

May 5, 1953

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2,637,402

PRESSURE OPERATED WELL APPARATUS

Filed Nov. 27, 1948

4 Sheets-Sheet 1

Fig. 1.

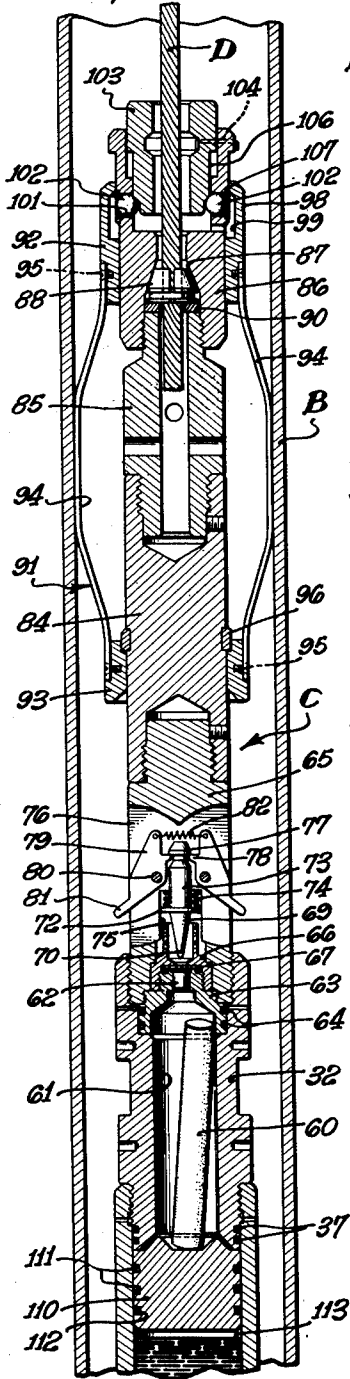


Fig. 1a.

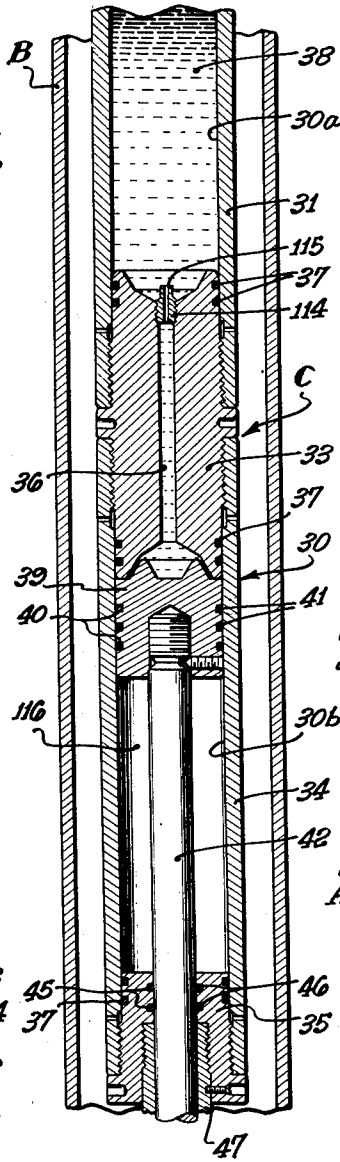
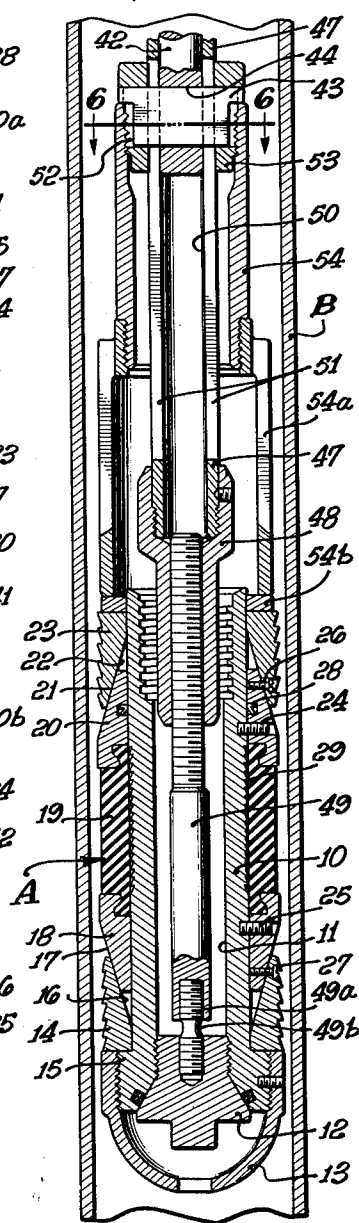


Fig. 1b.



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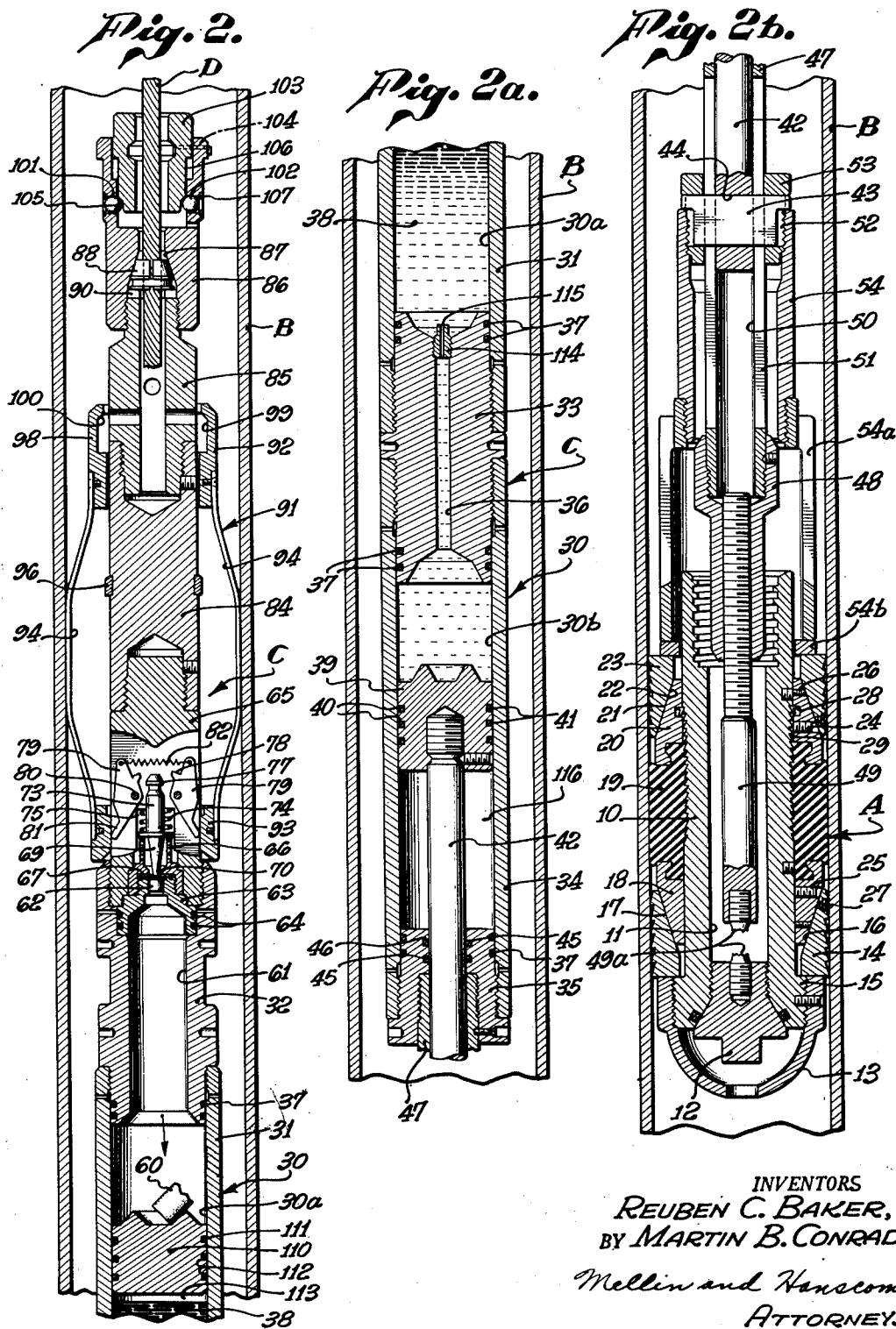
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Fig. 3.

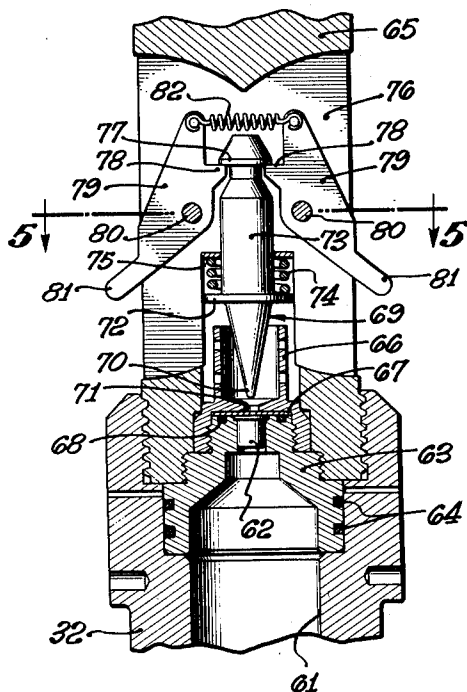


Fig. 4.

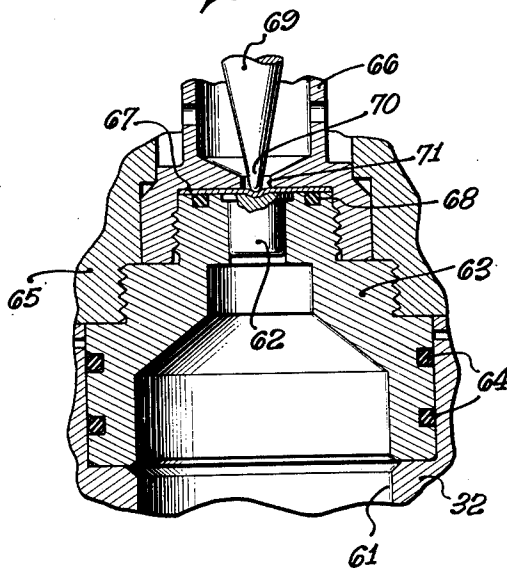


Fig. 5.

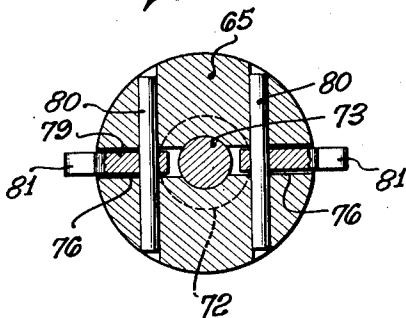
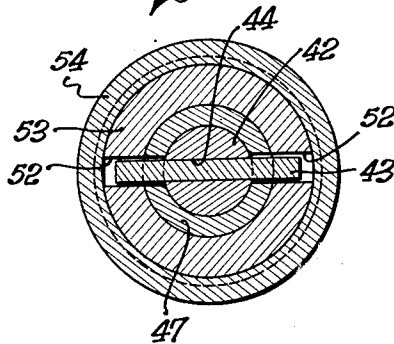


Fig. 6.



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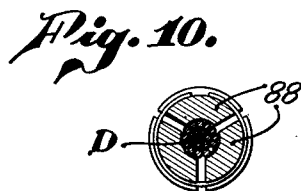
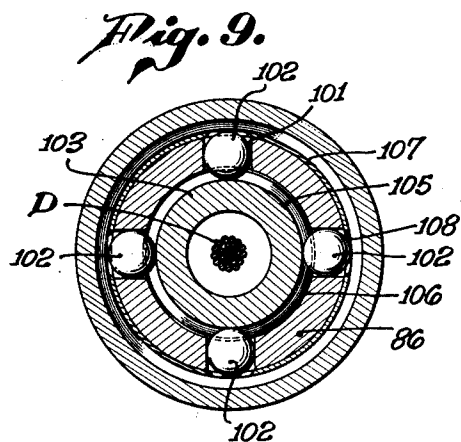
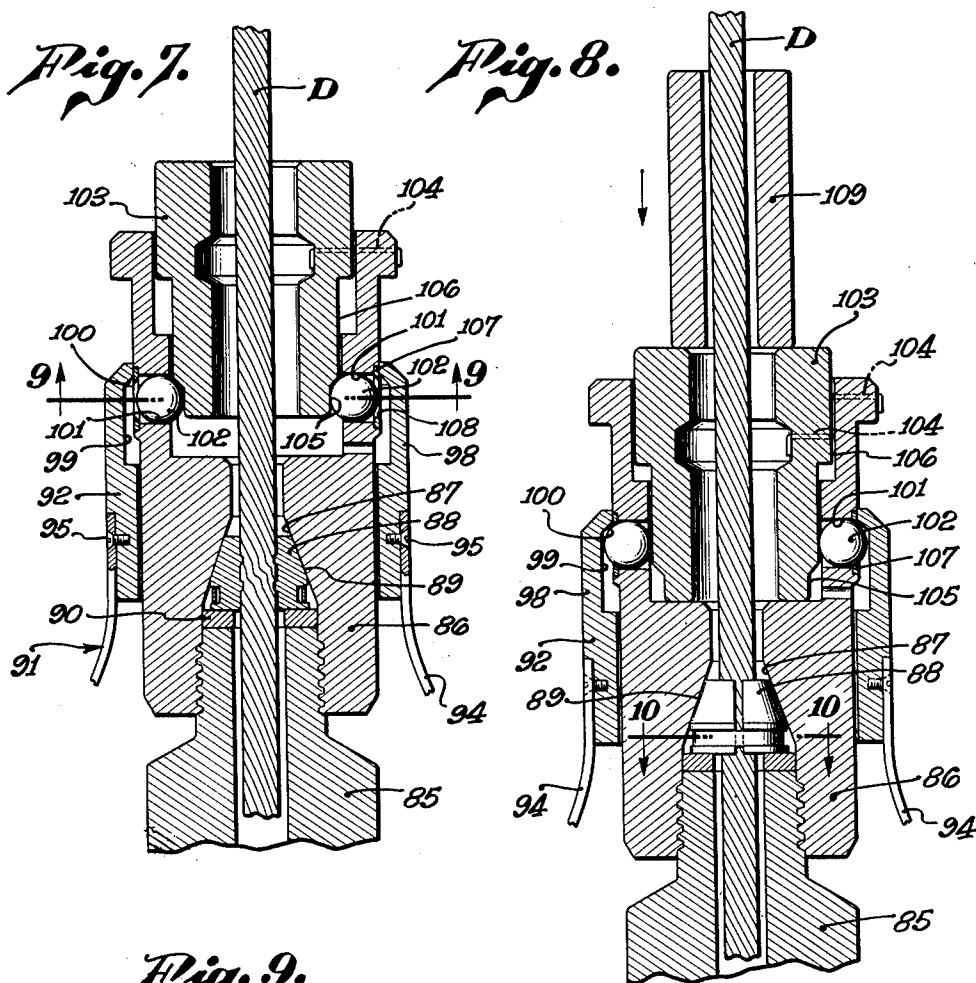
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PRESSURE OPERATED WELL APPARATUS

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4 Sheets-Sheet 4



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PRESSURE OPERATED WELL APPARATUS

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Application November 27, 1948, Serial No. 62,326

6 Claims. (Cl. 166—12)

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The present invention relates to well apparatus, and more particularly to sub-surface equipment useful in performing operations in oil, gas and similar well bores.

Fluid pressure has been utilized heretofore in operating sub-surface tools in well bores. Specifically, a well packer has been set in packed-off condition within a well casing by a setting tool which is automatically released from the packer upon the application of a predetermined setting force to the latter device. The releasing element may be constituted by a frangible connecting pin that is sheared when a sufficient shearing force is imposed upon it.

It is desirable to have the release of the setting tool from the packer occur upon subjecting the packer to the predetermined setting force. This has not always occurred in the past; probably due to non-uniformity in the materials from which the connecting pins are made. Instead, wide variations in the force necessary to shear the connecting pins have been noted, the actual force required being both below and above the desired predetermined value.

The disruptable connecting pin between the setting tool and well packer has been located at an end, as the upper end, of the packer body. The manner of anchoring the packer to the well casing has been such as to subject the packer body to a large tensile stress during the setting operation. Since it may be desirable to drill out the set well packers at a later date, their bodies are usually made of castings of iron, magnesium, aluminum, or the like. These bodies are not as strong in tension as in compression, which imposes limitations upon the safe loads to which the bodies can be subjected in setting the packers, and sometimes may prevent the packers from being set against the casing with sufficient force, because of fear of pulling the packer bodies apart.

Accordingly, it is an object of the present invention to provide a detachable connection between the setting tool and the well tool, such as a well packer, which insures the setting of the tool in the well bore with the predetermined force desired.

Another object of the invention is to provide a disruptable tension member for effecting a detachable connection between a setting tool and a well packer.

Yet another object of the invention is to minimize the quantity of a disruptable connection between a setting tool and well packer that remains attached to the well packer after the connection is broken.

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A further object of the invention is to set a well packer in a well casing or similar conduit by subjecting the packer body to compressive loads rather than to tensile loads.

Still a further object of the invention is to provide an improved wire line device for setting or operating a sub-surface well tool, which can be rendered inoperative whenever desired.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figures 1, 1a and 1b together constitute a longitudinal section through well apparatus positioned in a well casing, with the parts occupying their initial position for lowering the apparatus through the casing, Fig. 1b forming a lower continuation of Fig. 1a, and the latter forming a lower continuation of Fig. 1;

Figs. 2, 2a and 2b are views similar to Figs. 1, 1a and 1b, with part of the apparatus secured in a well casing and another part released from the first part for withdrawal from the well casing;

Fig. 3 is an enlarged longitudinal section of the cartridge firing mechanism, arranged in the position shown in Fig. 1;

Fig. 4 is a fragmentary longitudinal section through part of the firing pin mechanism, illustrating the firing pin after discharging the cartridge;

Fig. 5 is a cross-section taken along the line 5—5 on Fig. 3;

Fig. 6 is an enlarged cross-section taken along the line 6—6 on Fig. 1b;

Fig. 7 is an enlarged longitudinal section through the upper portion of the apparatus, with the parts disclosed in the position shown in Fig. 1;

Fig. 8 is a view similar to Fig. 7, with the drag device locked in ineffective position;

Fig. 9 is a cross-section taken along the line 9—9 in Fig. 7; and

Fig. 10 is a cross-section taken along the line 10—10 on Fig. 8.

In the form of the invention disclosed in the

drawings, it is desired to run a well packer A to a desired location in a well casing B disposed within a bore hole. The packer is then anchored in packed-off condition against the well casing through use of a setting tool C connected to it. This setting tool is attached to the lower end of a running-in string, such as a wire line D, extending to the top of the well bore.

The well packer A disclosed in the drawings includes a tubular main body 10 whose central passage 11 may be closed by a threaded plug 12. A guide 13 is secured to the lower end of the body, to prevent hanging up of the tool in the casing bore or coupling spaces during its lowering in the well casing B.

The well packer can be anchored against downward movement in the well casing by a plurality of lower segmental slips 14 engaging the guide 13 and the lower abutment or flange 15 on the body. The inner surfaces 16 of these slips are tapered in a downward and inward direction for slidable engagement with a corresponding, or externally tapered, surface 17 on a frusto-conical expander 18 slidable on the body. This expander is connected to the lower end of a packing sleeve 19, of rubber or similar material, disposed around the body 10, the upper end of this packing sleeve being connected to an upper expander 20 having an upwardly and inwardly inclined externally tapering surface 21 engageable with corresponding tapered surfaces 22 on a plurality of upper segmental slips 23.

Initially, the slips 14, 23 and packing element 19 are retained in retracted positions with respect to the packing body 10. Shear screws 24, 25, or other suitable frangible connecting elements, secure the upper and lower conical expanders 20, 18 to the body, with the intervening packing sleeve 19 held in retracted position. The upper and lower slips 23, 14 are also held in retracted positions by shear screws 26, 27, attaching them to their associated upper and lower expanders 20, 18.

The shear screws 26 attaching the upper slips 23 to the upper expander 20 have a combined shearing strength which is substantially less than the shear value of the screws 24 holding the upper expander to the body 10. These latter screws have a lesser shear value than the screws 25, 27 securing the lower expander 18 to the body, and the lower slips 14 to the lower expander. These relative shear values are selected to secure detachment, at first, of the upper slips 23 from the upper expander 20, and the movement of the upper slips downwardly along the upper expander and radially outward into anchoring engagement with the casing wall. A subsequent upward strain or pull on the packer body 10 then shears the screws 24 holding the upper expander 20 to the body 10 and moves the lower expander 18 and slips 14 with the body toward the upper expander 20 and slips 23, in order to effect compression of the packing 19 between the expanders and its outward expansion into firm sealing engagement with the wall of the casing.

Thereafter, an increase in the upward pull or force on the packer body 10 substantially simultaneously shears the screws 25, 27 holding the lower expander 18 to the body, and the lower slips 14 to the lower expander, to cause the lower flange 15 and guide 13 on the body to shift the lower slips 14 upwardly along the lower expander and radially outward into anchoring engagement with the wall of the casing B. A split retractor ring 28 may be disposed in the expander

20 for engagement with one of several buttress thread ratchet teeth 29 formed on the exterior of the body 10, to lock the latter against downward movement (see Fig. 2b).

In the form of invention disclosed in the drawings, setting of the well packer A is dependent upon the development of a gas pressure within a setting tool C secured initially to the well packer. This gas pressure is developed within the upper portion of a cylinder 30 consisting of a generally cylindrical upper sleeve 31, an upper head 32 threaded into the sleeve, and also an intermediate head 33 threaded into the sleeve. A lower cylinder sleeve 34 is threadably secured on the intermediate head 33, and is, in turn, threaded onto a lower cylinder head 35.

The upper head 32, upper sleeve 31 and intermediate head 33 form an upper cylinder portion 30a, whereas the intermediate head 33, lower cylinder sleeve 34 and lower head 35 form a lower cylinder portion 30b. These two cylinder portions 30a, 30b are separated by the intermediate head 33, but are communicable with each other through a central passage 35 formed through the intermediate head. Leakage from the cylinder through the several threaded connections may be prevented by suitable side seals 37 in the heads 32, 33, 35 engaging the inner walls of the cylinder sleeves 31, 34.

A motivating gas under pressure is generated in the upper cylinder portion 30a, and this force is transmitted through a suitable fluid medium 38 to the lower cylinder portion 30b through the intermediate head passage 35, for operation upon a piston 39 slidably mounted in the lower cylinder portion. This piston 39 has one or more ring grooves 40 in its periphery for the accommodation of seal rings 41, to prevent leakage between the piston 39 and lower cylinder sleeve 31. As disclosed, these rings 41 may consist of rubber, round in cross-section, to guard against leakage in both directions.

The upper end of a piston rod 42 is threadably connected to the piston 39, the rod extending downwardly through the lower cylinder head 35 to a point therebelow, where an anvil or cross piece 43 is mounted within a transverse slot 44 in the rod. Leakage between the rod 42 and lower cylinder head 35 is prevented by suitable rod packing 45, in the form of one or more round rubber or rubber-like seals, engaging the periphery of the rod 42 and disposed within suitable ring grooves 46 in the head 36. The packing or seal rings 45 prevent leakage of liquids from the well casing into the cylinder 30b below the piston 39, insuring that air under atmospheric pressure is present below the piston when the apparatus is assembled and lowered in the well casing B.

It is desired to transfer the downward movement of, or force imposed upon, the piston 39 and the piston rod 42 to the upper slips 23 of the packer A, and the relative upward movement of the cylinder 30 to the packer body 10, in order to obtain the desired anchoring of the packer in the well casing. To accomplish this purpose, a tubular actuating mandrel 47 is threadably connected to the lower end of the lower cylinder head 35. The lower end of the mandrel 47 is secured to the packer body 10 through the agency of a frangible connecting device. As specifically disclosed, the lower end of the mandrel 47 is threaded into the upper end of a sub 48 which is, in turn, threaded onto the upper end of a tension rod 49 extending within the packer body.

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The lower end of the rod 49 is threaded into the upper end of a releasing stud 49a screwed into the plug 12. As described hereinafter, the stud 49a has an intermediate, reduced diameter portion 49b, at which point the stud pulls apart under a predetermined tensile load, as an incident of setting the packer fully against the well casing.

The piston rod 42 is movable downwardly within the bore 50 of the actuating mandrel 47, the cross-piece 43 projecting in opposite directions from the rod through diametrically opposed longitudinally extending slots 51 formed through the mandrel wall. The cross-piece also extends into opposed slots 52 formed through a setting ring or sleeve 53 slidably mounted on the actuating mandrel 47, to form a connection between the piston rod 42 and the setting ring 53. A two-part setting sleeve or skirt 54, 54a is adjustably threaded on the setting ring 53, the lower portion 54a engaging a ring 54b resting on the tops of the upper slips 23.

As indicated above, a force or pressure is imposed upon a liquid 38, such as water, resting on top of the piston 39. This force moves the piston 39 and piston rod 42 downwardly and the cylinder 30 in a relative upward direction. The downward movement of the rod 42 is transmitted to the setting sleeve or skirt 54, 54a through the anvil 43 and setting ring 53; whereas, the upward movement of the cylinder 30 is transmitted to the packer body 10 through the actuating mandrel 47, sub 48, tension rod 49, stud 49a and plug 12. Accordingly, it is apparent that the development of sufficient pressure in the cylinder 30 acting upon the piston 39 will eventually shear the screws 26 holding the upper slips 23 to the expander 20, and move the slips outwardly against the casing B. Thereafter, the cylinder 30 will move upwardly to move the body 10 in the same direction for the purpose of expanding the packing sleeve 19 against the casing B, and the lower slips 14 against the casing, in the manner described above.

In order to obtain the desired operational sequence, a combustible fuel 60 may be contained within the upper end of the cylinder 30. The combustion charge, such as a railway flare of cylindrical or stick form, is placed in the upper head end 32 of the cylinder within a combustion chamber 61 formed therein. This charge 60 is ignited by a blank cartridge 62 contained within a gun barrel 63 inserted within the upper end of the upper cylinder head 32. Leakage between the barrel and head is prevented by suitable side seals 64 on the barrel engaging the wall of the head.

The barrel 63 is threaded into a gun body 65 that is threadably secured to the upper end of the cylinder head 32. This body also contains a breechblock or cap 66 threaded onto the upper end of the barrel 63, and having an inwardly directed flange firmly engaging a thin metallic disc 67 bearing against the cap of the cartridge 62. In effect, the breechblock 66 clamps the disc 67 and cartridge cap to the gun barrel 63, leakage from the barrel being prevented by a suitable gasket 68 in the barrel bearing against the thin disc 67.

The cartridge 62 is fired by a pin 69 whose tapered end 70 can enter a hole 71 in the breechblock, to strike and indent the disc 67 and thereby fire the cartridge. The flame from the cartridge ignites the upper end of the combustible charge or fusee 60 and initiates its combustion,

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which then becomes self-sustaining. As best seen in Fig. 3, the tapered lower end 70 of the firing pin 69 extends downwardly from a flange or spring seat 72 integral with the firing pin shaft 73, all elements of the firing pin being disposed within the gun body 65. A compressed helical spring 74 is disposed between the seat 72 and the upper end of the central bore 75 through the body 65, this spring exerting sufficient force to shift the pin 69 downwardly and strike its end 70 against the thin disc 67, in order to fire the cartridge 62.

The shaft 73 of the pin extends upwardly within an elongate transverse slot 76 within the body 65, its upper end being formed with a shoulder or flange 77 adapted to be engaged by inwardly directed latch fingers 78 on the upper ends of latch levers 79 disposed in the body slot 76 and pivotally mounted on pins 80 supported in the body. The lower arms 81 of the levers 79 are urged in an outward direction, to maintain the latch fingers 78 engaged under the firing pin shoulder 77, by a tension spring 82, whose opposite ends are connected to the upper ends of the latch levers 79. So long as the spring holds the lower lever arms 81 outwardly and the latch fingers 78 under the firing pin shoulder 77, the firing pin 69 is maintained in elevated position above the disc 67 and cartridge 62, holding the firing spring 74 in a highly compressed condition.

The latch lever arms 81 are movable inwardly toward each other, to swing the fingers 78 outwardly from engagement with the firing pin 69, allowing the firing spring 74 to move the point 70 of the pin downwardly and strike it against the disc 67. In the event that the point pierces the disc, rather than merely indents it, the downward movement of the pin 69 is limited by engagement of its flange 72 with the upper end of the breechblock 66.

The upper end of the gun body 65 is threaded into a sinker bar 84, which may be of any suitable length, to provide sufficient weight for forcing the entire apparatus through the well fluid during its descent in the casing B. The upper end of the sinker bar 84 is secured to a tubular sub 85 threaded into a rope socket 86 having a tapered bore 87 for the reception of the lower end of the wire line D. The wire line may be firmly secured in the socket by a plurality of internally wickered slips 88 forced against the socket by engagement of their tapered surfaces 89 with the companion internally tapered surface of the enlarged rope socket bore 87. The threading of the sub 85 into the rope socket 86 causes the upper end of the former to bear against a ring 90 engaging the lower end of the slips 88, urging the latter upwardly within the socket 86 and radially inwardly into firm gripping engagement with the wire line D.

For the purpose of moving the latch lever arms 81 inwardly, a friction drag device 91 may be employed. This device includes upper and lower collars 92, 93 slidable along the wire line socket 86, sub 85, sinker bar 84 and gun body 65. The upper and lower ends of outwardly bowed drag springs 94 are suitably secured to these collars 92, 93, as by means of screws 95. The springs 94 frictionally engage the wall of the well casing B, which tends to resist its movement therewithin. Nevertheless, the drag device 91 is forced through the well casing B during lowering movement of the apparatus by engagement of a ring 96 on the sinker bar with the lower drag collar 93. Upward movement of the wire line D, after the de-

sired packer setting location has been reached in the well bore, moves the entire apparatus, with the exception of the drag device 91, upwardly within the casing, pulling the latch levers 79 within the lower drag collar 93, and causing the latter to shift the latch lever arms 81 inwardly and release the fingers 78 from the firing pin shoulder 77; whereupon the spring 74 is free to strike the pin end 70 against the disc 67 and fire the cartridge 62.

Actually, the entire apparatus is lowered in the well casing B to a point below the desired setting location of the bridge plug A. This distance below the desired location is the relatively short distance that the lower drag collar 93 must travel along the sinker bar 84 and body 65 to release the latch levers 79 from the firing pin 69. Accordingly, subsequent elevation of the wire line D by this distance will pull the levers 79 within the drag collar 93 to release the pin, fire the cartridge 62, and ignite the combustible charge 60. Assurance is thus obtained of setting the packer A at the intended point in the well casing B.

As explained above, upward movement of the wire line D effects setting of the well packer A in the well bore. Under some circumstances, it is desired to remove the apparatus from the well casing B, after it has been lowered therewithin, without setting the packer. To prevent the upward movement from setting the packer, the drag device 91 can be locked in its upper position by a mechanism now to be described.

The upper drag collar 92 includes an upwardly extending sleeve portion 98 having a recess 99 terminating in an upwardly and inwardly inclined shoulder 100. The wire line socket 66 has a plurality of generally radial holes 101 extending therethrough, each of these holes receiving a ball detent or lock 102. Inward movement of the balls 102 is limited by their engagement with a retainer sleeve 103 disposed within the upper end of the rope socket 86 and held initially in an upward position by a shear pin 104 extending between the sleeve and the socket. This sleeve 103 has a lower reduced diameter portion 105 engageable by the balls 102 when the shear pin 104 is intact, to permit the balls to move radially inwardly out of the upper collar recess 99. The retainer sleeve 103 has an adjacent larger diameter portion 106, which, when disposed opposite the balls 102, holds them outwardly within the upper collar recess 99, in order to prevent relative downward movement of the drag device 91 along the setting apparatus, and thereby precluding release of the latches 79 from the firing pin 69.

When the lower drag collar 93 is in engagement with the stop ring 95, the recess 99 in the upper drag collar is disposed in transverse alignment with the balls 102. In this position, the balls can project outwardly through the openings 101 to an extent insuring their disposition in the recess 99, and subsequent engagement by its tapering shoulder 100. Outward movement of the balls is limited by their engagement with a ring 107 encompassing the upper portion of the wire line socket 66 in the region of the holes 101. The balls 102 may extend outwardly through openings 108 in this ring.

When the drag device 91 moves downwardly during its initiation of a bridge plug setting operation, the inclined shoulder 100 engages the balls 102 and moves them inwardly within the radial holes 101, as permitted by the lower portion 105 of the retainer sleeve. However, in the event it

is desired to prevent operation of the apparatus, a go-devil 109 is dropped down the wire line D into engagement with the upper end of the retaining sleeve 103, shearing the pin 104 and forcing the sleeve 103 downwardly, in order to place its larger diameter portion 106 opposite the locking balls 102. The balls are thus pushed outwardly into the recess 99 in the sleeve portion of the upper drag collar 92 and cannot be forced inwardly by the tapered shoulder 100, in view of their engagement with the enlarged diameter portion 106 of the retainer sleeve. Accordingly, upward movement of the wire line D will then move the upper drag collar 92 with it, since the balls 102 are held by the retainer sleeve 103 in engagement with the tapered shoulder 100, enabling the entire apparatus to be withdrawn from the well bore without being actuated.

When the combustible fuel or powder charge 60 is ignited, as by firing the cartridge 62, evolved gas under pressure is produced within the upper end of the upper cylinder portion 30a. This gaseous force acts downwardly upon an upper or floating piston 110 disposed initially adjacent the upper cylinder head 32. This piston carries suitable seal rings 111 in grooves 112 in its periphery engageable with the wall of the upper cylinder sleeve 31, to prevent leakage around the piston 110 in both directions.

Originally, the piston 110 rests upon the fluid medium 38, which substantially entirely fills the cylinder space between the upper piston 110 and the lower piston 39, including the volume of the passage 36 through the intermediate head. This fluid medium is predominantly and almost entirely a liquid, such as water, but the upper end 113 of the medium is preferably air, which forms an intermediate cushion between the floating piston 110 and the water 38 therebelow. In the event of an increase in the temperature of the intervening water, its expansion is permissible without operating the equipment in view of the presence of the air mass 113, which will merely be compressed to a certain extent.

For the purpose of delaying a transfer of the liquid medium 38 from the upper cylinder portion 30a into the lower cylinder portion 30b, as the floating piston 110 is forced downwardly by the gaseous pressure in the upper portion of the cylinder 30a, a flow restricting device 114, such as a bean or orifice, is threaded into the upper end of the passage 36 through the intermediate head 33. The cross-sectional area of the hole 115 through this bean or orifice 114 is much less than the area of the passage 36 itself, the orifice area being so chosen as to allow the fluid to flow from the upper cylinder portion 30a into the lower cylinder portion 30b at a slow or retarded rate, for a purpose to be explained below.

The apparatus is lowered in the well bore with the parts in the position shown in Figs. 1, 1a and 1b. When in this condition, the lower piston 39 is adjacent the intermediate cylinder head 33; while the upper or floating piston 110 is adjacent the upper cylinder head 32. The space between these pistons is substantially completely filled with water 38, or other suitable liquid, except for the small air space 113 on top of the liquid, which, as explained above, allows for thermal expansion and contraction of the liquid 38.

When the depth in the casing is reached at which the well packer A is to be set, the wire line D is pulled upwardly to effect firing of the cartridge 62, as explained above. The flame issuing

therefrom ignites the upper end of the combustible charge 60, initiating its combustion. This charge contains its own source of oxygen to support combustion. As combustion proceeds, a gaseous pressure is developed within the upper portion of the cylinder 30a above the floating piston 110. As the pressure increases, the floating piston 110 is urged downwardly and the cylinder 30 relatively upwardly. The force imposed on this floating piston is transmitted through the fluid medium 38 to the lower piston 39, and from this piston through the rod 42, cross-piece 43, and setting ring 53 to the sleeve 54, 54a, which bears against the ring 54b resting upon the upper slips 23. Downward movement of the lower piston 39 takes place against the relatively slight resistance of the air 116 in the lower cylinder portion 30b below the piston 39, which is initially at atmospheric pressure, and also against the hydrostatic head of fluid in the well casing acting upwardly across the cross-sectional area of the piston rod 42. When sufficient pressure has been developed within the upper cylinder portion 30a by the gaseous medium, and has been transmitted through the floating piston 110, fluid medium 38, lower piston 39, piston rod 42, cross-piece 43, setting ring 53, sleeve 54, 54a and ring 54b to the slips 23, to overcome the shear strength of the shear screws 26, and also the hydrostatic head of fluid acting upwardly on the piston rod 42, the slips 23 are released from the expander 20 and are pushed downwardly along the latter into outward engagement with the casing B.

As the combustible charge 60 continues to burn, the gas pressure within the upper cylinder portion 30a increases to a further extent, and this increased pressure or force is transmitted to the lower piston 39 through the intervening fluid medium 38. Since the upper slips 23 are wedged against the casing B, the piston 39 cannot move downwardly to any further appreciable extent. Instead, the cylinder 30, actuating mandrel 47, sub 48, tension rod 49, stud 49a, plug 12, and packer body 10 are urged in an upward direction. When the pressure and force within the cylinder 30 has increased sufficiently to overcome the shear strength of the screws 24 holding the upper expander 20 to the body, such screws are disrupted and the packer body 10 is moved upwardly within the upper expander 20 to compress the rubber packer sleeve 19 between the upper and lower expanders 20, 18, forcing it into firm sealing engagement with the casing wall.

Further increase in the cylinder gas pressure, as a result of the continued combustion of the charge 60, effects shearing of the screws 25, 27 attaching the lower expander 18 to the body 10 and the lower slips 14 to the lower expander, allowing the cylinder 30 to move upwardly and carry the body 10 and lower slips 14 in an upward direction to shift the latter radially outward into engagement with the casing B.

The pressure in the cylinder 30 continues to increase, as combustion of the charge 60 proceeds, and all of the packer elements are engaged more firmly with the casing B. When the pressure exceeds the tensile strength of the releasing stud 49a securing the actuating mandrel 47 indirectly to the body 10, this stud is pulled apart at its reduced diameter portion 49b to release automatically the setting tool C from the well packer A. All of the mechanism, with the exception of the packer A and the lower end of the stud 49a, may now be removed from the well casing B.

As was above indicated, a predetermined sequence of steps is preferred to insure proper setting of the well packer A in packed-off condition within the well casing. Thus, the screws 26 holding the upper slips 23 to the upper expander 20 are first sheared, to engage the upper slips with the casing B. Next, the screws 24 attaching the upper expander 20 to the body 10 are disrupted, to obtain expansion of the packing sleeve 19 against the casing. Thereafter, the screws 25 holding the lower expander 18 to the body 10 and the screws 27 holding the lower slips 14 to the lower expander are sheared, to obtain anchoring engagement of the lower slips with the casing wall. When all of the foregoing has occurred, the release stud 49a is pulled apart at its reduced diameter portion 49b, to obtain disconnection of the setting tool C from the well packer A.

It is preferred that a definite time interval elapse (which may be only several seconds) between each of the above-described operational sequences, to give the parts an opportunity to be shifted to their proper setting positions. The rate at which the combustion charge 60 burns may vary for different charges, and a pressure may be built up in the cylinder 30a above the floating piston 110 at an accelerated pace, which is greater than desired. This increase in pressure, however, is not transmitted directly to the lower piston 39, but indirectly through the intervening liquid medium 38, which must pass through the flow restricting orifice 114. Accordingly, relative downward movement of the lower piston 39 in the cylinder 30b proceeds at a slower rate than would be the case if the products of combustion acted directly upon the lower piston, since the only way in which the lower piston 39 can move relatively downward is through transferring of the intervening liquid 38 under pressure from the upper cylinder portion 30a, through the flow restricting orifice 114, to the lower cylinder portion 30b containing the lower piston 39.

Accordingly, downward movement of the floating piston 110 in the cylinder 30a is retarded, which is also true of the relative downward movement of the lower piston 39 in the cylinder 30b, which necessarily retards the rate at which the products of combustion can undertake an expansion in the upper cylinder portion 30a as its gaseous pressure increases. The operational sequences take place in a predetermined and ordered manner, to obtain shearing of the various screws at the proper time, and with sufficient time intervals between their disruptions to insure shifting of the parts of the apparatus to their proper operational positions.

At the time that the release stud 49a is disrupted, to release the setting tool C from the well packer A, the lower piston 39 has not been moved downwardly to its fullest extent within the lower cylinder sleeve 34. Pulling apart of the stud 49a releases the load on the lower piston 39. If the gas under pressure in the cylinder were acting directly upon the lower piston, it would partake of a sudden expansion, upon release of the load, to shift the lower piston relatively downward almost instantaneously to the extent limited by its engagement with the lower cylinder head 35. This sudden expansion and movement would cause the piston 39 to strike a tremendous blow on the lower cylinder head 35, since the device is operable at comparatively high unit pressures, the reaction of the blow and the sudden move-

ment of the cylinder 30 and piston 39 introducing a recoil, or shock load, on all of the equipment in the well bore, which might result in damage to some of its parts.

However, in the form of invention illustrated in the drawings, the gaseous pressure medium does not act directly upon the lower piston 39, but urges the latter relatively downward through the intervening fluid or liquid medium 38. When the stud 49a is disrupted, the load on the cylinder 30 and lower piston 39 is released suddenly, but such sudden release almost immediately causes relative downward movement of the lower piston 39 in the cylinder 30b to a slight extent, which relieves the liquid 38 between the lower piston 39 and the orifice 114 of substantially all pressure, and removes any forces on the lower piston 39 seeking to drive it relatively downward in the cylinder at a high rate of speed. Instead, the lower piston 39 is caused to move through the lower cylinder portion 39b in a downward direction at a relatively low rate, inasmuch as release of the load on the equipment still results in a gradual lowering of the floating piston 110 in the cylinder 30a, and a gradual expansion of the gaseous medium thereabove. Such gradual lowering can only occur since the floating piston 110 must force the liquid in the upper cylinder portion 39a through the flow restricting orifice 114. The flow through the orifice can only take place at a relatively slow rate because of the comparatively small cross-sectional area of its bore 115. As a consequence of restricting or retarding the flowing of the intervening liquid 38 through the orifice, the lower piston 39 is moved downwardly relatively to the cylinder 30 in a gradual manner, until it comes to rest against the lower cylinder head 35, without striking any sharp blows on the latter.

Since the packer body 10 is ordinarily made of a casting, preferably of a readily drillable material, the connection of the setting tool C to the packer A at the lower end of the latter subjects the body 10 to a compression load when it is pulled upwardly to fully set the packer against the casing, as disclosed in Fig. 2b. Initially, the upper slips 23 are anchored against the casing and the packer body 10 is then moved upwardly to compress the packing 19 against the casing and expand the slips 14 into firm anchored engagement with the casing. The extent of the ultimate compressive force on the body might be quite substantial. As an example, it may be 30,000 to 40,000 lbs. total force. The body 10 is much stronger in compression than in tension, and is, accordingly, better able to withstand compressive loads than tensile loads.

The setting tool C is to be released from the well packer A when a predetermined setting force has been applied to the packer. All of the setting tool, with the exception of the lower end of the releasing stud 49a remaining attached to the body plug 12, is removed from the well casing. This small lower portion of the releasing stud is relatively insignificant and does not interfere with any subsequent drilling out of the well packer. By reducing its intermediate diameter 49b to the proper extent, the releasing stud 49a may be caused to pull apart under a predetermined tensile load. By knowing the strength of the material of which the releasing stud is made, the portion 49b is reduced in diameter accordingly, in order to insure its disruption when subjected to a tensile pull that is substantially the desired maximum amount to be imposed upon the well packer. After

the setting tool C has been released from the well packer A, it may be withdrawn from the well bore and used again. The upper end of the releasing stud 49a is easily removable from the lower end of the tension rod 49 and can be replaced by another intact releasing stud.

The invention disclosed herein and relating to the feature of enabling the apparatus to be removed from the well casing without setting the packer is both described and claimed in our divisional application for "Devices for Rendering Subsurface Well Apparatus Inoperable," Serial No. 252,262, filed October 20, 1951.

The inventors claim:

1. In well apparatus: a well device having a tubular body and normally retracted means for engagement with a well casing; a plug at the lower end of said body closing its central bore; fluid actuated means for setting said device in the well casing, comprising a piston for exerting a downward force on said normally retracted means and a cylinder for exerting an upward force on said body; and means forming a detachable connection between said cylinder and plug, said detachable connection means comprising a releasing stud secured to said plug and having an intermediate portion of reduced diameter, a tension rod secured to said stud, and means secured to said cylinder and having an adjustable threaded connection with said tension rod.

2. In well apparatus: a well device having a tubular body and normally retracted means for engagement with a well casing; a plug at the lower end of said body closing its central bore; fluid actuated means for setting said device in the well casing; and disruptable means forming a detachable connection between said fluid actuated means and plug, said disruptable means comprising a releasing stud secured to said plug and having an intermediate portion of reduced diameter, a tension rod secured to said stud, and means secured to said fluid actuated means and having an adjustable threaded connection with said tension rod.

3. In well apparatus: a well device having a body and normally retracted means for engagement with a well casing; fluid actuated means for setting said device in the well casing; and disruptable means forming a detachable connection between said fluid actuated means and body, said disruptable means comprising a releasing stud having a weakened portion at which said stud will pull apart when subjected to a predetermined tension force, a tension rod secured to said stud, and means secured to said fluid operated means and having an adjustable threaded connection with said tension rod.

4. In well apparatus: a well device having a body and normally retracted means for engagement with a well casing; means for setting said device in the well casing; and disruptable means forming a detachable connection between said setting means and body, said disruptable means comprising a releasing stud threadedly secured to said body and having a weakened portion at which said stud will pull apart when subjected to a predetermined tension force, a tension rod threadedly secured to said stud, and means secured to said setting means and having an adjustable threaded connection with said tension rod.

5. In well apparatus: a well device having a tubular body and normally retracted means for engagement with a well casing; a plug at the lower end of said body closing its central bore;

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fluid actuated means for setting said device in the well casing, comprising a piston for exerting a downward force on said normally retracted means and a cylinder for exerting an upward force on said body; means comprising a sleeve for transmitting the downward force of said piston to said normally retracted means; and means forming a detachable connection between said cylinder and plug, said detachable connection comprising a releasing stud threadedly secured to said plug and having a weakened portion at which said stud will pull apart when subjected to a predetermined tension force, a tension rod threadedly secured to said stud, and means secured to said cylinder and having an adjustable threaded connection with said tension rod.

6. In well apparatus: a well device having a body and normally retracted means for engagement with a well casing; fluid actuated means for setting said device in the well casing comprising a cylinder member and a piston member slidable in said cylinder member, one of said members being movable upwardly and the other of said members being movable relatively downwardly; means comprising a sleeve for transmitting the downward force of said downwardly

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movable member to said normally retracted means; and means forming a detachable connection between said upwardly movable member and body, said detachable connection comprising a releasing stud threadedly secured to said body and having a weakened portion at which said stud will pull apart when subjected to a predetermined tension force, a tension rod threadedly secured to said stud, and means secured to said upwardly movable member and having an adjustable threaded connection with said tension rod.

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