The setting tool apparatus **11** in accordance with the principles of the present invention is constituted by an inner body structure **32** having its upper end threadedly coupled to the lower end of the pipe string **12** and its lower end releasably secured to the packer mandrel **13** by an annular shear member **33** which will transmit longitudinal motion and force until its predetermined shear value is reached, whereupon the member will shear and release the inner body structure **32** from the packer **10**. The lower portion of the body structure **32** extends downwardly over the tubular member **23** and valve sleeve **27**, and a latch device **34** is provided to couple the body structure to the valve sleeve so that upward and downward movement occasioned by like movement of the pipe string **12** can move the valve sleeve between its open and closed positions. The setting tool assembly **11** further includes an outer body structure **35** which is constituted by an upper tubular section **36** which is co-rotatively and slidably secured to a lower tubular section **37** by splines **38**. Bowed drag springs **39** are attached in any suitable manner to the upper section **36** and are arranged to frictionally engage the inner wall of the well casing C and resist rotational as well as longitudinal movement in a conventional manner. The lower section **37** is coupled to the inner body structure **32** of the setting tool by jack-screw threads **40** or the like so that rotation of the inner body structure by the pipe string relative to the sections **36** and **37** will cause downward feeding of the lower section **37** along the body structure **32**. The lower section **37** may include threadedly coupled members, the lower member being a setting sleeve **41** which extends downwardly and terminates in spaced relation to the setting head **20** of the packer **10**.

In order to provide an upper slip arrangement which can be set in anchoring condition against the casing C by the application of relatively low setting loads, the upper slips **14** can be of segmented construction, the upper end of each segment being slidably coupled to the setting head **20** by radially extending tongues **43** which engage in mating grooves **44** in the lower end of the setting head **20**. A suitable restraining element (not shown), such as a garter spring or the like, can surround the segments to normally maintain them in retracted positions. The lower end portion of the inner body structure **32** is initially releasably latched to the setting head **20** to prevent longitudinal movement of the setting head relative to the mandrel **13** during lowering into the well bore, thereby preventing any premature setting of the slips **14**. The latch includes a plurality of circumferentially spaced, radially extending recesses **45**, each of which receives a dog element **46**. Each dog element **46** is urged outwardly by a leaf spring **47** or the like and has an external recess **48** which receives an inwardly extending flange portion **49** at the upper end of the setting head **20**. The engaged relationship of the flange **49** within the respective recesses **48** of the dog elements **46** prevents longitudinal movement of the setting head **20** so that the slip elements **14** remain in retracted positions. However, each dog element **46** is provided with an upwardly and inwardly inclined cam surface **50** which can be engaged by the lower end of the setting sleeve **41** to cause inward shifting of the dog elements **46** against the influence of the springs **47** to an extent sufficient to release the setting head flange **49** from the detent recesses **48** in each dog element. When this occurs, the setting head **20** is freed to move downwardly relative to the packer mandrel **13**, so that the slip elements **14** can be shifted outwardly against the casing wall by the upper expander cone **16**.

As previously mentioned, the body structure **32** of the setting tool assembly **11** is also releasably latched to the valve sleeve **27** to that upward and downward movement of the body structure by the pipe string **12** after the packer **10** is set will cause movement of the valve sleeve between its open and closed positions. The body structure **32** includes a threadedly attached collar **52** which has an inwardly extending flange **53** to retain a guide ring **54** against a shoulder **55** on the body structure. The guide ring **54** has a bore which is sized for sliding reception on the valve sleeve **27** and an internal annular recess **56** is formed on the wall of the bore. The recess **56** receives a resilient split latch ring **57** which is radially movable therein between contracted and expanded positions. In the lower or open position of the valve sleeve **27**, a plurality of balls **58** releasbly lock the valve sleeve to the body structure **32** so that the valve sleeve becomes, in effect, an integral part of the body structure in this position. The balls **58** are movably received within radial holes **59** in the lower enlarged portion of the valve sleeve **27**. When the valve sleeve **27** is in its lower or open position, the balls **58** are held outwardly by the outer surface **60** of the tubular member **23** and the balls, in turn, hold the latch ring **57** in an outer position wherein its outer portion engages in the annular recess **56** in the guide ring **54**. With the parts thus latched together and an annular seal packing **61** positioned therebetween, the pressure of fluids being pumped through the ports **26** will act upwardly on a pressure area equal to the internal cross-sectional area of the pipe string **12**. However, the pressure is also acting downwardly on the cross-sectional area of the upper portion of the valve sleeve **27**. Thus, it will be appreciated by those skilled in the art that with this particular arrangement, the effective area on which fluid pressure can act tending to disengage the body structure of the setting tool assembly **11** from the packer mandrel **13**, is the relatively small area encompassed by the seal element **30** between the valve sleeve **27** and the tubular member **23**.

When the valve sleeve **27** is moved to its upper or closed position, the balls **58** are placed adjacent an annular recess **62** in the exterior of the tubular member **23** and are free to move inwardly into the recess **62**. Such inward movement will enable the latch ring **57** to move inwardly and disengage from the recess **56**. When this occurs, the body structure **32** of the setting tool assembly **11** is released from the valve sleeve **27** and can be moved upwardly within the well bore.

The setting tool assembly **11** of the present invention further includes a main valve structure **65** which enables the pipe string **12** to be pressure tested for leaks before conducting a pressure operation in the well bore. To this end, the body structure **32** is provided with an inwardly extending flange **66** having an inclined upper surface providing an annular upwardly facing valve seat **67**. A longitudinally movable valve element **68** cooperates with the seat **67** to open and close the bore **69** through the body structure to fluid flow. The valve element **68** is formed by an elongated rod with an enlarged annular portion 70 intermediate its ends, the annular portion having a seal ring 71 which can sealingly engage the valve seat 67. The lower portion 72 of the valve element 68 is dimensioned lengthwise to engage the nose portion 25 of the tubular member 23 and hold the valve element in an upper open position during lowering into a well bore. However, after the body structure 32 is disengaged from the packer mandrel 13, as will be subsequently described, the valve element 68 can move downwardly and close against the valve seat 67. If desired, a coil spring 73 can be utilized to assist in closing the valve element. When the valve element 68 is in its upper open position, a plurality of longitudinally extending slots 74 are provided in the exterior of the lower portion to enable fluid to flow past the valve seat 67.

When withdrawing the setting tool from the well bore after the packer 10 has been set, it is desirable not to pull a "wet" string, that is to say, a means should be provided to enable fluids in the pipe string 12 to be drained out as it is being withdrawn from the well. In further accordance with the present invention, the body structure 32 is provided with drain ports 75 near its upper end which are normally closed off by spaced seal rings 76 and 77 on the upper section 36 engaging above and below the ports 75. After the packer has been set, the lower section 37 will have been moved downwardly along the body structure 32 so that the resistance afforded by the drag springs 39 to upward movement will force the upper section 36 downwardly along the body structure 32, thereby opening the ports 75 so that fluids in the pipe string 12 can drain into the well bore. Moreover, it will be appreciated that the pipe string 12 can be pressure tested for leaks at any time while coming out of the hole, because the main valve 68 remains closed and the pipe string can be lowered slightly, whereupon the drag springs 39 will hold the upper section 36 stationary in the casing, causing the seals 76 and 77 to again span the drain ports 75. Thus, the lower end of the pipe string 12 can be closed off to permit pressure testing. Inasmuch as the pipe string 12 can be tested at any time while withdrawing it from the well bore, the precise location of a leak in the pipe string can be determined, as will be appreciated by those skilled in the art.

OPERATION

In operation, the various parts can be assembled as shown in the drawings with the inner body structure 32 coupled to the packer mandrel 13 by the shear member 33. The depending portion 72 of the test valve element 68 engages the nose portion 25 of the tubular member 23 in order to space the valve head 70 upwardly from the seat 67. The valve sleeve 27 is in its lower open position so that well bore fluids can enter the pipe string 12 during lowering into the well casing. The latch dogs 46 are coupled to the setting head flange 49 to prevent any downwardly motion of the setting head 20, thereby preventing premature settting of the slips 14. The upper section 36 spans the body ports 75, and the drag springs 39 can slide downwardly along the casing wall as the packer 10 is lowered to setting depth.

In order to set the packer 10, the pipe string 12 is first rotated to the right. Due to the interengagement of the splines 38 on the upper and lower sections 36 and 37, and to the jack-screw threads 40, rotation of the body structure 32 will cause the lower section 37 and the setting sleeve 41 to feed downwardly along the body structure. The lower end of the setting sleeve will first engage the inclined surfaces 50 on the latch dogs 46 and cam them inwardly, thus releasing the setting head 20 for downward movement relative to the mandrel 13. Such downward movement will cause the upper slips 14 to shift outwardly over the upper expander cone 16 until the slip teeth grip the well casing wall. At this point, the mandrel 13 can be drawn upwardly relative to the setting head 20 by applying an upward strain to the pipe string 12 at the surface to effect compression and expansion of the packing element 18, and expansion of the lower slips 15 against the well casing wall. The ratchet lock ring 19 will trap the mandrel 13 in the highest relative position to which it is moved, thereby trapping the slips and packing in permanently expanded and set positions.

When the predetermined shear value of the member 33 is reached, it will fail and release the body structure 32 from the packer mandrel 13. Now, the setting tool assembly 11 can be elevated somewhat and then lowered in order to enable testing of the pipe string 12 for leaks. As the body structure 32 is moved away from the tubular member 23 as shown in FIGS. 3A and 3B, the test valve 68 is permitted to move downwardly to closed position. However, upwardly movement will also effect opening of the drain ports 75 because it will be remembered that during setting of the packer 10, the lower section 37 was fed downwardly away from the upper section 36. Thus, the resistance to movement afforded by the drag springs 39 will enable the upper section 36 to be moved downwardly along the body structure 32, thereby uncovering the ports 75 as shown in FIG. 3A. Accordingly, it is only necessary to lower the pipe string 12 somewhat to reposition the upper section 36 in spanning relation to the ports 75, whereupon the lower end of the pipe string 12 is completely closed off and pressure can be applied to the pipe string to discover the presence or absence of leaks.

Moreover, when the body structure 32 is initially moved upwardly relative to the tubular member 23, the valve sleeve 27 is shifted upwardly to closed position, the latch balls 58 releasing the latch ring 57 from the guide ring 54 as previously described. It should be noted that whenever the body structure 32 is pulled away from tubular member 23, the valve sleeve 27 is always positioned and left in its upper or closed position.

Assuming that no leaks in the pipe string are found, a displacement can be made after raising the pipe string again to open the drain ports 75. Although the test valve 68 is closed, fluid can circulate into the well annulus via the ports 75. When the displacement is completed and it is desired to pump fluid through the packer 10, the pipe string 12 is again lowered. The lower portion of the body structure 32 telescopes over the tubular member 23 and the valve sleeve 27. When the inwardly extending shoulder on the guide ring 54 engages the enlarged section of the valve sleeve 27, the valve sleeve is forced downwardly, moving the latch balls 58 radially outwardly and forcing the latch ring 57 into the recess 56 to couple the valve sleeve to the body structure 32. The flow ports 26 are thus communicated with the pipe string 12 via the bore 69 so that fluids can be pumped under pressure into the well bore below the packer 10. The depending portion 72 of the test valve 68 engages the nose portion 25 to move the test valve upwardly to open position, and again the resistance afforded by the drag springs 39 to longitudinal movement will cause the upper section 36 to move relatively upwardly and span the ports 75 to close them off to fluid flow.

When the pressure operation is completed, the setting tool can be elevated to effect closing of the valve sleeve 27 as previously described. Upward movement also opens the drain ports 75 and fluids in the pipe string 12 can drain out as the pipe string 12 and setting tool 11 are withdrawn from the well. Of course, the open condition of the ports 75 also permits reversing out any fluids which should not remain in the pipe string for any length of time, and a pressure difference between the annulus and the pipe string will force the test valve 68 upwardly so that fluids are admitted into the pipe string through the body structure 32 also.

If a leak was found in the pipe string 12, the location of the leak can be determined by repeated pressure testing as the string is withdrawn from the well. As long as the pipe string is moving upwardly, the drain ports **75** will be open. However, each time a stand of pipe is uncoupled at the surface, the remaining pipe in the well is lowered somewhat during hanging of the pipe in the power slips. Such lowering will effect closing of the drain ports **75** as previously described, so that a flow manifold and conduit can be connected to enable pressurizing the pipe string. When the pipe string holds pressure, of course, it is determined that the leak is located in the extent of pipe pulled since the last test and the joint in the power slips.

It will be apparent that a new and improved setting tool apparatus has been disclosed which is simple and reliable in operation. A tubing tester valve is provided, as well as a drain valve to prevent pulling a wet pipe string, the valves being arranged whereby the pipe string can be leak tested at any time while coming out of the hole. Since certain changes and modifications may be made in the disclosed embodiment by those skilled in the art without departing from the concepts involved, 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 a well bore, comprising: a mandrel; normally retracted means on said mandrel expandable outwardly thereof; a member movable longitudinally of said mandrel for expanding said normally retracted means outwardly; a body structure releasably coupled to said mandrel and adapted for connection to a running-in string extending upwardly to the earth's surface; releasable means including laterally shiftable parts for latching said member to said body structure to prevent longitudinal movement of said member relative to said mandrel; and means responsive to rotation of said body structure by the running-in string for releasing said latching means and enabling longitudinal movement of said member and expansion of said normally retracted means.

2. The apparatus of claim **1** wherein said releasable latching means further includes an inwardly extending flange on said member, said laterally shiftable parts having detent means engageable with said flange, and spring means for yieldably maintaining said detent means and said flange in engaged relationship.

3. The apparatus of claim **2** wherein said releasing means includes a sleeve member having a jack-screw connection to said body structure, and drag means for enabling relative rotation to operate said jack-screw connection and to feed said sleeve member downwardly along said body structure, said sleeve means and laterally shiftable parts having coengageable surfaces cooperable to shift said laterally shiftable parts inwardly against the influence of said spring means to release said detent means from said flange.

4. Apparatus for use in a well bore, comprising: inner and outer tubular structures having means responsive to relative rotation for feeding said outer structure downwardly relative to said inner structure to effect setting of a well packer in a well bore, said inner structure being adapted for connection to a running-in string and having a fluid flow passage therethrough; a valve seat surrounding said flow passage; a valve element in said flow passage movable between an upper position enabling fluid flow through said flow passage and a lower position engaging said seat and preventing downward flow of fluids in said flow passage; and means on said valve element engageable with a part of the well packer for holding said valve element in its upper position, said valve element engaging said seat when said holding means is not engaging said part.

5. The apparatus of claim **4** wherein said holding means is constituted by a depending portion of said valve element extending through said seat, said portion having at least one longitudinally extending groove in its outer periphery for enabling fluid flow between said holding means and said seat.

6. The apparatus of claim **5** further including biasing means pressing between said inner tubular structure and said valve element for assisting downward movement of said valve element toward closed position.

7. In an apparatus for use in setting a well packer in a well bore, said well packer having a mandrel carrying normally retracted slip and packing means movable to expanded positions, a flow passage in said mandrel and a valve sleeve movable upwardly and downwardly for respectively closing and opening said flow passage, the combination comprising: inner and outer tubular structures, said inner structure having its upper end adapted for connection to a running-in string and its lower end releasably coupled to said mandrel; first latch means on said inner structure for shifting said valve sleeve between closed and open position in response to upward and downward movement of the running-in string; second latch means for preventing premature expansion of said slip and packing means; means on said structures responsive to relative rotation for effecting release of said second latch means and then expansion of said slip and packing means; test valve means in said inner structure for closing off the bore of said inner structure after expansion of said slip and packing means to enable testing of the running-in string for leaks; means for holding said test valve means open when said valve sleeve is in its lower position; flow ports in the wall of said inner structure for communicating the bore of said inner structure with the well annulus; and sleeve valve means having drag means engageable with a well conduit wall and movable between a position closing said flow ports during downward movement of the running-in string, and a position opening said flow ports during upward movement of the running-in string.

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U.S. Cl. X.R.

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