Dec. 10, 1957 R. C. BAKER 2,815,816

AUTOMATICALLY RELIEVED GAS PRESSURE WELL APPARATUS

Filed June 20, 1955 2 Sheets-Sheet 1

FIG. 1.

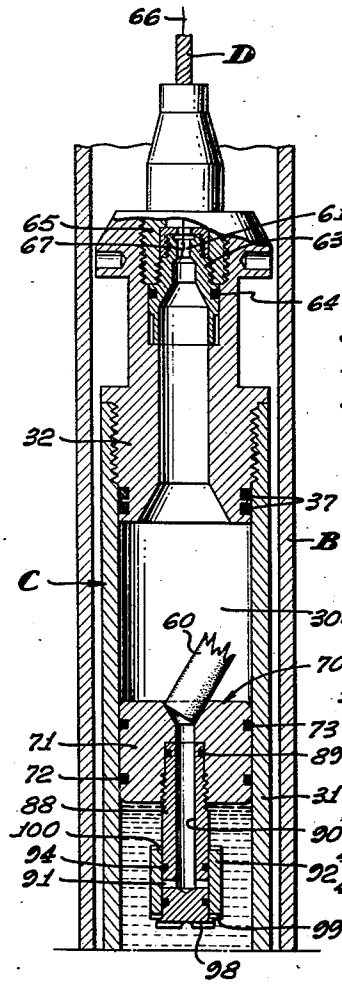


FIG. 1a.

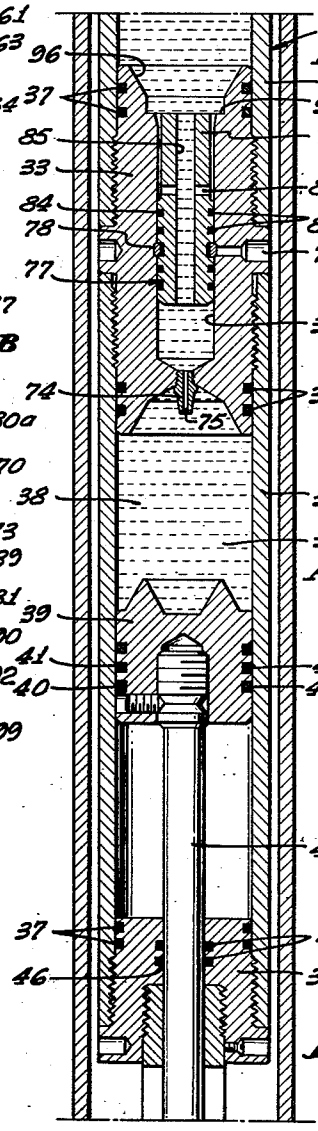
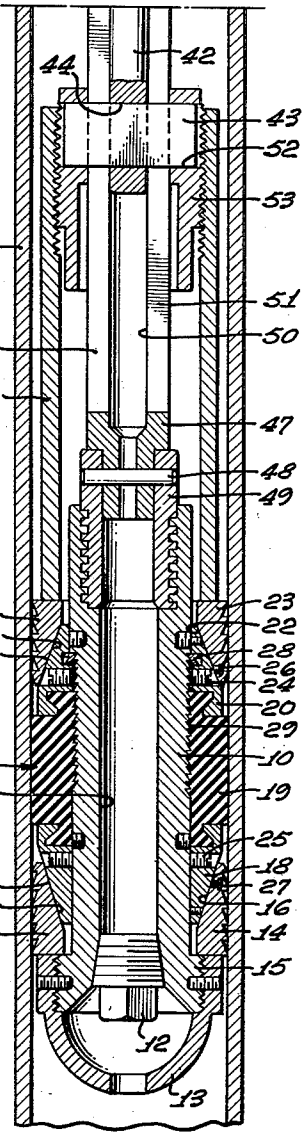


FIG. 1b.



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FIG. 2.

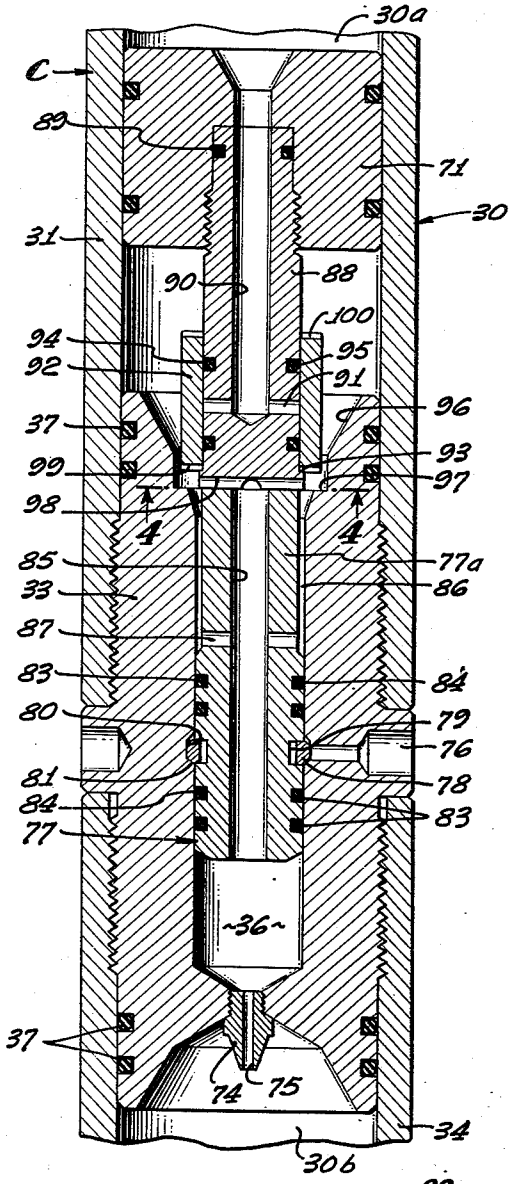


FIG. 3.

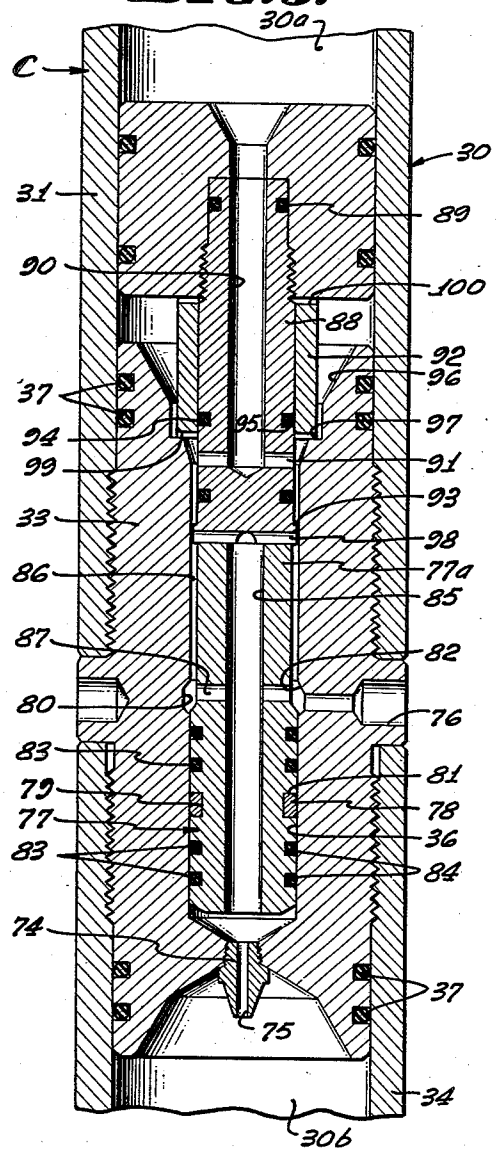
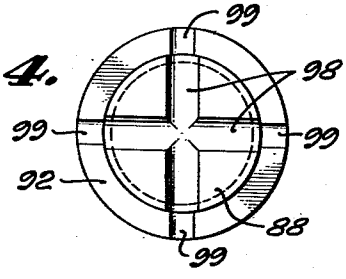


FIG. 4.



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AUTOMATICALLY RELIEVED GAS PRESSURE WELL APPARATUS

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Application June 20, 1955, Serial No. 516,477

20 Claims. (Cl. 166—63)

The present invention relates to subsurface apparatus adapted to perform certain desirable operations in oil, gas and similar well bores.

Certain types of well apparatus are operated in well bores by utilizing a gaseous medium under pressure to supply the necessary motivating force. As an example, a well packer may be set in a well bore through the exertion of a gaseous force thereon that might be present in a setting tool attached to the well packer, the setting tool being released from the latter after it has been set.

Heretofore, care had to be exercised in disassembling the setting tool after it was retrieved from the well bore to insure release and bleeding off of the gas pressure trapped within the tool before the parts of the setting tool were fully dismantled from each other. At times, which fortunately occurred very infrequently, dismantling of the setting tool has been attempted improperly without releasing the gas pressure in the tool, injury to persons and damage to property being an ever present danger.

Accordingly, it is an object of the present invention to provide an improved gas pressure operated subsurface apparatus from which the gas pressure is released automatically following the performance of the required operations in the well bore, thereby eliminating the danger of accident when the apparatus is dismantled improperly following its removal from the well bore.

Another object of the invention is to provide a setting tool for a well packer to be set in a well bore, in which the setting tool is operated by gas pressure and in which the gas pressure is released automatically in the well bore after the well packer has been set.

A further object of the invention is to provide a gas pressure operated apparatus for use in a well bore in which the gaseous force performs its function through the agency of a liquid medium, both the pressure of the gas and the pressure of the liquid medium being released automatically into the well bore following the performance of the required operation by the apparatus in the well bore.

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, 1*a* and 1*b* together constitute a longitudinal section through well apparatus positioned in a well casing, Fig. 1*b* forming a lower continuation of Fig. 1*a*, and Fig. 1*a* forming a lower continuation of Fig. 1, the parts occupying a position in which the well packer portion of the apparatus has been anchored in packed-off condition in the well casing;

Fig. 2 is an enlarged longitudinal section through a portion of the apparatus for releasing the pressure therewithin, the parts occupying the position just prior to release of the pressure;

Fig. 3 is a longitudinal section similar to Fig. 2, disclosing the parts in the position they occupy for the release of the pressure;

Fig. 4 is a cross-section taken along the line 4—4 on Fig. 2.

The invention is shown in the drawings as applied to a setting tool C releasably secured to a well packer A anchored in packed-off condition against the well casing B, the setting tool being attached to the lower end of a running-in string D, such as a wire line, extending to the top of the well bore. It is to be understood, however, that the invention has wider applications than is specifically disclosed, and that the setting of the well packer is merely illustrative of the invention.

The apparatus disclosed in the drawings may take the form specifically described and illustrated in the patent to Martin B. Conrad, 2,618,343, patented November 18, 1952, for "Gas Pressure Operated Well Apparatus," to which attention is directed for certain details of construction and relative locations of parts which are not specifically disclosed in the present application. In both the patent and the present application, a well packer A is shown anchored in packed-off condition within a well casing. This well packer includes a tubular main body 10 whose central passage 11 may be closed by a plug 12. A guide 13 is secured to the lower end of the body to prevent the tool from catching or hanging up in the casing or coupling spaces during its lowering in the well casing B.

The well packer has been 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 the 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 tapered surface 21 having wedging engagement 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 position with respect to the packer body 10. Shear screws 24, 25, or other suitable frangible connecting elements, secure the upper and lower expanders 20, 18 to the body, with the intervening packing sleeve held in retracted position. The upper and lower slips 23, 14 are also held in retracted position 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 shear 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 shears the screws 24 holding the upper expander to the body 10 and moves the lower expander 18 and slips 14 with the body toward the upper expander 20 and slips 23, 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. The packer is now anchored in packed-off condition within the well casing, as disclosed in Fig. 1*b*.

As shown in the drawings, setting of the well packer A is dependent upon the development of a gas pressure within the setting tool C releasably 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 this sleeve and also an intermediate head **33** threaded into this sleeve. A lower cylinder sleeve **34** is threadedly 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 **30***a*, whereas the intermediate head **33**, lower cylinder sleeve **34** and lower head **35** form a lower cylinder portion **30***b*. These two cylinder portions **30***a*, **30***b* are separated by the intermediate head **33**, but are communicable with each other through a central passage **36** 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 provided in the upper cylinder portion **30***a*, and the force of this gas is transmitted through a suitable liquid medium **38** to the lower cylinder portion **30***b* through the intermediate head passage **36** for operation upon a piston 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 in both directions between the piston **39** and lower cylinder sleeve **31**.

The upper end of a piston rod **42** is threadedly connected to the piston **39**, the rod extending downwardly through the lower cylinder head **35** to a point therebelow. 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** disposed within suitable ring grooves **46** in the head **36**, to prevent leakage of liquids from the well casing into the cylinder **30***b* 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**, to secure the desired anchoring of the packer in the well casing. To accomplish this purpose, a tubular actuating mandrel **47** is threadedly connected to the lower end of the lower cylinder head **35**. The lower end of the mandrel **47** is secured, through the agency of the frangible connecting pins **48**, to a sleeve **49** threaded to the upper end of the body **10**. As specifically disclosed, the lower end of the mandrel **47** is of reduced diameter and is piloted within the sleeve **49**, the pin **48** extending transversely through the sleeve and pilot mandrel portion.

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 through 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 cross-piece **43**. A setting sleeve or skirt **54** is adjustably threaded on the setting ring **53**, its lower end engaging the top of the upper slips **23**.

As indicated above, a force or pressure is imposed on the liquid **38**, such as oil or 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 relatively upward direction. The downward movement of the rod **42** is transmitted to the setting sleeve or skirt **54** 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**, frangible pin **48** and sleeve **49**. 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 pull 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.

To secure the desired operational sequence, gas under pressure is provided within the upper end of the cylinder **30**. Such gas under pressure may be generated in the upper end of the cylinder, as by burning a combustible charge **60** in the cylinder. As specifically illustrated and described in Patent 2,618,343, the charge is ignited by a blank cartridge **61** contained within a gun barrel **63** inserted within the upper end of the upper cylinder head **32**. Leakage between the barrel and the cylinder head is prevented by a suitable side seal **64** in the barrel engaging the wall of the head **32**. This barrel **63** is threaded into a firing head **65** which, in turn, is threadedly secured to the upper end of the cylinder head **32**. The wire line running-in string D is suitably secured to the firing head, in a known manner, and has the lower end of its electrically conductive wire or core **66** connected electrically to a heating filament **67** contained within the cartridge **61**.

When the combustible fuel or power charge **60** is ignited, evolved gas under pressure is produced within the upper end of the upper cylinder portion **30***a*, or some other form of gas under pressure may be provided therein. This gaseous force acts downwardly upon an upper or floating piston structure **70** disposed initially adjacent the upper cylinder head **32**. The piston portion **71** of this structure carries one or more suitable seal rings **72** in one or more peripheral grooves **73** to prevent leakage around the exterior of the piston in both directions.

Originally, as disclosed in Patent 2,618,343, the piston structure **70** rests upon the fluid medium **38**, which substantially entirely fills the cylinder space between the upper piston structure 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 or oil. For the purpose of delaying a transfer of the liquid medium **38** from the upper cylinder portion **30***a* into the lower cylinder portion **30***b* as the floating piston structure **70** is forced downwardly by the gaseous pressure in the upper portion of the cylinder **30***a*, a flow restricting device **74**, such as a bean or orifice, is threaded into the lower end of the passage **36** through the intermediate head **33**. The cross-sectional area of the hole **75** through the bean or orifice **74** is much less than the area of the passage **36** itself, the orifice area being so chosen as to allow fluid to flow from the upper cylinder **30***a* into the lower cylinder portion **30***b* for action upon the lower piston at a

slow or retarded rate, for a purpose to be explained below.

The apparatus is lowered in the well bore with the slips and packing elements of the well packer disposed in their initial retracted position, with the lower piston 39 adjacent the lower end of the intermediate cylinder head 33 and with the floating piston structure 70 in its upper position adjacent the upper cylinder head. The oil or water 38 substantially completely fills the cylinder between the upper piston structure 70 and the lower piston 39.

When the depth in the casing is reached at which the well packer A is to be set, the electric circuit through the cartridge filament 67 is completed to fire the cartridge 61. The flame issuing therefrom ignites the upper end of the combustible charge 60 resting upon the upper piston structure 70, 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 30*a* above the floating piston structure 70. As the pressure increases the floating piston structure is urged downwardly and the cylinder 30 relatively upwardly. The force imposed on the floating piston structure 70 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 sleeve 53 to the sleeve 54, which bears against the upper slips 23. Downward movement of the lower piston 39 takes place against the relatively slight resistance of the air in the lower cylinder portion 30*a* 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 30*a* by the gaseous medium and has been transmitted through the piston structure 70, fluid medium 38, lower piston 39, piston rod 42, cross-piece 43, setting ring 53, and sleeve 54 to the slips 23, to overcome the shear strength of the shear screw 26, and also the hydrostatic head of fluid acting upwardly on the piston 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 30*a* progressively increases to a further extent, and the increased pressure and 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, sleeve 49 and packer body 10 are urged in an upward direction. When the pressure and force within the cylinder 30 is 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 is then moved upwardly within the upper expander 20 to compress the rubber packing sleeve 19 between the upper and lower expanders 20, 18, forcing the packing sleeve 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 proceeds, and all of the packer elements are engaged more firmly with the casing B (as disclosed in Fig. 1*b*). When the pressure exceeds the shear strength of the connecting pin 48 securing the lower end of the actuating mandrel 47 to the sleeve 49, this pin is sheared to release automatically the setting tool C from the well packer A. All of the mechanism, with the exception of the packer A can now be removed from the well casing B.

The orifice 74 retards the downward movement of the floating piston structure 70 in the cylinder as the gas pressure increases and as the sequence of operation on the well packer takes place, so that no sudden movement can occur, particularly the sudden descent of the piston structures 70, 39 relatively within the cylinder 30 following disruption of the shearable connector pin 48. When this occurs, the upper piston structure 70 can only move downwardly at a relatively slow rate (which may consume several seconds) until the piston structure 70 engages the intermediate cylinder head 33. The lower piston 39 will only move downwardly to the extent determined by the volume of liquid 38 thereabove that has been forced through the orifice 74 into the lower cylinder portion 30*b*. Accordingly, the parts of the apparatus will come to rest without any sudden shock blows being struck against portions of the cylinder 30, which might damage the apparatus. However, the upper cylinder 30*a* above the piston structure 70 will still contain gas under relatively high pressure (which may be as high as 7500 p. s. i.), which pressure could remain trapped within the cylinder until the setting tool C is withdrawn from the well bore to the top of the hole. Extreme care must be exercised in releasing this gas pressure at the top of the hole, during disassembly of the setting tool, to obviate a dangerous condition and to prevent injury to persons and damage to property.

The present invention provides for the automatic relieving of the gas pressure into the well bore, and of the pressure in the intervening liquid medium 38 between the upper piston structure 70 and the lower piston 39, following the completion of the operation in the well bore, such as determined by release of the shearable connector pin 48, which will disconnect the setting tool C from the well packer A.

To secure the automatic relieving of the pressure in the well tool C, following the release of the connector pin 48, communication is established between the interior of the cylinder 30 and the surrounding well bore. It is to be noted that the intermediate cylinder head 33 is provided with a comparatively large diameter passage 36, this head having one or more side bleeder ports 76 establishing communication between the passage 36 and the exterior of the cylinder. Initially the bleeder or release port or ports 76 are closed by an internal sleeve valve 77 slidable in the passage. This sleeve valve initially occupies an upper position in the passage 36 to close the bleeder port 76, being releasably retained in this closed position by a split expansible snap ring 78 contained within a peripheral groove 79 in the sleeve valve and partially received within an opposed companion interval groove 80 in the intermediate head 33. The upper and lower sides 81 of the snap ring are tapered, converging toward each other in a lateral outward direction for cooperation with companion tapered side walls 82 in the internal groove 80 in the intermediate head. The tapered sides 81, 82 are provided to secure retraction of the snap or latch ring 78 from the intermediate head groove 80 when the sleeve valve 77 is to be shifted within the head passage 36.

Leakage of fluid between the exterior of the sleeve valve 77 and the head 33, and out through the relief port 76, is prevented by a plurality of side seal rings 83 disposed in ring grooves 84 on the periphery of the sleeve valve and sealingly engaging the wall of the intermediate head passage 36 on opposite sides of the bleeder port. The sleeve valve has a central passage 85 extending throughout its length to allow the intervening liquid between the upper piston structure 70 and the lower piston 39 to flow therethrough, this liquid passing from the upper cylinder 30*a*, down through the sleeve valve passage 85 and the intermediate head passage 36 therebelow, continuing on through the orifice 74 and into the lower

cylinder 30*b*. For a purpose that will be described, the upper portion 77*a* of the sleeve valve 77 above its seal rings is substantially reduced in diameter, to provide an annular clearance space 86 between the sleeve valve and the surrounding wall of the intermediate head passage 36. At the lower end of its reduced diameter portion the sleeve valve has one or more side ports 87 extending completely through it, which establish communication between the central passage 85 through the sleeve valve and the surrounding annulus 86.

The upper floating piston structure 70 includes the main piston portion 71 having the seal rings 72 previously referred to. A piston stem 88 is threaded upwardly into the piston, this stem carrying a seal ring 89 for engagement with the piston to prevent leakage through the threaded stem and piston connection. The stem 88 depends from the piston 71, both the piston and the stem having a central passage 90 extending from the upper end of the piston and terminating above the lower end of the piston stem. One or more side ports 91 extend through the piston stem to establish communication between the piston and stem passage 90 and the exterior of the piston stem. These side ports 91 are initially closed by an outer sleeve valve 92 slidable along the exterior of the stem and initially occupying a lower position in engagement with a shoulder 93 formed at the lower end of the stem 88. When in this position, the sleeve valve 92 is disposed across the stem ports 91, to close the latter. Leakage between the sleeve valve and the piston stem is prevented by the provision of side seal rings 94 in peripheral grooves 95 in the stem on opposite sides of the ports 91 which sealingly engage the inner surface of the sleeve valve member 92.

Initially, the sleeve valve 92 is disposed over the ports 91 to prevent fluid passage from the upper cylinder 30*a* above the floating piston structure 70 to the cylinder portion therebelow. When the sleeve valve 92 is in this position, the upper piston structure 70 is, in effect, an imperforate member. Accordingly, as the gas under pressure in the upper cylinder 30*a* above the piston structure acts downwardly on the latter, it will shift it downwardly in the cylinder 30, forcing the liquid 38 therebelow down through the sleeve valve 77 in the intermediate head, which is then latched across bleeder ports 76, the fluid passing through the orifice 74 to the lower cylinder 30*b* for action on the lower piston 39, securing the setting of the well packer A in the well bore. The sleeve valve 77 remains in its closed position across the bleeder ports 76 during the entire time that the well packer is being anchored in packed-off condition in the well casing and until after the connector pin 48 has been disrupted, to release the setting tool C from the well packer A. When this occurs, the load on the setting tool has been released, which will then allow the floating piston structure 70 to move downwardly under the impetus of the gas under pressure thereabove, until the lower end of the piston stem 88 enters an enlarged counterbore 96 in the intermediate head and engages the upper end of the inner sleeve valve 77. Continued downward movement of the piston structure 70 will then cause the latch or snap ring 78 to be retracted completely within its groove 79, to move the inner sleeve valve 77 downwardly within the passage 36. After only slight downward movement has occurred, the outer sleeve valve 92 on the stem engages a shoulder 97 defining the lower end of the counterbore 96, which will prevent further downward movement of such sleeve valve. However, the piston 71 and the piston stem 88 can continue to move downwardly, the piston stem entering the passage 36 in the intermediate head 33 below the counterbore, continuing to push the inner sleeve valve 77 downwardly. During such downward movement, the stem or ports 91 will be shifted below the outer sleeve valve 92 to open position, establishing communication between the cylinder above the piston structure 70 and the bleeder port 76, the gas being capable of flowing down through the central passage 90 and out through the stem port 91, continuing on down around the exterior of the stem 88 and the exterior of the reduced diameter portion 77*a* of the sleeve valve 77, the seals 83 of the latter by then having been moved below the bleeder ports 76.

The piston 71 and stem 88 can move downwardly relative to the outer sleeve valve 92 to push the inner sleeve valve 77 downwardly to the extent limited by engagement of the piston 71 with the upper end of the outer sleeve valve 92, or possibly by engagement of the inner sleeve valve 77 with the intermediate head 33 at the lower end of its passage 36.

The parts will now occupy the position illustrated in Fig. 3, from which it is evident that not only is communication established between the interior of the cylinder 30 above the piston structure 70 and the exterior of the cylinder through the bleeder ports 76, but communication is also established between the lower cylinder 30*b* above the lower piston 39 and the bleeder ports 76, the fluid being capable of flowing up through the orifice 74 into the passage 36 and through the central passage 85 in the inner sleeve valve, discharging laterally through the ports 87 of the latter and out through the bleeder ports 76.

To offer assurance that the sleeve valve 77 can be shifted in the manner described, one or more cross slots 98, 99 may be provided across the lower end of the piston stem and also across the lower end of the outer sleeve 92, so that these members, when they engage the upper end of the inner sleeve valve 77 and the counterbore shoulder 97, respectively, will not entrap any liquid between the upper piston 71 and intermediate head 33 and in the annulus 86 between the piston stem 88 and the cylinder sleeve 31. Despite the engagement of the outer sleeve 92 with the counterbore shoulder 97, the liquid in the cylinder therearound can still be forced by the piston 71 through the sleeve cross slots 99 and down into the passage 86 around the inner sleeve valve 77, this liquid either passing inwardly through the cross slots 98 in the lower end of the stem 88 or through the inner sleeve valve ports 87 to the central passage 85 of the inner sleeve valve, and thence down through the orifice 74 into the lower cylinder 30*b*. If desired, cross slots 100 may also be provided in the upper end of the outer sleeve valve member 92 to insure against inadvertent assembly of this sleeve valve in an inverted position on the piston stem 88.

By virtue of the construction described, both the gaseous medium in the upper cylinder 30*a* above the upper piston structure 70 and the liquid 38 are placed in communication with the well bore surrounding the cylinder 30. Accordingly, the pressure in the cylinder 30 can be reduced, to correspond to the hydrostatic pressure in the well bore. As the setting tool C is elevated toward the top of the hole, then the pressure in the cylinder will gradually bleed out and be substantially at atmospheric when the tool is lifted to the top of the well bore. As this condition is approached, any air that might have been compressed in the lower cylinder 30*b* below the lower piston 39 can reexpand, to force the intervening liquid 38 out through the bleeder or relief ports 76.

In the absence of any pressure in the cylinder 30, the setting tool can be disassembled without fear of damage caused by sudden release of pressure, as in prior art devices.

The inventor claims:

1. In well apparatus: a well device adapted to be operated in a well bore; cylinder and piston means for operating said well device in the well bore; means adapted to provide a gas under pressure within said cylinder and piston means to actuate said cylinder and piston means, whereby said cylinder and piston means operate said well device; said cylinder having a lateral passage

extending from its exterior to its interior on the high pressure side of said piston means; means initially closing said passage; and means responsive to predetermined movement of said piston means in said cylinder for opening said closing means, whereby said gas under pressure can pass through said passage to the exterior of said cylinder.

2. In well apparatus: a well device adapted to be operated in a well bore; cylinder means and piston means within said cylinder means for operating said well device in the well bore; means adapted to provide a fluid under pressure within said cylinder means to shift said piston means relatively in said cylinder means to operate said well device; said cylinder means having a lateral passage extending from its exterior to its interior on the high pressure side of said piston means; shiftable valve means closing said passage; and means operated by said piston means for shifting said valve means to open position, whereby said gas under pressure can pass through said passage to the exterior of said cylinder means.

3. In well apparatus: a well device adapted to be operated in a well bore; cylinder means and piston means within said cylinder means for operating said well device in the well bore; means adapted to provide a gas under pressure within said cylinder means on one side of said piston means to shift said piston means relatively in said cylinder means to operate said well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston means; shiftable valve means closing said passage; means providing a normally closed by-pass within said cylinder means from said one side to said other side of said piston means; means responsive to movement of said piston means in said cylinder means for opening said by-pass; and means responsive to movement of said piston means in said cylinder means for shifting said valve means to open position, whereby said gas under pressure can pass from said one side of said piston means to the exterior of said cylinder means.

4. In well apparatus: a well device adapted to be operated in a well bore; cylinder means and piston means within said cylinder means for operating said well device in the well bore; means adapted to provide a gas under pressure within said cylinder means on one side of said piston means to shift said piston means relatively in said cylinder means to operate said well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston means; shiftable valve means closing said passage; means providing a by-pass passage in said piston means from said one side to said other side of said piston means; valve means normally closing said by-pass passage; means responsive to movement of said piston means in said cylinder means for shifting one of said valve means to open position; and means responsive to movement of said piston means in said cylinder means for shifting the other of said valve means to open position, whereby said gas under pressure can pass from said one side of said piston means to the exterior of said cylinder means.

5. In well apparatus: a well device adapted to be operated in a well bore; cylinder means and piston means within said cylinder means for operating said well device in the well bore; means adapted to provide a fluid under pressure within said cylinder means on one side of said piston means to shift said piston means relatively in said cylinder means to operate said well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston means; shiftable valve means closing said passage; means providing a normally closed by-pass within said cylinder means from said one side to said other side of said piston means; means responsive to movement of said piston means in said cylinder means for shifting said valve means to open position; and means responsive to movement of said piston means in said cylinder means

for opening said by-pass, whereby said fluid under pressure is releasable from said one side of said piston means to the exterior of said cylinder means.

6. In well apparatus: a well device adapted to be operated in a well bore; cylinder means and piston means within said cylinder means for operating said well device in the well bore; means adapted to provide a fluid under pressure within said cylinder means on one said of said piston means to shift said piston means relatively in said cylinder means to operate said well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston means; shiftable valve means closing said passage; means providing a by-pass passage in said piston means from said one side to said other side of said piston means; valve means normally closing said by-pass passage; means responsive to movement of said piston means in said cylinder means for shifting one of said valve means to open position; and means responsive to movement of said piston means in said cylinder means for shifting the other of said valve means to open position, whereby said fluid under pressure is releasable from said one side of said piston means to the exterior of said cylinder means.

7. In well apparatus: a well device adapted to be operated in a well bore; cylinder means and piston means within said cylinder means for operating said well device in the well bore; means adapted to provide a fluid under pressure within said cylinder means on one side of said piston means to shift said piston means relatively in said cylinder means to operate said well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston means; a shiftable sleeve valve in said cylinder means initially closing said passage; means providing a by-pass passage in said piston means from said one side to said other side of said piston means; a shiftable sleeve valve on said piston means normally closing said by-pass passage; means operable by said piston means and movable relatively in said cylinder means for shifting one of said sleeve valve means to passage opening position; and means operable by said piston means and moving relatively in said cylinder means for shifting the other of said sleeve valves to passage opening position, whereby said fluid under pressure can pass from said one side of said piston means to the exterior of said cylinder means.

8. In well apparatus for operating a well device in a well bore: cylinder means and piston means within said cylinder means for operating the well device in the well bore; means adapted to provide fluid under pressure within said cylinder means on one side of said piston means to shift said piston means relatively in said cylinder means to operate the well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston means; shiftable valve means normally closing said passage; means providing a normally closed by-pass within said cylinder means from said one side to said other side of said piston means; means responsive to movement of said piston means in said cylinder means for shifting said valve means to open position; and means responsive to movement of said piston means in said cylinder means for opening said by-pass, whereby said fluid under pressure can pass from said one side of said piston means to the exterior of said cylinder means.

9. In well apparatus for operating a well device in a well bore: cylinder means and piston means within said cylinder means for operating the well device in the well bore; means adapted to provide fluid under pressure within said cylinder means on one side of said piston means to shift said piston means relatively in said cylinder means to operate the well device; said cylinder means having a passage extending from its exterior to its interior on the other side of said piston

means; shiftable valve means normally closing said passage; means providing a by-pass passage in said piston means from said one side to said other side of said piston means; valve means normally closing said by-pass passage; means responsive to movement of said piston means in said cylinder means for shifting one of said valve means to open position; and means responsive to movement of said piston means in said cylinder means for shifting the other of said valve means to open position, whereby said fluid under pressure can pass from said one side of said piston means to the exterior of said cylinder means.

10. In well apparatus for operation in a well bore: fluid actuated means comprising a lower cylinder device; a lower piston device in said lower cylinder device; an upper cylinder secured to one of said devices; an upper piston device in said upper cylinder; means providing a fluid passage between said upper cylinder and lower cylinder device for an intervening fluid medium adapted to be contained in said upper cylinder, lower cylinder device and passage; means supplying a fluid under pressure in said upper cylinder to shift said upper piston device relatively in said upper cylinder and cause said upper piston device to force the fluid medium in said upper cylinder through said passage into said lower cylinder device to shift one of said lower devices relative to the other of said lower devices; and means for automatically releasing said fluid under pressure from said upper cylinder into the well bore upon movement of said upper piston device to a predetermined extent.

11. In well apparatus for operation in a well bore: fluid actuated means comprising a lower cylinder device; a lower piston device in said lower cylinder device; an upper cylinder secured to one of said devices; an upper piston device in said upper cylinder; means providing a fluid passage between said upper cylinder and lower cylinder device for an intervening fluid medium adapted to be contained in said upper cylinder, lower cylinder device and passage; means supplying a fluid under pressure in said upper cylinder to shift said upper piston device relatively in said upper cylinder and cause said upper piston device to force the fluid medium in said upper cylinder through said passage into said lower cylinder device to shift one of said lower devices relative to the other of said lower devices; and means for automatically releasing said fluid under pressure and intervening fluid medium from said upper cylinder and lower cylinder device into the well bore upon movement of said upper piston device to a predetermined extent.

12. In well apparatus for operation in a well bore: fluid actuated means comprising a lower cylinder device; a lower piston device in said lower cylinder device; an upper cylinder secured to one of said devices; an upper piston device in said upper cylinder; means providing a fluid passage between said upper cylinder and lower cylinder device for an intervening fluid medium adapted to be contained in said upper cylinder, lower cylinder device and passage; means supplying a fluid under pressure in said upper cylinder to shift said upper piston relatively in said upper cylinder and cause said upper piston device to force the fluid medium in said upper cylinder through said passage into said lower cylinder device to shift one of said lower devices relative to the other of said lower devices; said fluid actuated means having a lateral passage for releasing said fluid under pressure into the well bore; means normally closing said lateral passage; and means responsive to shifting of one of said piston devices for opening said lateral passage, whereby said fluid under pressure can pass from the interior of said upper cylinder to the exterior of said upper cylinder.

13. In well apparatus for operation in a well bore: fluid actuated means comprising a lower cylinder device; a lower piston device in said lower cylinder device; an upper cylinder secured to one of said devices; an upper piston device in said upper cylinder; means providing a fluid passage between said upper cylinder and lower cylinder device for an intervening fluid medium adapted to be contained in said upper cylinder, lower cylinder device and passage; means supplying a fluid under pressure in said upper cylinder to shift said upper piston device relatively in said upper cylinder and cause said upper piston device to force the fluid medium in said upper cylinder through said passage into said lower cylinder device to shift one of said lower devices relative to the other of said lower devices; said fluid actuated means having a lateral passage for releasing said fluid under pressure and said fluid medium into the well bore; means normally closing said lateral passage; and means responsive to shifting of said upper piston device for opening said lateral passage, whereby said fluid under pressure can pass from the interior of said upper cylinder to the exterior of said upper cylinder.

14. In well apparatus for operation in a well bore: a lower cylinder; a lower piston in said lower cylinder; an upper cylinder secured to said lower cylinder; an upper piston in said upper cylinder; means providing a fluid passage between said upper and lower cylinders for an intervening fluid medium adapted to be contained in said upper cylinder, passage, and lower cylinder; means supplying a fluid under pressure in said upper cylinder to shift said upper piston relatively in said upper cylinder and cause said upper piston to force the fluid medium in said upper cylinder through said passage into said lower cylinder to shift said lower piston relatively in said lower cylinder; means providing a lateral passage communicable with the exterior of said cylinders and with said cylinders between said pistons; valve means normally closing said lateral passage; and means responsive to shifting of said upper piston in said upper cylinder for shifting said valve means to open position, whereby said fluid under pressure can pass from the interior of said upper cylinder to the exterior of said upper cylinder.

15. In well apparatus for operation in a well bore: a lower cylinder; a lower piston in said lower cylinder; an upper cylinder secured to said lower cylinder; an upper piston in said upper cylinder; means providing a fluid passage between said upper and lower cylinders for an intervening fluid medium adapted to be contained in said upper cylinder, passage, and lower cylinder; means supplying a fluid under pressure in said upper cylinder to shift said upper piston relatively in said upper cylinder and cause said upper piston to force the fluid medium in said upper cylinder through said passage into said lower cylinder to shift said lower piston relatively in said lower cylinder; means providing a lateral passage communicable with the exterior of said cylinders and with said cylinders between said pistons; valve means normally closing said lateral passage; means providing a normally closed by-pass within said upper cylinder for the flow of said fluid under pressure from said upper cylinder on the high pressure side of said upper piston to said upper cylinder on the other side of said upper piston; means responsive to shifting of said upper piston in said upper cylinder for shifting said valve means to open position; and means responsive to shifting of said upper piston in said upper cylinder for opening said by-pass, whereby said fluid under pressure can pass from the interior of said upper cylinder to the exterior of said upper cylinder.

16. In well apparatus for operation in a well bore: a lower cylinder; a lower piston in said lower cylinder; an upper cylinder secured to said lower cylinder; an upper piston in said upper cylinder; means providing a fluid passage between said upper and lower cylinders for an intervening fluid medium adapted to be contained in said upper cylinder, passage, and lower cylinder; means supplying a fluid under pressure in said upper cylinder to shift said upper piston relatively in said

upper cylinder and cause said upper piston to force the fluid medium in said upper cylinder through said passage into said lower cylinder to shift said lower piston relatively in said lower cylinder; means providing a lateral passage communicable with the exterior of said cylinders and with said cylinders between said pistons; a sleeve valve normally closing said lateral passage; means providing a normally closed by-pass within said upper cylinder for the flow of said fluid under pressure from said upper cylinder on the high pressure side of said upper piston to said upper cylinder on the other side of said upper piston; means responsive to shifting of said upper piston in said upper cylinder for opening said by-pass; and means on said upper piston engageable with said sleeve valve for shifting said sleeve valve to open position upon relative movement of said upper piston in said upper cylinder.

17. In well apparatus for operation in a well bore: a lower cylinder; a lower piston in said lower cylinder; an upper cylinder secured to said lower cylinder; an upper piston in said upper cylinder; means providing a fluid passage between said upper and lower cylinders for an intervening fluid medium adapted to be contained in said upper cylinder, passage, and lower cylinder; means supplying a fluid under pressure in said upper cylinder to shift said upper piston relatively in said upper cylinder and cause said upper piston to force the fluid medium in said upper cylinder through said passage into said lower cylinder to shift said lower piston relatively in said lower cylinder; means providing a lateral passage communicable with the exterior of said cylinders and with said cylinders between said pistons; a sleeve valve normally closing said lateral passage; means providing a by-pass passage in said upper piston for the flow of said fluid under pressure from said upper cylinder on the high pressure side of said upper piston to said upper cylinder on the other side of said upper piston; a sleeve valve normally closing said by-pass; said upper piston being movable within said upper cylinder to engage said first-mentioned sleeve valve to open said lateral passage and to engage said second-mentioned sleeve valve with one of said cylinders to open said by-pass.

18. In well apparatus: a well device adapted to be operated in a well bore; fluid actuated means including shiftable instrumentalities for operating said well device in the well bore; means adapted to provide a gas under pressure within said fluid actuated means to shift said instrumentalities, whereby said fluid actuated means operates said well device; and means on the high pressure side of said instrumentalities operable in response to predetermined shifting of said instrumentalities in operating said well device for releasing said gas under pressure from the interior of said fluid actuated means laterally into the well bore externally of said fluid actuated means.

19. In well apparatus: a well device adapted to be operated in a well bore; fluid actuated means including shiftable instrumentalities for operating said well device in the well bore; means adapted to provide a gas under pressure within said fluid actuated means to shift said instrumentalities, whereby said fluid actuated means operates said well device; said fluid actuated means having a lateral passage extending from its exterior to its interior on the high pressure side of said instrumentalities; means initially closing said passage; and means operable in response to predetermined shifting of said instrumentalities in operating said well device for opening said closing means, whereby said gas under pressure can pass through said passage to the exterior of said fluid actuated means.

20. In well apparatus for operating a well device in a well bore: fluid actuated means including shiftable instrumentalities for operating the well device in the well bore; means adapted to provide a gas under pressure within said fluid actuated means to shift said instrumentalities; and means on the high pressure side of said instrumentalities for releasing said gas under pressure from the interior of said fluid actuated means laterally into the well bore externally of said fluid actuated means in response to movement of said instrumentalities to a predetermined position.

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