

## [54] REMOVABLE SUBSEA PRODUCTION TEST VALVE ASSEMBLY

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[51] Int. Cl. .... E21b 33/00

[58] Field of Search ..... 166/.5, .6, 72, 315, 224, 166/224.8; 251/315; 137/81

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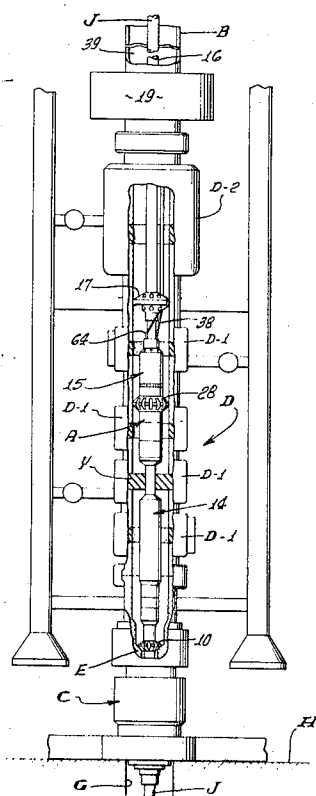
Attorney, Agent, or Firm—Bernard Kriegel

## [57]

## ABSTRACT

A test valve assembly is adapted to be incorporated in a tubing or drill pipe string lowered from a drilling vessel or platform to dispose the lower portion of the string in an underwater or subsea well bore, and the test valve assembly in a subsea blowout preventer stack which is suitably actuated to close around the assembly. The assembly includes one or more lower ball valves pressure actuated to open position from the vessel or platform to permit well testing, and also an upper latch mechanism releasably secured to the valve portion of the assembly. Relieving of the pressure effects closing of the one or more valves, permitting the latch mechanism to be released and removed with the upper portion of the tubing or drill pipe string to the vessel or platform. A blind ram of the blowout preventer stack can be closed above the lower portion of the test valve assembly. The pistons controlling the valves are pressure balanced, the valves being adapted to permit reverse flow around them when in closed condition. The assembly further embodies a pressure actuated piston capable of forcing a lower ball valve to closed position, and, in so doing, cutting a wire line which may have parted above the assembly, and which would otherwise hold the ball valve open.

43 Claims, 19 Drawing Figures



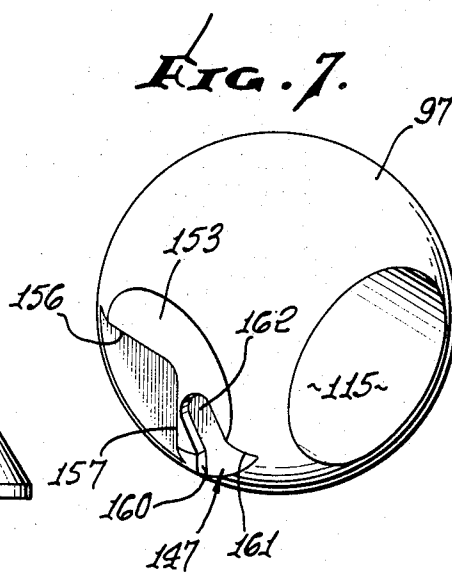
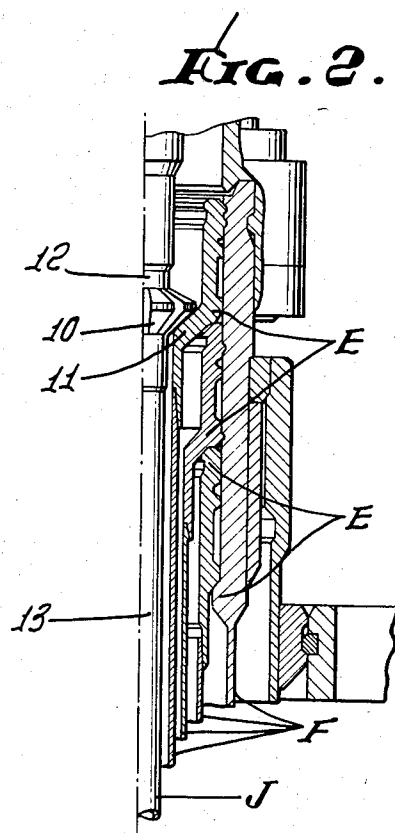
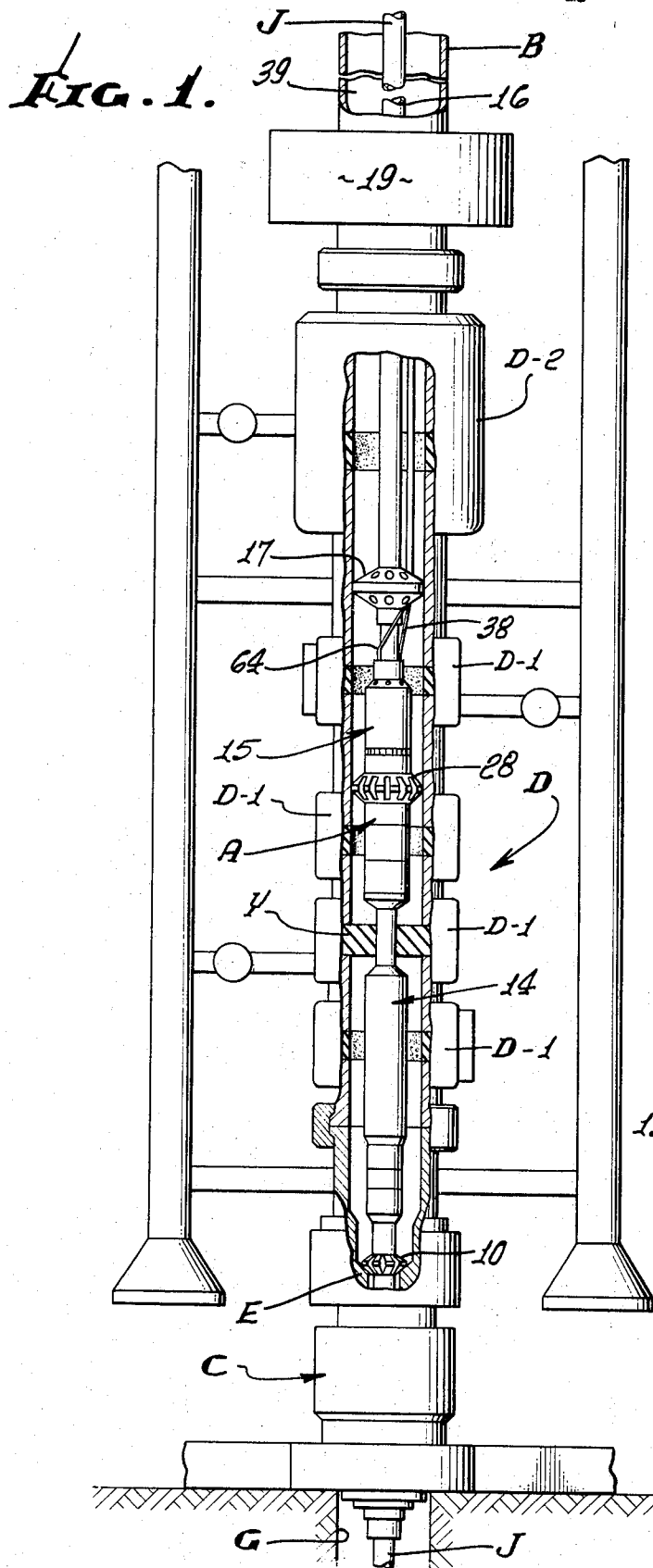


FIG. 3a.

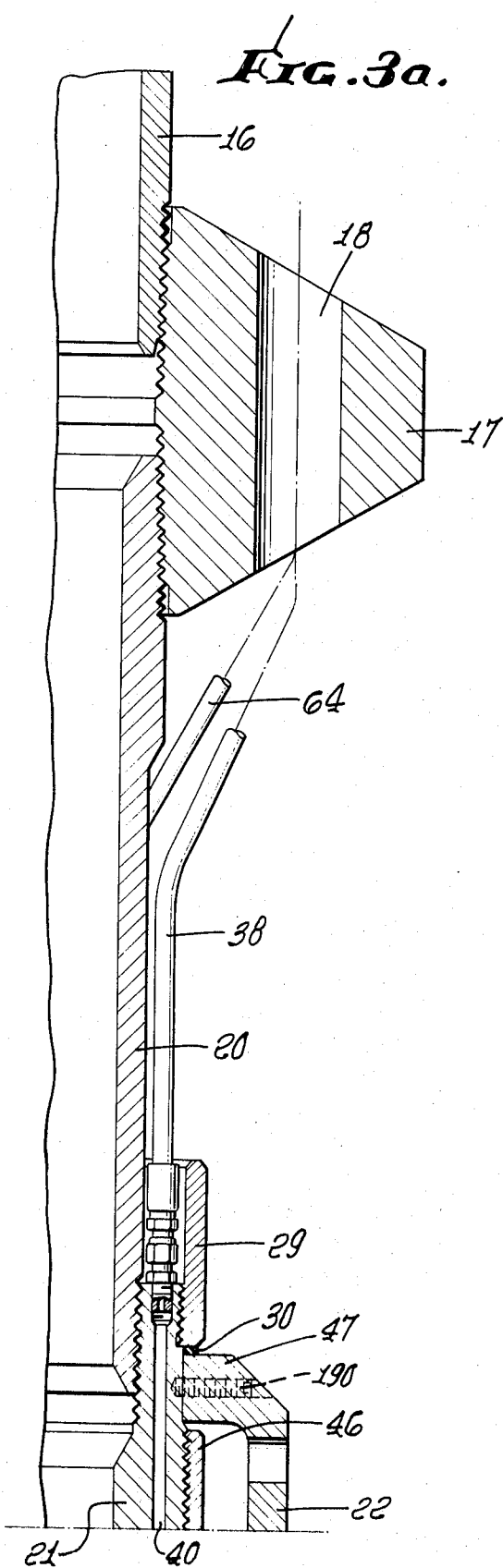


FIG. 3b.

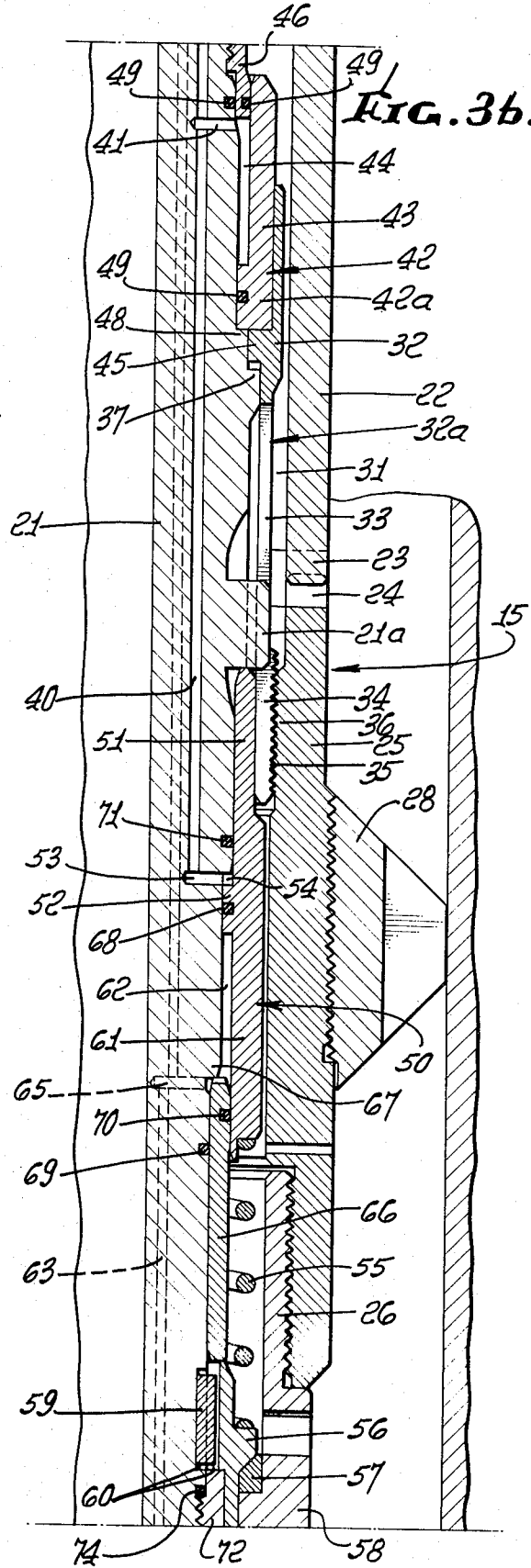


Fig. 3c. *72*

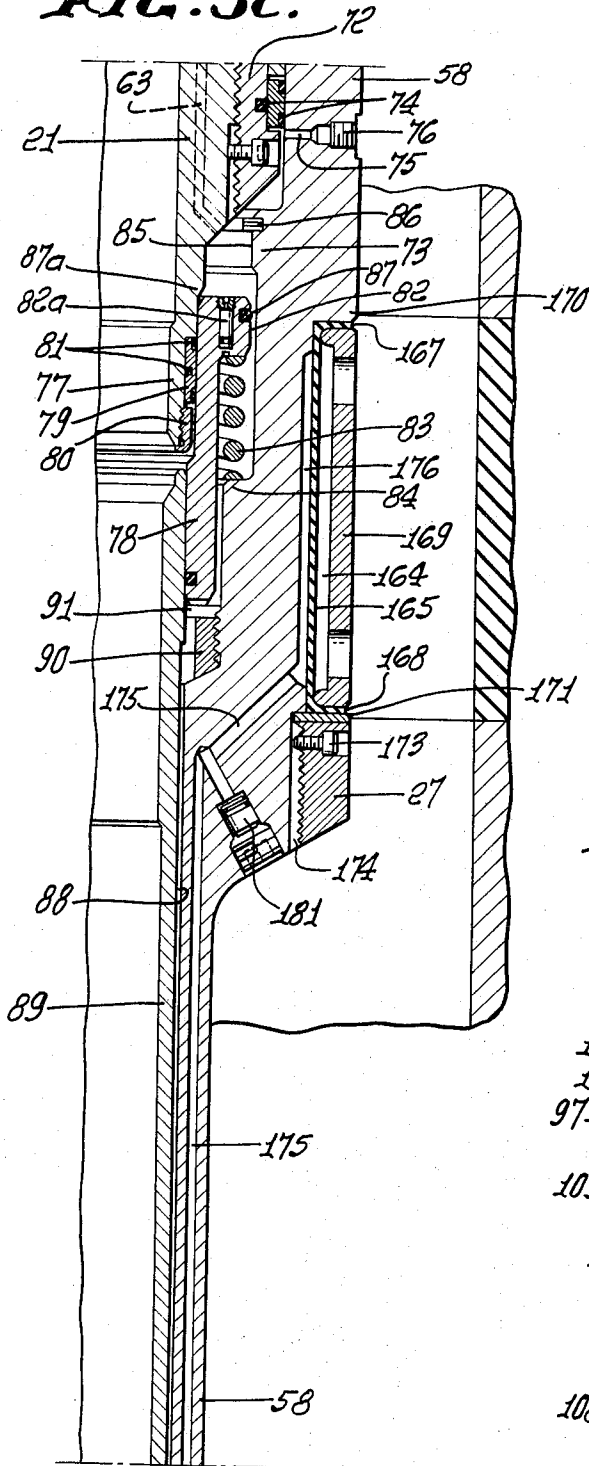


FIG. 3d.

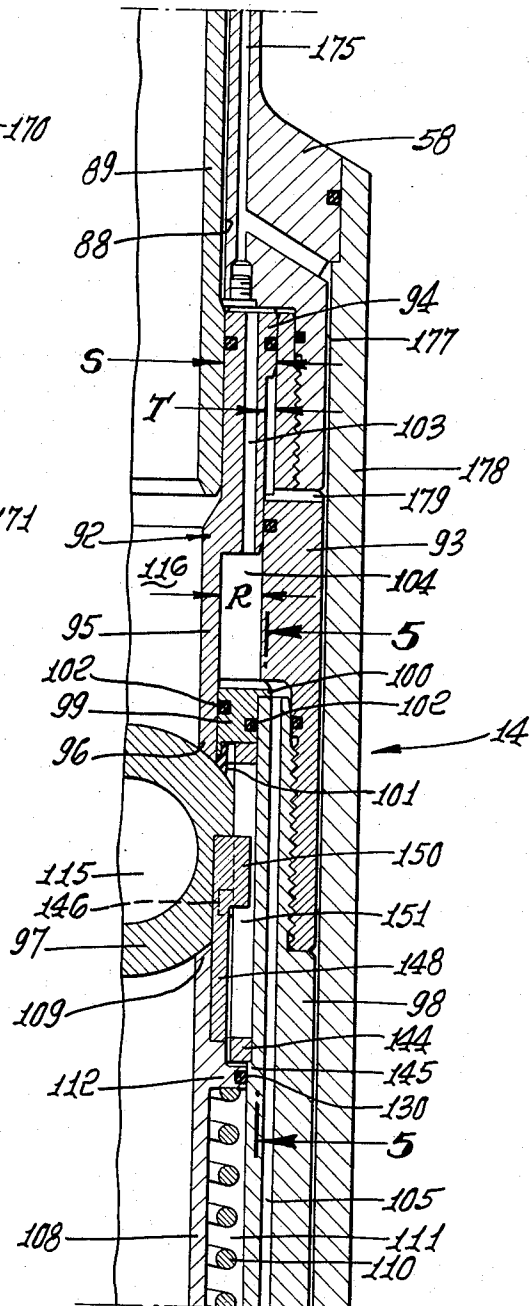


FIG. 3e.

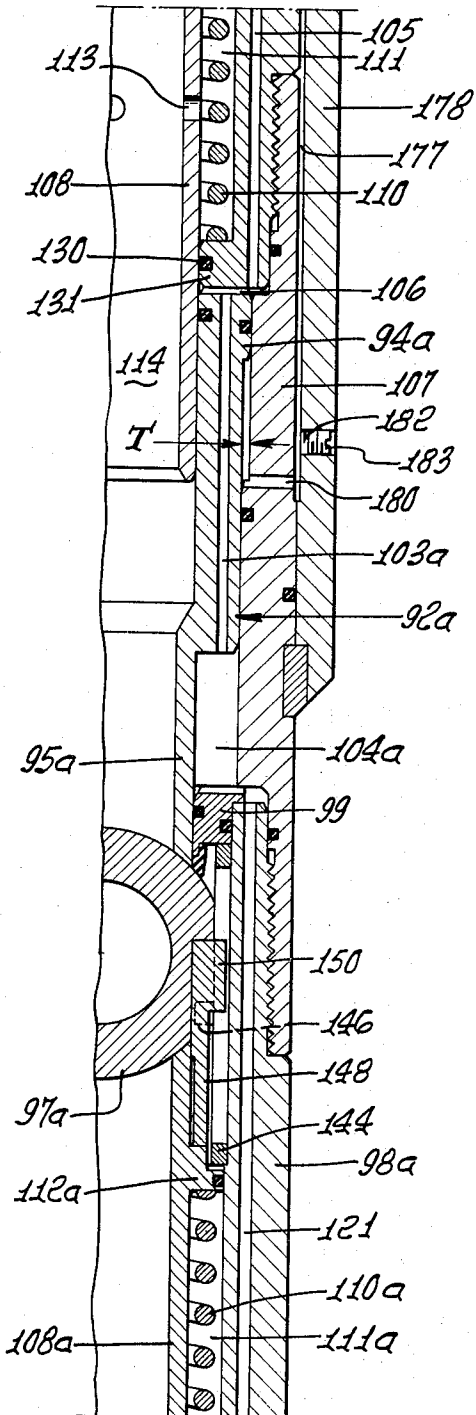


FIG. 3f.

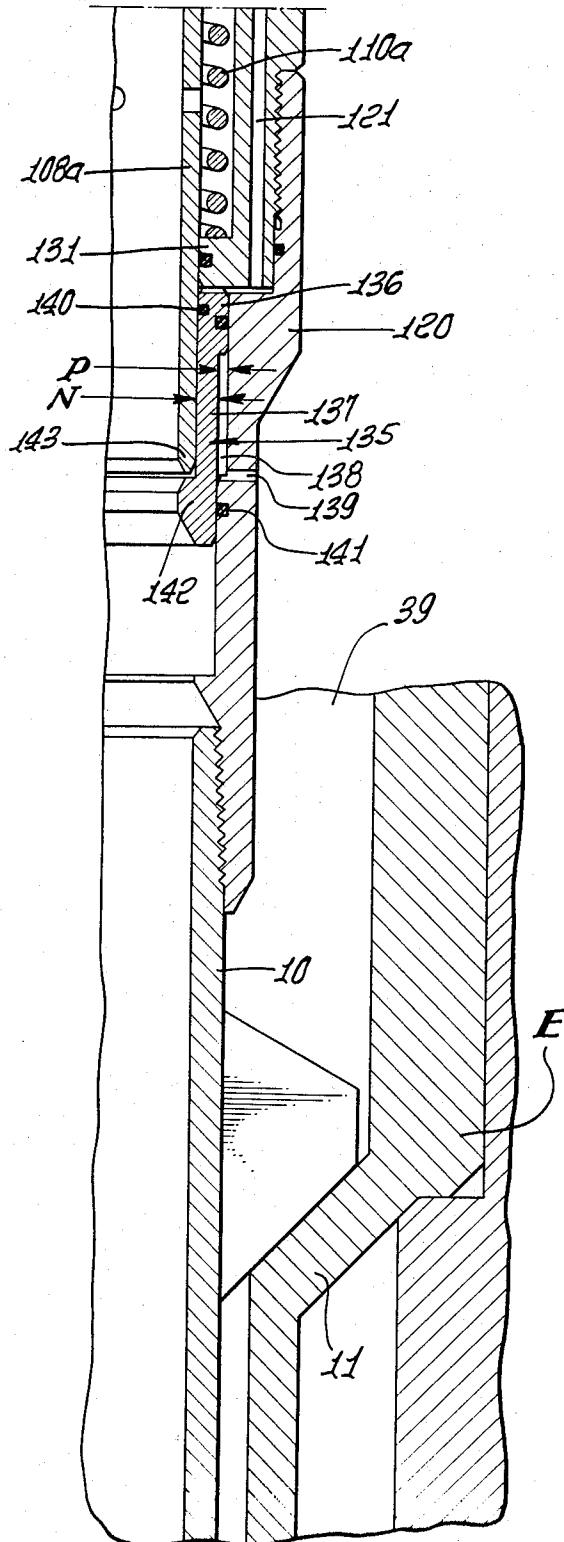


FIG. 4a.

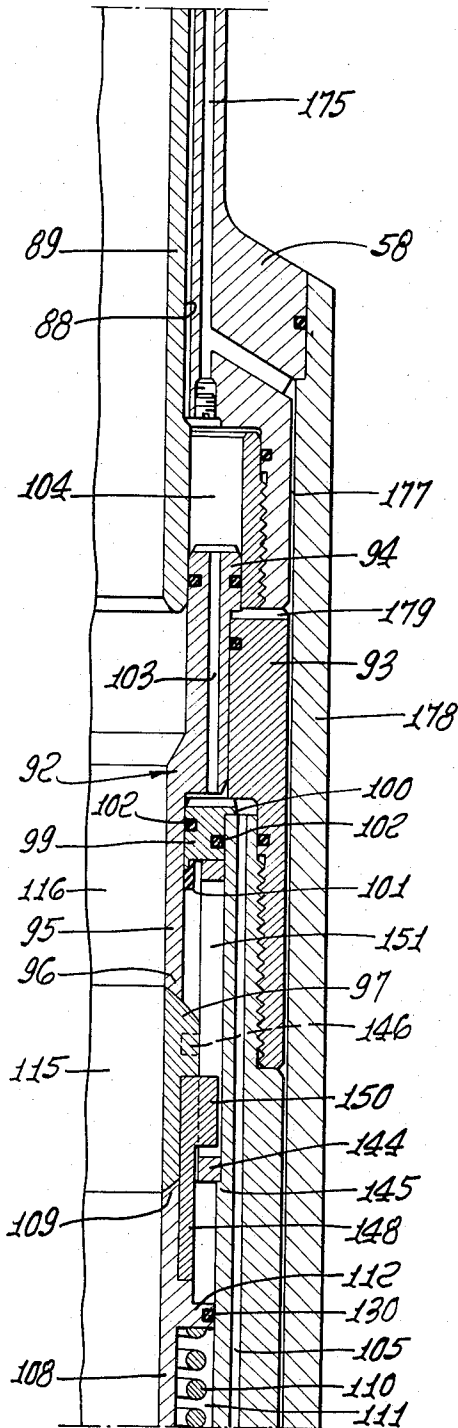


FIG. 4b.

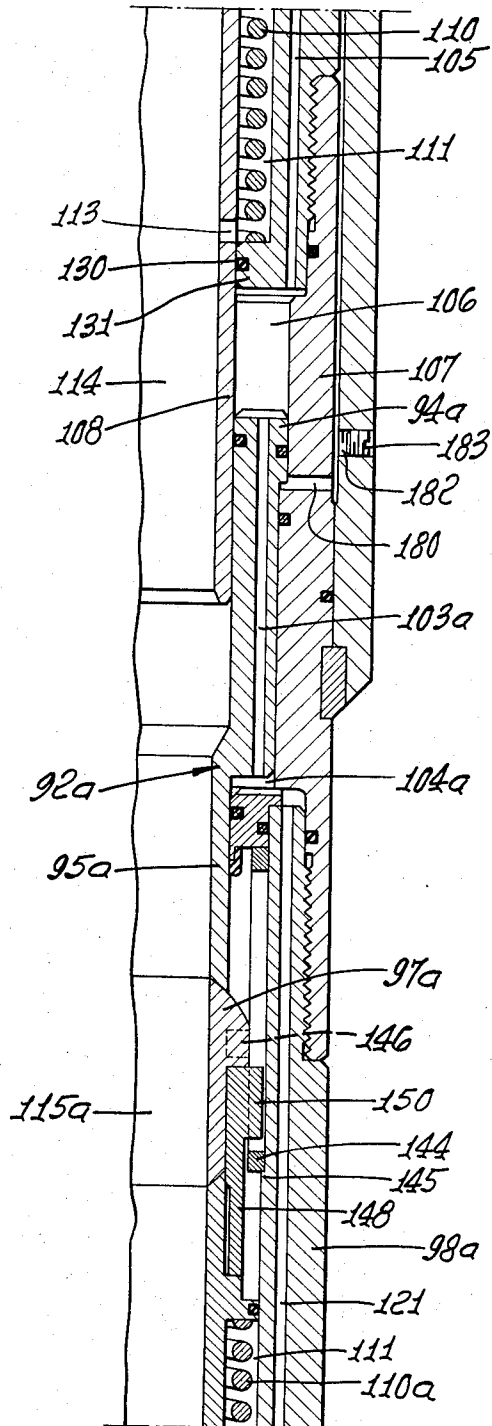


FIG. 4c.

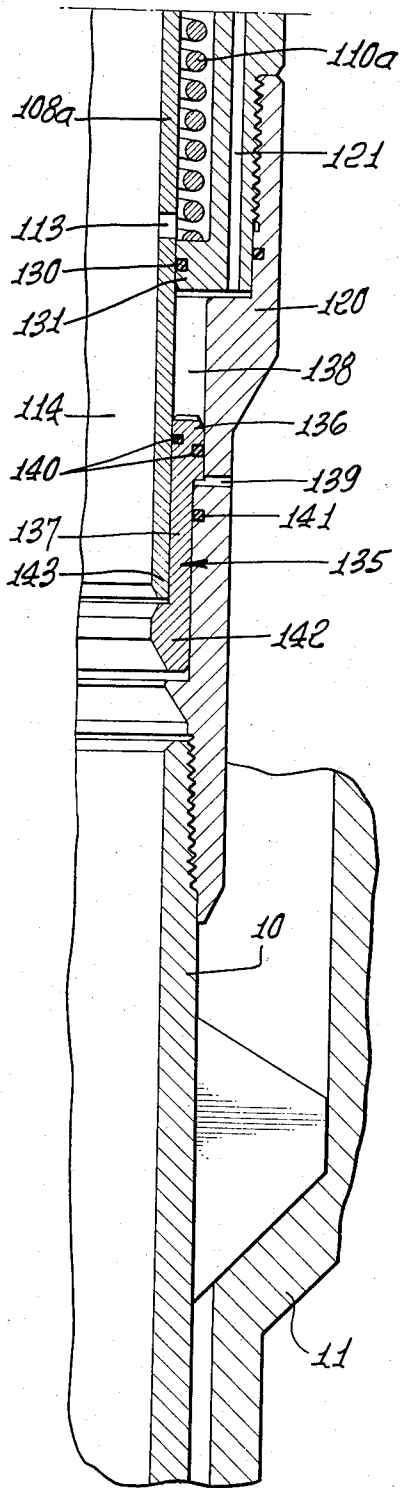


FIG. 8.

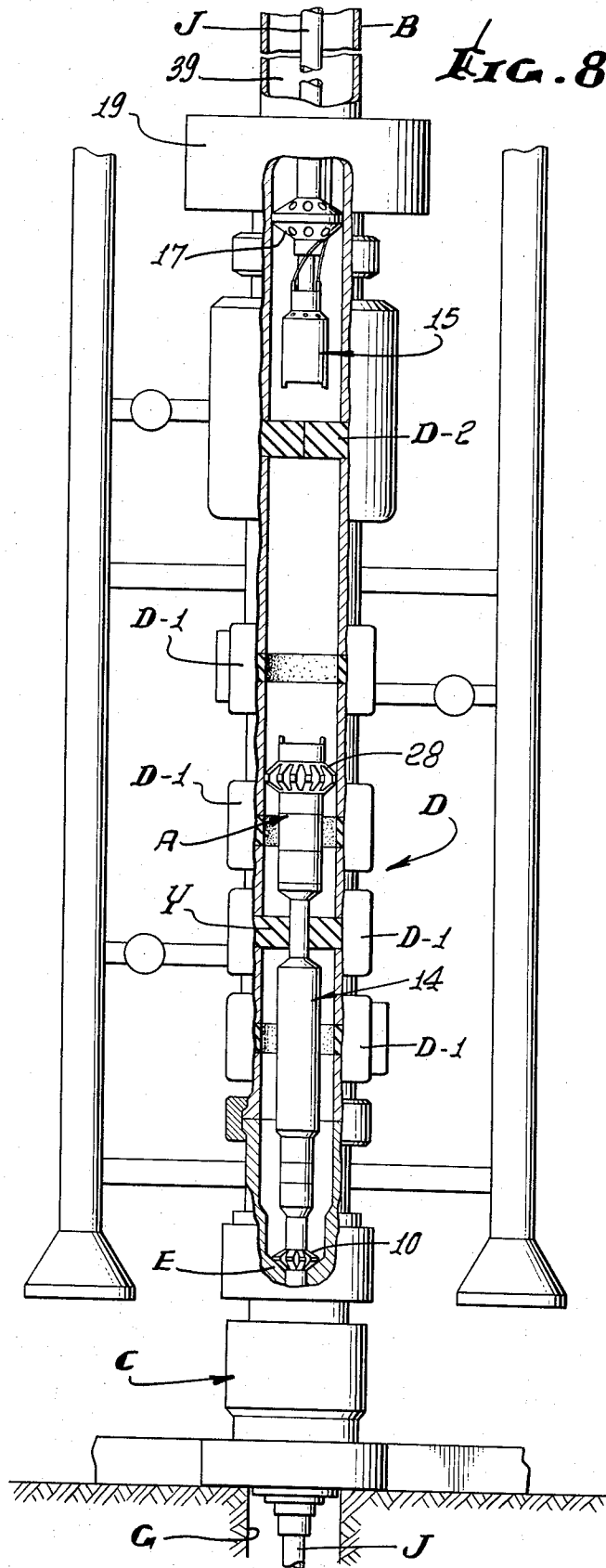


FIG. 6.

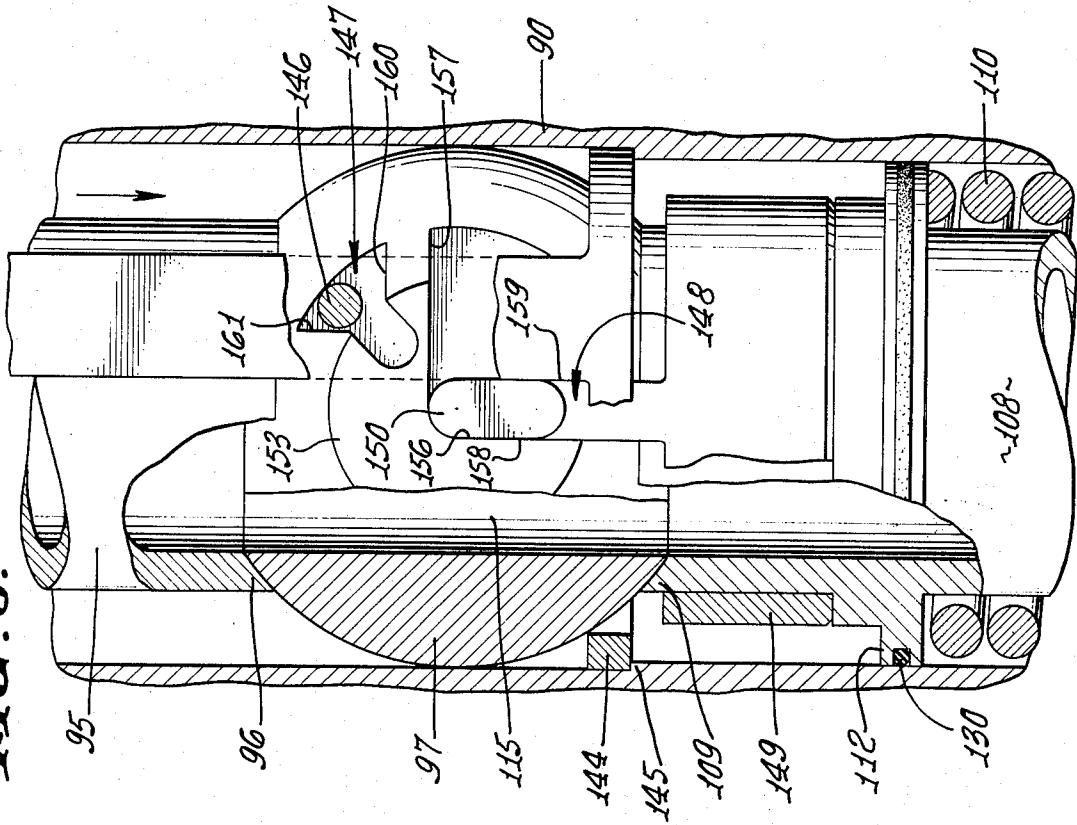


FIG. 5.

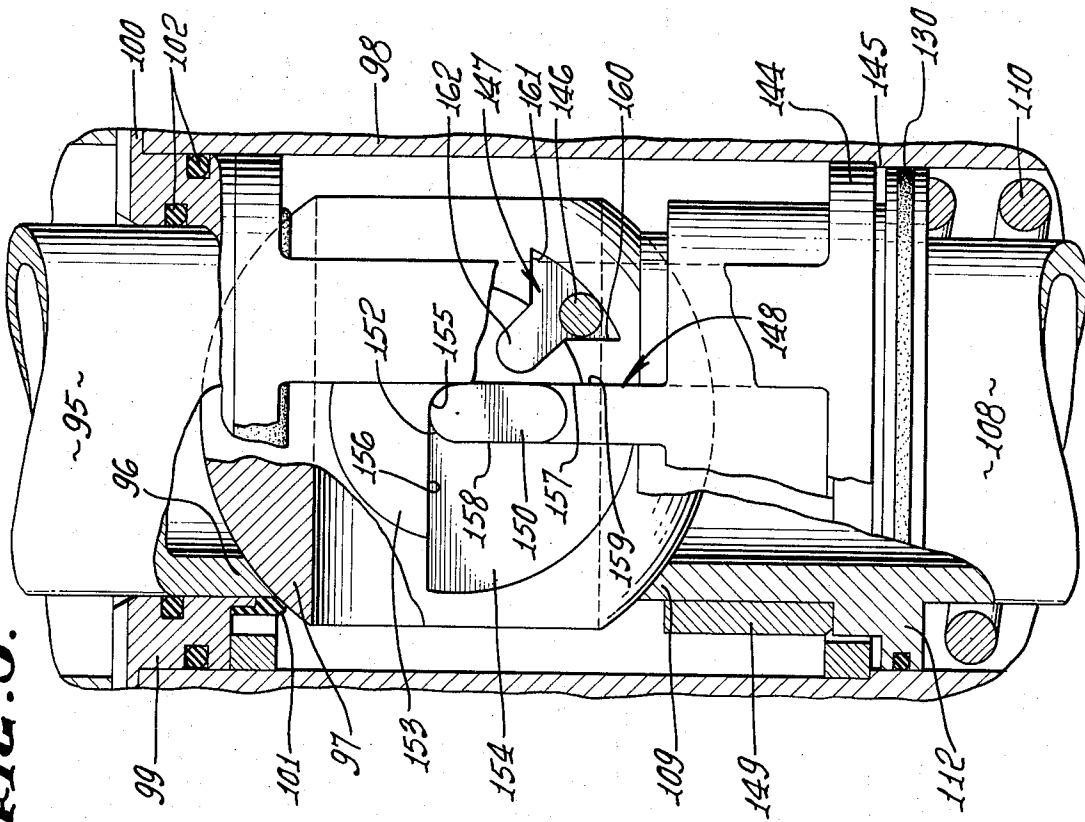


FIG. 9a.

FIG. 9b.

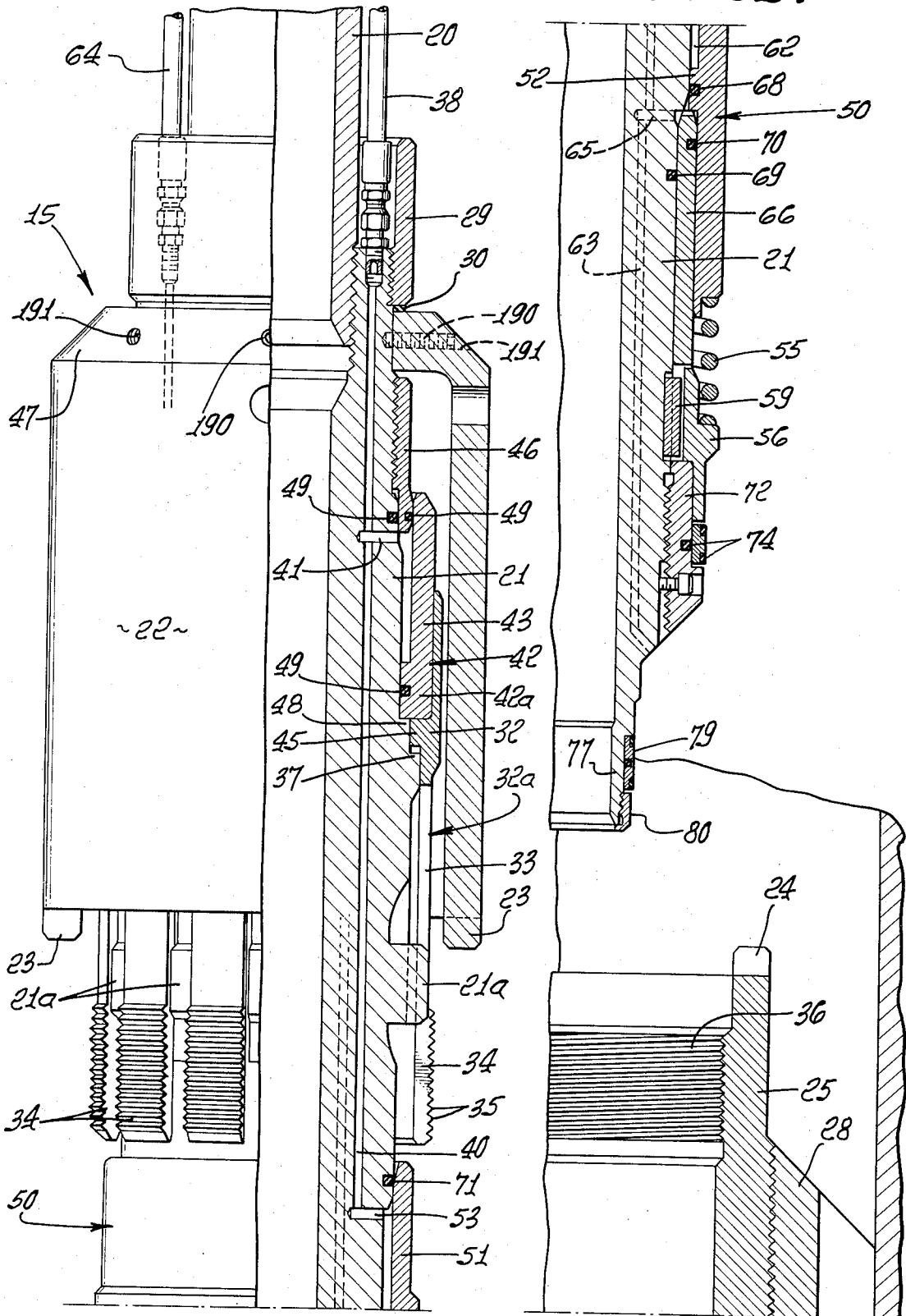


Fig. 9c.

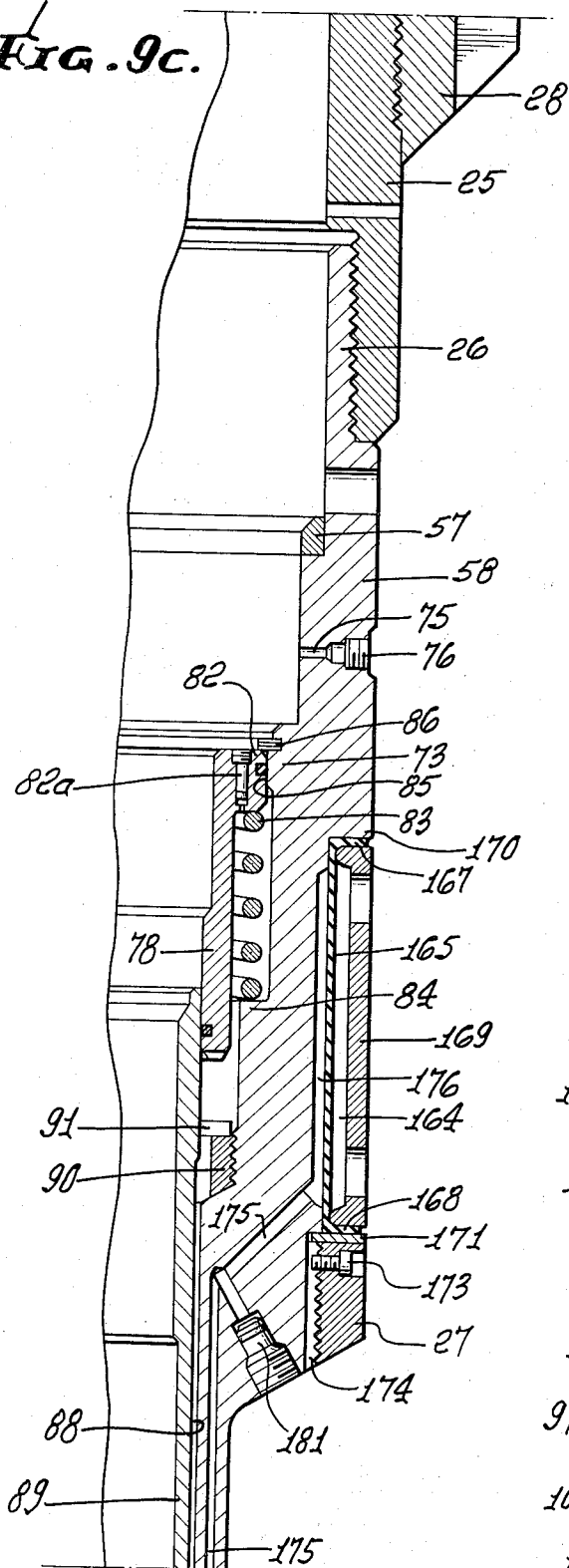
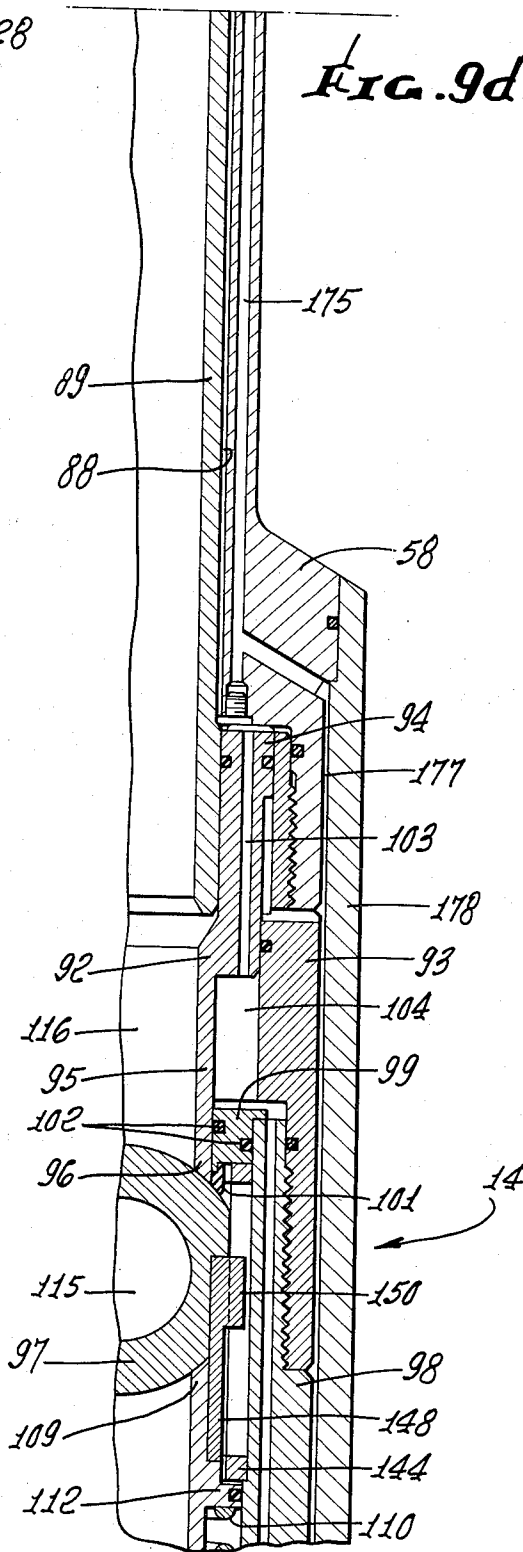


Fig. 9d.



## REMOVABLE SUBSEA PRODUCTION TEST VALVE ASSEMBLY

The present invention relates to apparatus for performing well bore tests, and more particularly to subsea well bore test apparatus adapted to be located in a blowout preventer stack.

A removable subsea test tree is known adapted to be located in a blowout preventer stack and which has an upper releasable latch assembly to permit the drill pipe or other tubular string above the test tree to be released from the valve portion when the latter is in a closed condition, permitting removal of the tubular string thereabove and the temporary abandonment of the well in the event that high seas or inclement weather makes it necessary, or desirable, to do so. More specifically, one or more valves are placed in an open condition by fluid pressure pumped down a hydraulic control line extending from a drilling vessel to the tree disposed in the blowout preventer stack. The hydraulic pressure control line also extends from the drilling vessel to the releasable connection. When pressure is applied through the line, the connection is released.

In apparatus embodying the present invention, one or more ball valves are provided in series, each valve being placed in open position by pressure pumped from the drilling vessel or platform through a control line to a piston that effects actuation of an associated ball valve. One of the objects of the present invention is to provide a piston that is pressure balanced to avoid the necessity for overcoming the hydrostatic head of fluid surrounding the test valve assembly. Additionally, by virtue of the apparatus, reverse flow can occur through each of the valve mechanisms to kill the well despite the fact that each ball valve is in closed position.

The apparatus also has the capability of having torque transmitted through it for the purpose of setting a well packer in the well bore without effecting disengagement of the latch mechanism that releasably interconnects the tubular string above the apparatus from the apparatus itself.

The releasable latch of the apparatus can be released hydraulically, or mechanically in the event hydraulic pressure is unavailable, as by rotating the tubular string to the right and without the requirement for placing the tubular string in tension. The latch cannot be released, so long as the ball valve (or valves if more than one is used) is open, since pressure applied to the valve piston for holding the valve open is also applied to the latch mechanism to retain it in a locked condition. It is the absence of pressure applied to the apparatus for maintaining a ball valve in open condition that permits the latch mechanism to be released.

A further object of the invention is to provide a subsea production test valve embodying a mechanism for effecting a cutting action on a wire line which has parted above the valve assembly, and which would tend to hold the valve of the apparatus open since it extends through it; that is, until the wire line is removed by cutting through it. More specifically, the well pressure is utilized to apply a force too a piston that is transmitted to a portion of the mechanism which shifts the ball valve to a closed position, and in so doing causes the ball valve itself to cut the interfering wire line.

A further objective of the invention is to provide a removable subsea production test valve assembly that is comparatively short, and which enables the apparatus to be disposed within a blowout preventer stack

having rams, or the like, that are closed around the tool and blind rams, or the like, located above the tool after its upper portion has been released to effect a full and complete closure across the stack above the apparatus.

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.

Referring to the drawings:

FIG. 1 is a diagrammatic view of the test valve assembly disposed in a blowout preventer stack adjacent a subsea floor from which a well bore depends, parts being shown in section and parts in side elevation;

FIG. 2 is an enlarged quarter longitudinal sectional view of the casing head portion of the apparatus disclosed in FIG. 1;

FIGS. 3a, 3b, 3c, 3d, 3e and 3f in combination are a quarter longitudinal sectional view of the test valve assembly on an enlarged scale, FIGS. 3b, 3c, 3d, 3e and 3f being lower continuations of FIGS. 3a, 3b, 3c, and 3e, respectively, the valve portion of the apparatus being in closed condition;

FIGS. 4a, 4b and 4c are views corresponding to FIGS. 3d, 3e and 3f with the valve portion in an open condition, FIGS. 4b and 4c being lower continuations of FIGS. 4a and 4b, respectively;

FIG. 5 is an enlarged longitudinal section and side elevational view of one of the valve devices, the valve being in closed condition;

FIG. 6 is a view similar to FIG. 5 with the valve device in an open condition;

FIG. 7 is an isometric view of one of the ball valve members embodied in the apparatus;

FIG. 8 is a view similar to FIG. 1, disclosing the upper or latch portion of the apparatus released from the ball valve portion of the apparatus, and with the uppermost blowout preventer in closed condition;

FIGS. 9a, 9b, 9c and 9d are views corresponding to FIGS. 3a, 3b, 3c and 3d illustrating the latch portion of the apparatus released from the shutoff valve portion of the apparatus.

The embodiment of the invention illustrated in the drawings includes a removable underwater or subsea test valve apparatus A which can be lowered from a platform or floating drilling vessel (not shown) through a marine riser B releasably connected to a casing hanger assembly C disposed at the subsea or ocean floor H, the test valve apparatus being positionable within a blowout preventer stack D. As shown, a plurality of casing hangers E are supported one upon each other, different size casing strings F depending from the hangers and extending into the well bore G depending from the ocean or subsea floor, all in a known manner. A tubular string J, such as drill pipe or tubing, extends into the well bore, being supported by a tubing hanger 10 resting upon a seat 11 of the uppermost casing hanger E. The test valve assembly A is suitably connected to the upper end 12 of the lower tubular string portion 13, this assembly including a valve portion 14 that can be shifted between open and closed positions, and an upper latch mechanism or portion 15 releasably secured thereto and connected to the upper portion 16

of the tubular string that extends through the marine riser B to the drilling vessel or platform.

The blowout preventer stack D includes a plurality of blowout preventers D-1, D-2 of a known type or types, which are arranged in series and adapted to close around different diameters of tubular devices disposed therewithin. The uppermost blowout preventer D-2 consists of a blind ram adapted to be closed across the full diameter of the blowout preventer passage after the upper portion 16 of the tubular string and the latch mechanism 15 have been removed, as described hereinbelow.

The latch portion of the apparatus includes an upper guide 17 secured to the lower end of the upper portion 16 of the tubular string, this guide having circumferentially spaced longitudinal passages 18 therethrough to facilitate lowering of the guide through the liquid in the marine riser, a releasable connector 19 secured to the lower end of the riser B securing the latter to the upper portion of the blowout preventer stack D. Such releasable connectors are of a known type, a detailed illustration thereof being unnecessary to an understanding of the present invention. The guide 17 is threaded, or otherwise suitably secured, to an upper body sub 20, the lower end of which is threadedly secured to a stinger body 21 disposed within an upper torque sub 22 having a plurality of clutch dogs 23 at its lower end adapted to coact with upwardly extending clutch dogs 24 on the upper end of a lower torque sub 25 forming part of the test valve apparatus. The lower torque sub is threadedly attached to an elongate landing head 26 carrying a bearing ring 57 thereon. A slotted body guide 28 is affixed to the torque sub 25.

An upper torque sleeve 29 is adjustably and threadedly disposed on the upper portion of the stinger body 21, its lower end engaging a friction bearing 30 that bears upon the upper end of the upper torque sub 22.

Disposed in an annular space 31 between the stinger body 21 and the upper torque sub 22 is a latch device 32a, including an upper latch sleeve portion 32 from which depend a plurality of arms 33 terminating in lower threaded latch fingers 34 having external threads 35 thereon adapted to mesh with companion internal threads 36 in the lower torque sub 25. Preferably, the threads are left hand. Downward movement of the latch 32a is limited by engagement of its sleeve portion 32 with an upwardly facing shoulder 37 on the stinger body. The latch is urged downwardly of the stinger body hydraulically by virtue of fluid under pressure conducted through a latch control line 38, extending from the drilling vessel or platform through the annular space 39 between the marine riser and the upper tubular string 16, the lower end of which is suitably secured to the upper end of the stinger body 21, communicating with an elongate passage 40 in the stinger body. A side port 41 extends from the passage 40 to the interior of a latch return piston 42 slidable along the periphery of the stinger body and an upper skirt portion 43 spaced from the periphery of the latch body to provide an annular space 44 communicating with the port. The piston is disposed within the latch sleeve 32, its lower end engaging an internal flange 45 of the latter. It is also slidable along a spacer sleeve 46 fixed to the body 21, the upper end of which is disposed below an inwardly directed flange 47 of the upper torque sub. Downward movement of the piston along the stinger body is prevented by its engagement with a companion upwardly

facing shoulder 48 on the body. Suitable seals 49 are provided between the stinger body 21 and the spacer sleeve 46 and piston 42, head 42a and also between the spacer sleeve 46 and the piston skirt 43 to prevent fluid leakage from the annular space 44 to the exterior of the piston 42 and the spacer sleeve 46, as well as between the spacer sleeve and the stinger body 21 itself. Upon applying pressure to the fluid in the latch control line 38, the latch return piston 42 is urged in a downward direction forcing the latch 32a itself to its lowermost position along the stinger body 21.

The latch mechanism includes a latch lock piston 50 shiftable longitudinally along the stinger body and having an upper portion 51 adapted to be disposed behind the latch fingers 34 to retain them fully meshed with the internal threads 36 of the lower torque sub 25. The upper portion 51 of the latch piston is slidable along the stinger body 21, the piston including an inwardly directed head 52 slidable along a smaller diameter portion of the stinger body. A side port 53 extends from the fluid passage 40 in the body into the annular space 54 between the body and the latch lock piston head. When pressure is applied to the fluid in the latch control line 38 and the passage 40 communicating therewith, such pressure shifts the latch lock piston 50 downwardly from its locking position behind the latch fingers 34, freeing the latter and permitting them to flex inwardly and out of meshing engagement with the internal threads 36 in the lower torque sub. Such downward movement of the lock piston occurs against the force of a helical compression spring 55, the upper end of which engages the piston 50, and the lower end of which engages a stinger bearing 56 seated upon a bearing ring 57 carried in the upper portion of a landing head 58. Torque can be transmitted from the stinger body 21 to the stinger bearing 56 through a key 59 fitting into opposed grooves 60 in the bearing and the stinger body.

The lock piston 50 has a lower skirt 61 depending from its head 52 and providing an annular space 62 with the stinger body into which fluid can pass from a valve control passage 63 communicating with a control line 64 connected to the upper portion of the body 21 and which extends upwardly through the annular space 39 between the tubular string 16 and marine riser B to the drilling vessel or platform. The passage 63 in the stinger body (only the lower portion of which is shown) has a side port 65 communicating with the annular space 62 between the lower piston skirt 61 and the stinger body 21, such that such fluid under pressure shifts the latch lock piston 50 upwardly to its locked position behind the latch fingers 34 to retain the latter meshed with the internal threads 36 in the lower torque sub 25. The lower lock piston skirt 61 is slidable downwardly along a spring guide 66 surrounding the stinger body, the upper end of this guide engaging a shoulder 67 on the stinger body, the lower end engaging the upper end of the stinger bearing 56. Fluid under pressure in the control passage 63 and annular space 62 is prevented from leaking from such space by a suitable seal ring 68 on the piston head slidably and sealingly engaging the periphery of the stinger body, by a seal ring 69 on the stinger body engaging the spring guide 66, and by a seal ring 70 on the spring guide in relative slidable engagement with the inner wall of the lower piston skirt 61. Similarly, fluid under pressure is prevented from leaking upwardly between the upper lock piston skirt 51

and the stinger body 21 by a side seal 71 on the latter sealingly engaging the upper skirt. The spring guide 66 and stinger bearing 56 are retained in appropriate position by a seal retainer 72 threaded on the stinger body and bearing against the stinger bearing to hold the latter against the spring guide, which, in turn, engages the body shoulder 67.

The control passage 63 extends downwardly within the stinger body and opens into an upper valve head portion 73 of the landing head 58. Fluid from the control passage and head 73 is prevented from leaking upwardly by suitable seal rings 74 between the body and seal retainer 72, between the seal retainer and stinger bearing 56, and between the latter and the landing head 58. To facilitate the filling of the control passage 63 with fluid, a port 75 is provided, adapted to be closed by a suitable pipe plug 76, and extending from the exterior of the landing head 58 to a position communicating with the head 73.

The lower end 77 of the stinger body 21 is of reduced diameter, being adapted to fit into an annular piston valve 78 mounted in the landing head 58. A sleeve 79 surrounds the body, being retained in position by a suitable retainer 80 threaded on the lower end of the body. This sleeve carries internal and external seals 81 to prevent leakage therearound when the lower portion 77 of the stinger body is disposed within the poppet or piston valve member 78.

The poppet valve includes an upper head 82 movable upwardly by a helical compression spring 83 extending between a lower spring seat 84 on the landing head and the head 82, urging the latter upwardly in a cylindrical seat 85 in the landing head portion 73, such upward movement being limited by engagement of the valve head 82 with a suitable snap retainer ring 86 disposed in the landing head. A seal ring 87 on the head engages the seat to prevent leakage therearound. When the stinger body 21 and the parts carried thereby are lowered into the lower torque sub 25 and landing head 58, the lower portion 72 of the stinger body becomes piloted in the poppet valve member 78, its shoulder 87a engaging the upper end of the valve member and shifting it downwardly against the force of the spring 83 out of engagement from its companion seat 85, permitting fluid in the control line passage 63 to flow around the poppet valve head 82 and into an annular passage 88 provided between the landing head 58 and a connector sleeve 89 disposed within the latter, this connector sleeve also extending upwardly within the poppet valve member 78. A ring 90 is threaded into the landing head which has radial slots 91 therethrough, and which is engaged by the poppet valve 78 to limit downward movement of the latter, while permitting fluid to flow into the annular space 88 between the connector sleeve and the landing head.

The lower portion of the connector sleeve is disposed within an upper annular piston 92 slidable longitudinally within an upper piston housing 93 threaded secured to the lower end of the landing head 58. The upper head 94 of this piston is slidable along its housing 93 and also along the connector sleeve 89, a lower skirt portion 95 spaced inwardly from the piston housing 93 providing an upper seat 96 engaging an upper ball valve member 97 rotatably supported within an upper ball housing 98 which is threadedly secured to the lower portion of the piston housing 93. The lower skirt 95 is slidable downwardly within a resilient seal ring 99 hav-

ing an upper flange 100 engaging the upper end of the ball housing and carrying a lower elastomer seal ring 101 adapted to engage the periphery of the spherical or ball valve member. Suitable inner and outer seals 102 are provided on the retainer ring 99 for sealing engagement with the piston skirt 95 and with the upper ball housing 98. A longitudinal passage 103 extends through the piston 92 from its upper head to the location of its skirt, permitting the control fluid to pass from the upper passage 88 into the annular space 104 between the skirt and piston housing, from where the fluid can flow laterally of the seal ring 99 into a control passage 105 extending through the upper ball housing 98 and into an annular cylinder 106 provided between a lower piston housing 107 threadedly secured to the upper ball housing 98 and a follower sleeve 108 having a seat 109 on its upper end adapted to engage the periphery of the upper ball 97.

A helical compression spring 110 is disposed in an annular space 111 between the follower sleeve and the upper ball housing 98, its lower end bearing against the latter and its upper end against an upwardly directed flange 112 of the follower sleeve. This sleeve has ports 113 extending through its wall to permit free passage of fluid between its interior and the annular space 111 containing the spring, which tends to shift or translate the upper ball 97 longitudinally within its ball housing, whereas the pressure acting on the upper piston 92 tends to shift the ball longitudinally downwardly within the housing 98. During such upward and downward longitudinal shifting of the ball, it rotates between open and closed conditions to open the passage 114 through the follower sleeve, the passage 115 through the ball, and the upper piston 116, or to prevent fluid from flowing between the upper follower sleeve passage 114 and the upper piston passage 116.

The follower sleeve 108 is piloted within a lower annular piston 92a disposed in the annular or cylinder space 106, the lower piston having an annular head 94a sealingly engaging the lower piston housing 107 and follower sleeve 108, and a reduced diameter lower skirt 95a engaging a lower ball valve member 97a disposed within a lower ball housing 98a threadedly secured to the lower piston housing 107 to a bottom sub 120. The lower ball housing 98a contains a lower ported follower sleeve 108a and a helical compression 110a 110a tending to urge the sleeve in an upward direction. Fluid can flow through a passage 103a extending through the lower piston 92a into the annular space 104a between its skirt and the lower piston housing, such fluid then being capable of passing through a longitudinal passage 121 extending through the lower ball housing 98a and into the sub 120 therebelow.

The lower ball valve assembly is essentially a duplicate of the upper ball valve assembly making a detailed description of the lower ball valve assembly unnecessary to an understanding of the invention. It is sufficient to point out that suitable seal rings are provided between each control piston 92, 92a and its companion housing 93, 107 and sleeve 89, 108 to prevent leakage of control fluid past the interiors and exteriors of each piston. It is further to be noted that the annular area S of each piston head 94, 94a across which control fluid under pressure can act is substantially greater than the area R of the annular space between the piston skirt 95, 95a and opposed housing wall providing a differential area T at the upper portion of each piston across which

control fluid under pressure can act for the purpose of shifting the piston downwardly within the housing, and, in so doing, longitudinally shifting its companion ball 97, 97a, the parts associated therewith, and the follower sleeve 108, 108a downwardly against the force of the spring 110, 110a, for the purpose of rotating the ball to its passage opening position, as illustrated in FIGS. 4a to 4c. Relieving of the control fluid pressure will permit each spring 110, 110a to act through its follower sleeve 108, 108a and shift the ball upwardly within its companion housing, as well as shifting its associated piston 92, 92a upwardly, whereupon the ball will rotate to its closed position (FIGS. 3d, 3e).

Suitable seal or wiper rings 130 are provided between each follower sleeve flange and its associated ball housing 98, 98a, between the lower portion of each follower sleeve and rearwardly directed flange portion 131 of each ball housing to prevent eddy currents.

The bottom sub 120 has an annular tubing piston 135 therein that has an upper head 136 slidable along the wall of the bottom sub, and also along the periphery of the lower follower sleeve 108a. This piston has a skirt portion 137 of a smaller external diameter than the piston head 136, providing an annular chamber 138 communicating through a port 139 with the exterior of the apparatus. Suitable inner and outer seal rings 140 are provided on the tubing piston head to prevent fluid leakage internally and externally of such head, whereas the bottom sub has a seal ring 141 therein below its port slidably and sealingly engaging the periphery of the skirt 137. The control fluid in the passage 121 can act downwardly on the tubing piston shifted to its downward position when the ball valves have been opened, as illustrated in FIG. 4c. The tubing piston has an inwardly directed flange 142 adapted to engage the lower end 143 of the lower follower sleeve 108a, such that upward shifting of the tubing piston 135 will cause it to move the follower sleeve 108a upwardly. This action can occur in the absence of control fluid pressure, the well pressure within the tubing string 13 acting over the area N of the tubing piston to shift it upwardly, and thereby cause it to shift the follower sleeve 108a upwardly. In the event that such pressure is insufficient to shift the follower sleeve upwardly to the desired extent, as described hereinbelow, the pressure in the annulus 39 between the tubular string and the marine riser can be increased, such pressure being imparted through the port 139 to the fluid in the annulus 138 surrounding the piston skirt and acting on its head 136 to shift the piston upwardly.

In order to support each ball valve 97, 97a and cause rotation thereof between its piston 92, 92a and sleeve 108, 108a, while minimizing friction between the spherical ball surface and the sealing end surfaces 96, 109 of the piston and sleeve, a cage 144 is mounted within the housing 98, 98a between a housing shoulder 145 and the retainer ring 99. Affixed to the cage are diametrically opposed pins 146 fitting within opposed slots or notches 147 in the ball valve, the pins being offset from the rotational axis of the ball 97, 97a for the purpose of rotating the latter between open and closed positions. As best shown in FIGS. 5 and 6, each ball is rotatable about a horizontal axis, being supported on elongate parallel follower arms 148, on opposite sides of the ball, extending upwardly from a support sleeve 149 resting on a follower sleeve 108, 108a and having lugs 150 slidable in vertical slots 151 in the cage. The

arms terminate in end portions 152 formed on a small radius struck from a center corresponding substantially with the axis of rotation of the ball.

On each of its opposite sides, the ball has a flat surface 153 in which the notch 147 is formed, such surface also having a recess or notch 154 terminating at an inner curved wall portion 155 formed on a radius substantially corresponding to the arm end portion 152 and engaging the latter, whereby the ball is supported on a complementary arched surface and closed positions in response to longitudinal or translational movement of the ball. In FIG. 5, the ball valve member is shown fully closed and sealed by the piston 96. In FIG. 6, the ball valve member has been rotated to the fully open position as a result of its being downwardly translated or shifted away from the resilient seal 101.

More particularly, the notch 154 on at least one side of the ball valve member is bounded by walls disposed in right angularly spaced locations, which form a first stop surface 156 and a second stop surface 157 cooperable with companion stop surfaces 158, 159 provided on the longitudinal parallel sides of an arm 148. To limit the rotation of the ball 97, 97a between the closed and open extreme positions illustrated in FIGS. 5 and 6, the stop surface 157 engages the stop surface 159, as shown in FIG. 5, thereby limiting rotation of the valve member to the position at which the valve is closed. The stop surface 156 engages stop surface 158, as shown in FIG. 6, to limit rotation of the valve member to the position at which the valve is opened.

Rotation of the ball valve between the open and closed positions is caused by its longitudinally or bodily translation relative to the cage 144 to which the pins 146 are affixed. As stated above, the ball is shifted or translated longitudinally by the annular piston 95, 95a and by the lower follower sleeve 108, 108a. The slot 147 into which each pin 146 projects is formed in such manner as to cause such rotation of the valve ball as the latter moves longitudinally within the cage 144 and the body 98, 98a. Thus, each slot is formed in the valve member by opposed walls, 160, 161 which are disposed at right angle to each other, and which, respectively, are parallel to the stop surfaces 156, 157 that coact with the follower arms 148. At the apex of the angle defined between the walls 160, 161, the slot opens radially inwardly to provide an inner portion 162. The relationship between each pin 146 and the walls 160, 161 is such that the ball valve will be rotated from the position of FIG. 5 to the position of FIG. 6 when the valve member moves downwardly relative to the pin by the piston 95, 95a. Conversely, the flat wall 160 will engage the pin 146 and rotate the ball valve member from the position of FIG. 6 to the position of FIG. 5 upon upward longitudinal movement of the valve member.

A further description of the relationship between the ball valve member and the follower arms and pins is unnecessary to an understanding of the present invention, being illustrated, described and claimed in the application of Talmadge L. Crowe, Ser. No. 303,623, filed Nov. 3, 1972 for "Anti-Friction Ball Valve Operating Means."

Both the upper and lower pistons 95, 95a that actuate the ball valves 97, 97a by the control pressure exerted through the control line 64, are pressure balanced with respect to the hydrostatic head of fluid in the annulus 39 between the upper tubular string 16 and the marine riser B. The landing head 58 has an external elongate

circumferential groove 164 formed therein, across which a diaphragm sleeve 165 of elastomer material is disposed, this sleeve having upper and lower flanges 167, 168. A diaphragm protector sleeve 169 is disposed around the diaphragm, its upper end bearing against the upper flange 167 to secure it against a downwardly facing shoulder 170 of the landing head; whereas, the lower end of the protector sleeve bears against the lower flange 168, forcing it against an annular disc 171. A diaphragm retainer 27 is threaded on the landing head 158 and bears against the annular disc 171 to effect a clamping of the upper flange 167 between the protector 169 and landing head shoulder 170, and the lower flange 168 between the protector 169 and the disc 171. Assurance is had against loosening of the diaphragm retainer 27 by threading a set screw 173 therein that extends within a longitudinal slot 174 in the landing head.

A longitudinally extending passage 175 is provided in the landing head 58 that establishes communication between the annulus 176 behind the diaphragm 165 and an annular space 177 between a housing 178 surrounding the lower end of the landing head 58, the upper piston housing 93, the upper ball housing 98, and the lower piston housing 107. A side port 179 in the upper piston housing extends from the annular space 177 to the annular space T in the upper piston housing below the piston head 94. A similar port 180 provides communication between the annular space 177 within the outer housing 178 and the annular space or area T below the head 94a of the lower piston.

The annular space behind the diaphragm 165, the passage 175 through the landing head, and the annular space 177 between the outer housing and the several housings therewithin, as well as the ports 179, 180 and the annular spaces T below the upper piston head 94 and the lower piston head 94a are all filled with a liquid which may be introduced from the exterior of the landing head through an inwardly opening check valve 181 (of any suitable type) disposed in the landing head 58 that opens into the passage 175. The check valve permits entry of fluid into the several pressure balancing regions, but prevents reverse flow therethrough. Filling the several regions just referred to is facilitated, and the entrapment of air prevented, by a lower port 182 in the outer housing 178 closed by threaded pipe plug 183 after the filling action has been completed.

As the apparatus is lowered through the fluid in the marine riser B and into its position within the blowout preventer stack D, the hydrostatic head of fluid externally of the apparatus exerts its force through the diaphragm 165 on the liquid in the several pressure balancing regions. This pressure is transmitted in an upward direction over the area T of the upper piston 92 and over the same area T of the lower piston 92a. The hydrostatic head of fluid in the control line 64 is being exerted over the full area of each upper piston head 94, 94a and also over the annular area R of the intermediate portion of each piston. This last-mentioned area is substantially equal to the area S across the piston head minus the annular area T against which the balancing liquid under pressure is acting. Accordingly, each piston is substantially pressure balanced with respect to the hydrostatic fluid acting on it. When the pressure is exerted through the control line 64, such pressure will act effectively over the outer annular area T of each piston head, exerting its downward force on both the

upper and lower pistons to effect shifting of the ball valves to open condition. The pressure required is not varied because of the depth at which the production test valve assembly A is installed in the blowout preventer stack D.

In the use of the apparatus, its bottom sub 120 is secured to the tubing hanger 10 from which the tubular string 13 therebelow depends. Usually, this tubular string will be connected to a well packer (not shown) set in the well casing F at a desired location, as above casing perforations communicating with a formation zone to be tested. The upper portion 15 of the apparatus is connected to the upper tubular string 16, by means of which the entire apparatus is lowered through the marine riser B, the blowout preventer stack D, the tubular string 13, with the well packer (not shown) secured thereto, moving downwardly into the innermost casing string F. Prior to lowering of the apparatus through the marine riser B, it is in coupled condition securing the lock portion 15 to the valve portion, with the latch lock piston 50 retained behind the latch fingers 34 by the latch spring 55. The control passage 64, 63 will be devoid of fluid, allowing the several springs 110, 110a to shift the follower sleeves 108, 108a upwardly, placing the ball valves 97, 97a in their closed conditions, as illustrated in FIGS. 3a to 3f. Prior to the lowering of the apparatus from the vessel or platform, a desired number of shear screws 190 will be threaded in holes 191 in the upper portion of the upper torque sub 22 and secured to the stinger body 21, thereby causing the upper torque sub to be rotated upon rotation of the upper tubular string portion 16 and the stringer body 21. This rotation and torque is transmitted through the interengaging clutch dogs 23, 24 and the lower torque sub 25 to the landing head 58, and through the several housings directly and indirectly secured thereto to the bottom sub 120, from where it is transmitted through the lower portion 13 of the tubular string, for the purpose of controlling and actuating the well packer secured thereto. The apparatus is lowered with all blowout preventers D in the open condition, until the landing head 10 engages its companion seat 11, at which time the apparatus will be disposed within the blowout preventer stack. One of the blowout preventers D-1 can then be closed by actuating its rams Y, which will close around a smaller diameter portion of the landing head, as disclosed in FIG. 1. Pressure can now be imposed on the fluid in the control line 64, which will pressure the fluid in the control passage 63, such fluid under pressure acting on the latch lock piston head 52 and holding the piston 50 to its upper locking position behind the latch fingers 34 to retain such lock fingers fully meshed with the internal threads 36 in the lower torque sub 25. The check or poppet valve 78 will have already been forced to its open position, as illustrated in FIG. 3c, as a result of piloting the stinger body portion 77 into the poppet valve member. The fluid pressure then acts through the control passages 88, 103, 105 downwardly on the upper and lower pistons 92, 92a, shifting them downwardly and also shifting the ball valves 97, 97a and the follower sleeves 108, 108a downwardly, the ball valves being rotated to the open condition illustrated in FIGS. 4a, 4b and 4c. The pressure also shifts the lowermost piston 135 downwardly to its fullest extent. So long as the control line pressure is maintained, the ball valves will be in their open condition. It is to be noted that the passage

115 through each ball valve is preferably the same in diameter as the passage through the tubular string J and the passages through the pistons 92, 92a, follower sleeves 108, 108a, which will permit necessary equipment to be lowered from the drilling vessel or platform through the apparatus A in the performance of testing and other operations.

In the event that adverse weather, or other conditions, dictate the rapid removal of that portion of the test string which is above the blowout preventer stack D, so that the marine riser B can be disconnected from the blowout preventer stack, and the drilling vessel be free to be moved from the well location, the control pressure in the line 64 is relieved, which causes the springs 110, 110a and the bottom hole pressure to shift the follower sleeves 108, 108a upwardly and elevate the ball valves 97, 97a to rotate them to their fully closed position, and with the ball valves engaging the resilient seals 101 to prevent leakage around the balls (FIGS. 3a to 3e). Pressure is then applied to the fluid in the latch control line 38 which acts downwardly on the latch lock piston head 52 and shifts the piston 50 downwardly against the force of its spring 55 completely from engagement with the latch fingers 34. An upward pull can be taken on the upper portion 16 of the tubular string J, which will raise the upper torque sub 22 from the lower torque sub 25, at the same time elevating the latch 32a and causing the latch fingers 34 to be cammed inwardly by the left hand threads 35, 36 to produce full disengagement of the latch fingers from the lower torque sub 25. The latch mechanism 15 is then in a position illustrated in FIGS. 9a, 9b, the stinger body 21 having been removed from the poppet valve member 78, all of the apparatus above the poppet valve member and within the landing head 58 then being elevated above the lower torque sub 25. When this occurs, the poppet valve spring 83 will shift it upwardly into a position within its cylindrical seat 85 to the extent limited by engagement of the member with the snap stop ring 86, thereby closing the control passages 88, 103, 103a, 121 in the landing head 58 and bodies from the pressure or action of the fluid thereabove. The upper portion 16 of the tubular string, the stinger body 21, latch 32a, lock piston 50, and the parts therebelow, can then be elevated through the marine riser B to the drilling vessel or platform (FIGS. 9a to 9d). The closed ball valves 97, 97a in connection with the closing of the annulus around the valve portion of the apparatus by the blowout preventer rams Y effectively closes all regions through which fluid can flow in an upward direction through the blowout preventer stack D. If desired, following the removal of the stinger body 21 and its associated mechanism, the blind rams of the uppermost blowout preventer D-2 can be actuated, such rams moving across the whole cross-sectional area of the blowout preventer to effect a full closing of the blowout preventer thereabove from the action of the water above the blowout preventer stack, after the connector 19 has been released and the marine riser B removed (FIG. 8).

In the event that the upper latch portion 15 of the apparatus cannot be released from its lower portion, due to the unavailability of fluid pressure to shift the latch lock piston 50 downwardly, mechanical release of the latch mechanism can still be performed. The tubular string 16 above the apparatus is rotated to the right without any tension being necessarily applied thereto,

and a torque applied to it in excess of the shear capacity of the shear screws or pins 190, which will be disrupted. The rotary effort and torque of the stinger body 121 will then be transmitted to the latch arms 32 and fingers 34 through body lugs 81a that extend radially between the arms and fingers, effecting rotation of the latch fingers within the lower torque sub 25. Since the threaded connection 35, 36 is left hand, such right hand rotation of the latch fingers 34 causes them to unthread in an upward direction. Such unthreading action cannot be prevented since there is no hydraulic pressure acting on the latch retainer piston 50. The latch mechanism is, therefore, able to move upwardly along the stinger body 21 until the latch fingers are completely disengaged from the threads 36 in the lower torque sub 25. Then rotation is facilitated by the ability of the upper torque sub 29 to rotate freely around the bearing ring 30 that rests against the upper torque sub 22.

Following full disconnection of the latch fingers 34 from the lower torque sub 25, the upper tubular string portion 16 is elevated to remove the stinger body 21 and associated mechanism in an upward direction from the lower ball valve portion 14 of the apparatus. As stated above, this permits the tubular string 16 and the latch portion 15, together with the upper torque sub 22, to be elevated to the platform or drilling vessel, the blind ram D-2 being shifted to a closed position and the marine riser B disconnected from the blowout preventer stack D and removed to the drilling vessel, allowing the latter to be moved off location.

In the event the marine riser B has been subsequently reconnected to the blowout preventer stack D, latch portion 15 can be placed in coupled relation to the lower valve portion 14 of the apparatus. The tubular string 16 with the upper portion 15 of the apparatus connected thereto is again relowered through the marine riser B, and the stinger body 21 moved through the lower torque sub 25 until it is piloted within the poppet valve 78 as determined by the resting of the stinger bearing 56 upon the bearing seat 57 in the landing head 58. Before such full piloting occurs, pressure is applied to the fluid in the control line 38 and control passages 40 to shift and hold the latch lock piston 50 downwardly against the force of the spring 55, free from interference with the latch fingers 34, which permits the latter to ratchet downwardly over the internal threads 36, until the landing of the stinger 56 upon its bearing seat 57 has been effected. The latch control pressure can then be relieved which permits the latch spring 55 to shift the latch lock piston 50 behind the latch fingers 34 and secure them in full threaded engagement with the lower torque sub threads 36. To determine that the latch fingers are sufficiently engaged, the upper tubular string 16 and upper portion 15 of the tool is rotated relative to the lower portion 14 of the tool, as, for example, relative to the lower torque sub 24, first to the left and then to the right. If rotation is limited to the arcuate distance between the upper dogs 23 and lower dogs 24 of the clutch, a sufficient length of engagement of the latch fingers 34 with the threads 36 in the lower torque sub has been effected. If not, the dogs 23, 24 have not reached a position of such sufficient engagement, requiring additional rotation to be effected for the purpose of threading the latch fingers further downwardly within the lower torque sub 25.

As stated above, relieving the pressure from the ball valve control line 64 causes the ball valves to close automatically. This action is accomplished by the upward force of the return springs 110, 110a acting through the follower sleeves 108, 108a. This closing action is assisted by the differential in fluid densities between the control fluid and the fluid in the annulus 39 between the upper portion 16 of the tubular string J and the marine riser B. A greater density of fluid in the annulus can act on the tubing piston 135 in an upward direction, its force being exerted upon by the annulus pressure acting over the annular area P of the piston, urging it in an upward direction and causing its flange 142 to urge the lower follower sleeve 108a in an upward direction. In the event that a wire line used in the performance of the testing operation has been cut above the lower valve 97a, and interferes with the closing of the lower valve, the force exerted by the well pressure (if any well pressure exists) will be transmitted through the tubing piston 135 to the follower sleeve 108a, forcibly rotating the ball valve 97a and enabling it to sever the wire line, whereupon the lower ball shifts to its fully closed position. In the event that well pressure is relatively low, additional force may be obtained by applying pressure to the fluid in the annulus 39 between the marine riser and the tubular string, such pressure being transmitted to the lower side or annular area P of the tubing piston head 136, forcing it upwardly, and correspondingly shifting the follower sleeve 108a upwardly to sever the wire line and rotate the ball valve 97a to its fully closed position.

The poppet valve 78 has an upwardly opening check valve 82a of any suitable type, controlling passage of fluid through poppet valve head 82, which will insure upward escape of fluid from the passages 88, 103, 105, 103a and 121 as a result of release and removal of the latch portion 15 of the test valve assembly from its latched relation to the lower valve portion 14 of the assembly. During upward movement of the latch portion 15, with respect to the lower valve portion 14, the spring 83 shifts the valve 78 upwardly to closed position within its companion cylindrical valve seat 85. In the event that the poppet valve 78 does not move upwardly to its fullest extent, which might trap some fluid in the passages 88, 103, 105, 103a and 121, resulting in slight disalignment between the passages 115 in the ball valve members 97, 97a and the housing passage, the full upper movement of the pistons 92, 92a can still occur to an additional extent as a result of forcing the fluid in the passages upwardly through the check valve 82a. The check valve opens in an upward direction to permit bleeding of fluid therethrough and automatically closes to prevent downward flow of fluid therethrough.

It is, accordingly, apparent that a test valve assembly A has been provided in which the latch portion 15 of the assembly can be readily stabbed into latching position to connect it to the lower valve portion 14 of the assembly, or released and pulled out of such lower portion of the assembly. The stabbing in or pulling out is effected hydraulically through the downward shifting of the latch lock piston 50 from its holding location behind the latch fingers 34. In the event that sufficient hydraulic pressure is not available to accomplish this purpose, the latch fingers can be disconnected from the lower portion of the assembly merely by rotating the tubular string 16 above the assembly to the right.

Assurance is had that the latches fully engage as a result of the right and left hand rotary effort imparted to the stinger body 21 and upper torque sub 22, which will continue unless the clutch dogs 23, 24 are in overlapping relation and will engage after a fractional revolution of the upper sub 22 relative to the lower sub 25. When this occurs, assurance is had that the latch fingers are sufficiently engaged with the threads 36 of the lower torque sub 25.

The hydraulic pistons 92, 92a for actuating the ball valves to open condition are pressure balanced, and are, therefore, not sensitive to the depth at which the apparatus is used. Moreover, the ball valves permit reverse flow to take place around them to kill the well with the balls closed. Fluid under pressure is forced downwardly through the tubular string 16, acting upon the upper ball 97 and shifting it downwardly, causing its rotation to at least a partially open condition, whereupon the fluid continues on down through the upper follower sleeve 108 and acts on the lower ball 97a, urging it downwardly and rotating it to at least a partially open condition, the fluid being pumped through both valves when in their initially closed position, and into the tubular string therebelow to effect killing of the well.

The wire cutting piston 135, which may or may not be embodied in the apparatus, permits the sensing of well pressure and will also exert a hydraulic force on the lower follower sleeve 108a sufficient to forcibly rotate the ball 97a against a wire line extending through or into the ball for the purpose of cutting completely through it, which will allow the lower ball 97a to close.

The complete tool assembly may be rotated to set packers, or the like, in the well casing without disengaging the latch. The design is short and compact and permits a blowout preventer to close around the tool and the blind rams D-2 to close above the tool after the upper portion of the tool has been released from the lower portion and elevated above the location of the blind rams.

A plurality of ball valve mechanisms arranged in series are illustrated, since greater assurance is provided for obtaining leak-proof and complete shut-off through the apparatus when the balls are shifted to closed position. However, the apparatus will function properly in the event it embodies one ball valve mechanism only.

I claim:

1. In a valve assembly adapted to be lowered on the tubular string into position within a blowout preventer stack at the upper end of a well bore underlying a body of fluid: a housing structure adapted to be subjected to the hydrostatic head of the body of fluid and having a fluid flow passage therethrough; a valve member shiftable in said housing structure between positions opening and closing said passage; pressure responsive means for shifting said valve member to open position; means for conducting fluid under pressure to said pressure responsive means to shift said valve member to open position; closing means for shifting said valve member to closed position upon decrease in fluid pressure in said conducting means; and means for subjecting said pressure responsive means to the hydrostatic head of fluid surrounding said housing structure to offset the hydrostatic head of fluid in said conducting means.

2. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-

through; said pressure responsive means pivoting said ball in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to closed position across flow passage.

3. In a valve assembly as defined in claim 1; said pressure responsive means comprising an annular piston engaging said valve member and having an upper surface acted on by fluid under pressure in said conducting means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure.

4. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-through; said pressure responsive means comprising an annular piston engaging said ball and having an upper surface acted on by fluid under pressure in said conductive means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said piston pivoting said ball in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to a closed position across said flow passage.

5. In a valve assembly as defined in claim 1; said pressure responsive means comprising an annular piston engaging said valve member and having an upper surface acted on by fluid under pressure in said conducting means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said closing means comprising a sleeve engaging said valve member to shift said valve member to a closed position.

6. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-through; said pressure responsive means comprising an annular piston engaging said ball and having an upper surface acted on by fluid under pressure in said conductive means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said piston pivoting said ball in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to a closed position across said flow passage; said closing means comprising a sleeve engaging said ball to shift said ball to closed position.

7. In a valve assembly as defined in claim 1; said pressure responsive means comprising an annular piston engaging said valve member and having an upper surface acted on by fluid under pressure in said conducting means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said closing means comprising a sleeve engaging said valve member to shift said valve member to a closed position; and spring means acting on said sleeve to urge said sleeve upwardly against said valve member.

8. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-through; said pressure responsive means comprising an annular piston engaging said ball and having an upper surface acted on by fluid under pressure in said conductive means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said piston pivoting said ball in one direction to open position with its fluid passage in alignment with

said flow passage; said closing means pivoting said ball in the opposite direction to a closed position across said flow passage; said closing means comprising a sleeve engaging said ball to shift said ball to closed position; and spring means acting on said sleeve to urge said sleeve upwardly against said ball.

9. In a valve assembly as defined in claim 1; and supplemental fluid actuating means engaging said closing means for assisting said closing means in shifting said valve member to closed position.

10. In a valve assembly as defined in claim 1, and supplemental fluid actuating means engaging said closing means for assisting said closing means in shifting said valve member to closed position, said supplemental means being responsive to the pressure of fluid in said flow passage below said valve member.

11. In a valve assembly as defined in claim 1; and supplemental fluid actuating means engaging said closing means for assisting said closing means in shifting said valve member to closed position, said supplemental means being responsive to the pressure of fluid externally of said housing structure.

12. In a valve assembly as defined in claim 1; said pressure responsive means comprising an annular piston engaging said valve member and having an upper surface acted on by fluid under pressure in said conducting means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said closing means comprising a sleeve engaging said valve member to shift said valve member to a closed position; and supplemental fluid actuated means engaging and assisting said sleeve in shifting said valve member to closed position.

13. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-through; said pressure responsive means comprising an annular piston engaging said ball and having an upper surface acted on by fluid under pressure in said conductive means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said piston pivoting said ball in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to a closed position across said flow passage; said closing means comprising a sleeve engaging said ball to shift said ball to closed position; and supplemental fluid actuated means engaging and assisting said sleeve in shifting said ball to closed position.

14. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-through; said pressure responsive means comprising an annular piston engaging said ball and having an upper surface acted on by fluid under pressure in said conductive means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said piston providing said ball in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to a closed position across said flow passage; said closing means comprising a sleeve engaging said ball to shift said ball to closed position; and supplemental fluid actuated means engaging and assisting said sleeve in shifting said ball to closed position, said supplemental means comprising an annular

piston responsive to the pressure of fluid in said flow passage below said ball.

15. In a valve assembly as defined in claim 1; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage there-  
through; said pressure responsive means comprising an annular piston engaging said ball and having an upper surface acted on by fluid under pressure in said conductive means and a lower surface subject to said hydrostatic head of fluid surrounding said housing structure; said piston pivoting said ball in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to a closed position across said flow passage; said closing means comprising a sleeve engaging said ball to shift said ball to closed position; and supplemental fluid actuated means engaging and assisting said sleeve in shifting said ball to closed position, said supplemental means being responsive to the pressure of fluid externally of said housing structure.

16. In a valve assembly as defined in claim 1; said last-mentioned means comprising a passageway in said housing structure leading to said pressure responsive means and containing a liquid, and diaphragm means subject to the hydrostatic head of fluid surrounding said housing structure and bearing against said liquid.

17. In a valve assembly adapted to be lowered on a tubular string into position within a blowout preventer stack at the upper end of the well bore; a housing structure having a fluid passage therethrough; a valve member shiftable in said housing structure between positions opening and closing said passage; pressure responsive means for shifting said valve member to open position; means for conducting fluid under pressure to said pressure responsive means to shift said valve member to a closed position upon decrease in fluid pressure in said conducting means; and supplemental fluid actuated means engaging said closing means to shift said closing means and assist said closing means in shifting said valve member to a closed position.

18. In a valve assembly as defined in claim 17; said supplemental means being responsive to the pressure of fluid internally of said housing structure.

19. In a valve assembly adapted to be lowered on a tubular string into position within a blowout preventer stack at the upper end of the well bore: a housing structure having a fluid flow passage therethrough; a valve member shiftable in said housing structure between positions opening and closing said passage; pressure responsive means for shifting said valve member to open position; means for conducting fluid under pressure to said pressure responsive means to shift said valve member to open position; means for shifting said valve member to a closed position upon decrease in fluid pressure in said conducting means; and supplemental fluid actuated means engaging said closing means for assisting said closing means in shifting said valve member to a closed position; said pressure responsive means comprising an annular piston engaging said valve member and having an upper surface acted on by fluid under pressure in said conducting means; said closing means comprising a sleeve engaging said valve member to shift said valve member to closed position; said supplemental means engaging said sleeve.

20. In a valve assembly as defined in claim 19; said supplemental means comprising an annular piston en-

gaging and assisting said sleeve in shifting said valve member to closed position.

21. In a valve assembly adapted to be lowered on a tubular string with respect to a well bore; a housing structure having a fluid flow passage therethrough; a body connectable to the tubular string and adapted to be piloted within said structure in sealed relation thereto; coengageable latch means on said body and structure connecting said body to said structure; lock means for retaining said latch means coengaged; first pressure responsive means for releasing said lock means to permit disengagement of said latch means; a valve member shiftable in said housing structure between positions opening and closing said passage; second pressure responsive means for shifting said valve member to open position; first means for conducting fluid under pressure to said second pressure responsive means to shift said valve member to open position; closing means for shifting said valve member to closed position upon decrease in fluid pressure in said first conducting means; third pressure responsive means on said lock means subject to fluid pressure in said first conducting means for holding said lock means in its position retaining said latch means coengaged; and second means for conducting fluid under pressure to said first pressure responsive means.

22. In a valve assembly as defined in claim 21; said coengageable latch means comprising a latch portion on said housing structure; latch members on said body movable laterally into and from coengagement with said latch portion; said lock means comprising an annular lock piston movable behind said latch members to retain them coengaged with said latch member, said first pressure responsive means and third pressure responsive means being operatively associated with said lock piston.

23. In a valve assembly as defined in claim 21; said coengageable latch means comprising a latch portion in said housing structure, latch members on said body movable laterally outwardly into coengagement with said latch portion; said lock means comprising an annular lock piston movable upwardly behind said latch members to retain outwardly in coengagement with said latch portion, said first pressure responsive means being operatively associated with said lock piston to shift said lock piston downwardly from behind said latch members, said third pressure responsive means being operatively associated with said lock piston to hold said lock piston in its upward position behind said latch members.

24. In a valve assembly as defined in claim 21; said coengageable latch means comprising a threaded latch portion on said housing structure, threaded latch members on said body movable laterally into and from threaded coengagement with said threaded latch portion; said lock means comprising an annular lock piston movable behind said latch members to retain them threadedly engaged with said threaded lock portion, said first pressure responsive means and third pressure responsive means being operatively associated with said lock piston; and means for transmitting rotation of said body to said latch members to unthread said latch members from said threaded latch portion.

25. In a valve assembly as defined in claim 21; said coengageable latch means comprising a threaded latch portion in said housing structure, threaded latch members on said body movable laterally outwardly into

threaded coengagement with said threaded latch portion; said lock means comprising an annular lock piston movable upwardly behind said latch members to retain them threadedly engaged with said threaded latch portion, said first pressure responsive means being operatively associated with said lock piston to shift said lock piston downwardly from behind said latch members, said third pressure responsive means being operatively associated with said lock piston to hold said lock piston in its upward position behind said latch members; and means for transmitting rotation of said body to said latch members to unthread said latch members from said threaded latch portion.

26. In a valve assembly as defined in claim 21; said coengageable latch means comprising a latch portion on said housing structure; latch members on said body movable laterally into and from coengagement with said latch portion; said lock means comprising an annular lock piston movable behind said latch members to retain them coengaged with said latch member, said first pressure responsive means and third pressure responsive means being operatively associated with said lock piston; and spring means engaging said lock piston to move said lock piston behind said latch members.

27. In a valve assembly as defined in claim 21; said coengageable latch means comprising a latch portion in said housing structure, latch members on said body movable laterally outwardly into coengagement with said latch portion; said lock means comprising an annular lock piston movable upwardly behind said latch members to retain them outwardly in coengagement with said latch portion, said first pressure responsive means being operatively associated with said lock piston to shift said lock piston downwardly from behind said latch members, said third pressure responsive means being operatively associated with said lock piston to hold said lock piston in its upward position behind said latch members; and spring means engaging said lock piston to move said lock piston upwardly behind said latch members.

28. In a valve assembly as defined in claim 21; said coengageable latch means comprising a threaded latch portion in said housing structure, threaded latch members on said body movable laterally outwardly into threaded coengagement with said threaded latch portion; said lock means comprising an annular lock piston movable upwardly behind said latch members to retain them threadedly engaged with said threaded latch portion, said first pressure responsive means being operatively associated with said lock piston to shift said lock piston downwardly from behind said latch members, said third pressure responsive means being operatively associated with said lock piston to hold said lock piston in its upward position behind said latch members; and means for transmitting rotation of said body to said latch members to unthread said latch members from said threaded latch portion; said latch members being movable upwardly along said body in response to unthreading of said latch members from said threaded latch portion.

29. In a valve assembly as defined in claim 21; said valve member comprising a ball pivotally mounted in said housing structure and having a fluid passage therethrough; said second pressure responsive means pivoting said ball in one direction to open position with its fluid passage in alignment with said flow passage; said

closing means pivoting said ball in the opposite direction to close position across said flow passage.

30. In a valve assembly as defined in claim 21; said valve member comprising a ball valve pivotally mounted in said housing structure and having a fluid passage therethrough; said second pressure responsive means comprising an annular piston engaging said ball valve and having an upper surface acted on by fluid under pressure in said conducting means; said piston pivoting said ball valve in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to closed position across said flow passage.

31. In a valve assembly as defined in claim 21; said valve member comprising a ball valve pivotally mounted in said housing structure and having a fluid passage therethrough; said second pressure responsive means comprising an annular piston engaging said ball valve and having an upper surface acted on by fluid under pressure in said conducting means; said piston pivoting said ball valve in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to closed position across said flow passage; said closing means comprising a sleeve engaging said valve member to shift said ball valve to closed position.

32. In a valve assembly as defined in claim 21; and supplemental fluid actuated means engaging said closing means for assisting said closing means in shifting said valve member to closed position.

33. In a valve assembly as defined in claim 21; said valve member comprising a ball valve pivotally mounted in said housing structure and having a fluid passage therethrough; said second pressure responsive means comprising an annular piston engaging said ball valve and having an upper surface acted on by fluid under pressure in said conducting means; said piston pivoting said ball valve in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to closed position across said flow passage; said closing means comprising a sleeve engaging said valve member to shift said ball valve to closed position; and supplemental fluid actuated means engaging and assisting said sleeve in shifting said ball valve to closed position.

34. In a valve assembly as defined in claim 21; said valve member comprising a ball valve pivotally mounted in said housing structure and having a fluid passage therethrough; said second pressure responsive means comprising an annular piston engaging said ball valve and having an upper surface acted on by fluid under pressure in said conducting means; said piston pivoting said ball valve in one direction to open position with its fluid passage in alignment with said flow passage; said closing means pivoting said ball in the opposite direction to closed position across said flow passage; said closing means comprising a sleeve engaging said valve member to shift said ball valve to closed position; and supplemental fluid actuated means engaging and assisting said sleeve in shifting said ball valve to closed position, said supplemental means comprising an annular piston responsive to the pressure of fluid in said flow passage below said ball valve.

35. In a valve assembly as defined in claim 21; and means for subjecting said second pressure responsive means to the hydrostatic head of fluid surrounding said housing structure to offset the hydrostatic head of fluid in said second conducting means.

36. In a valve assembly as defined in claim 21; and means for subjecting said second pressure responsive means to the hydrostatic head of fluid surrounding said housing structure to offset the hydrostatic head of fluid in said second conducting means; said subjecting means comprising a passageway in said passage structure leading to said second pressure responsive means and containing a liquid, and diaphragm means subject to the hydrostatic head of fluid surrounding said housing structure and bearing against said liquid.

37. In a valve assembly as defined in claim 21; and means including a releasable clutch for transmitting torque from said body to said housing structure.

38. In a valve assembly as defined in claim 21; and means for transmitting torque from said body to said housing structure comprising a torque sub surrounding said body, means releasably securing said torque sub to said body, and releasable coengageable clutch means on said torque sub and housing structure.

39. In a valve assembly as defined in claim 21; said coengageable latch means comprising a threaded latch portion on said housing structure, threaded latch members on said body movable laterally into and from threaded coengagement with said threaded latch portion; said lock means comprising an annular lock piston movable behind said latch members to retain them threadedly engaged with said threaded lock portion, said first pressure responsive means and third pressure responsive means being operatively associated with said lock piston; and means for transmitting rotation of said body to said latch members to unthread said latch members from said threaded latch portion; and means for transmitting torque from said body to said housing structure comprising a torque sub surrounding said body, means releasably securing said torque sub to said body, and releasable coengageable clutch means on said torque sub and housing structure.

40. In underwater well bore apparatus in which a blowout preventer stack is attached to a well casing extending into a well bore; the combination therewith of a housing structure having a fluid flow passage therethrough and adapted to be landed in said blowout preventer stack; a body connectable to a tubular string and adapted to be piloted within said structure in sealed relation thereto; coengageable latch means on said body and structure connecting said body to said structure; lock means retaining said latch means coengaged; first pressure responsive means for releasing said lock means to permit disengagement of said latch means; a

valve member shiftable in said housing structure between positions opening and closing said passage; second pressure responsive means for shifting said valve member to open position; first means for conducting fluid under pressure to said second pressure responsive means to shift said valve member to open position; closing means for shifting said valve member to closed position upon decrease in fluid pressure in said conducting means; third pressure responsive means on said lock means subject to fluid pressure in said first conducting means for holding said lock means in its position retaining said latch means coengaged; second means for conducting fluid under pressure to said first pressure responsive means; said blowout preventer stack including a first blowout preventer adapted to close in engagement with said housing structure, and a second blowout preventer adapted to fully close the entire bore across said second blowout preventer above said housing structure after release of said coengageable latch means and upward withdrawal of said body from said blowout preventer stack.

41. In apparatus as defined in claim 40; and means for subjecting said second pressure responsive means to the hydrostatic head of fluid surrounding said housing structure to offset the hydrostatic head of fluid in said first conducting means.

42. In apparatus as defined in claim 40, and means for subjecting said second pressure responsive means to the hydrostatic head of fluid surrounding said housing structure to offset the hydrostatic head of fluid in said first conducting means, said hydrostatic head offsetting means comprising a passageway in said housing structure leading to said pressure responsive means and containing a liquid, and diaphragm means subject to the hydrostatic head of fluid surrounding said housing structure and bearing against said liquid.

43. In a valve assembly adapted to be lowered on a tubular string into position within a blowout preventer stack at the upper end of the well bore; a housing structure having a fluid flow passage therethrough; a valve member shiftable in said housing structure between positions opening and closing said passage; pressure responsive means for shifting said valve member to open position; means for conducting fluid under pressure to said pressure responsive means to shift said valve member to open position; means for shifting said valve member to a closed position upon decrease in fluid pressure in said conducting means; supplemental fluid actuated means engaging said closing means for assisting said closing means in shifting said valve member to a closed position; and means for conducting fluid from the exterior of said housing structure to said supplemental means to actuate said supplemental means.

\* \* \* \* \*

UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

PATENT NO. : 3,870,101  
DATED : March 11, 1975  
INVENTOR(S) : SYDNEY S. HELMUS

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

- Column 1, line 60: change "too" to --to--.
- Column 3, line 15: change "thiss" to --this--.
- Column 4, line 48: change "communiating" to --communicating--.
- Column 6, line 46: after "compression" insert --spring--.  
line 46: cancel "l10a" (second occurrence).
- Column 7, line 13: change "is" to --its--.  
line 15: change "follow" to --follower--.  
line 65: change "upardly" to --upwardly--.
- Column 8, line 10: after "surface" insert --152 at each side  
of the ball for rotation between the open--.  
line 42: after "at" insert --a--.
- Column 9, line 28: change "siimilar" to --similar--.
- Column 12, line 5: cancel "81a" and substitute --21a--.
- Column 13, line 53: change "automaticaly" to --automatically--.
- Column 17, line 14: change "oppsite" to --opposite--.  
line 22: change "meanss" to --means--.
- Column 18, line 57: change "tham" to --them--.
- Column 19, line 2: change "close" to --closed--.
- Column 21, line 19: change "assmelby" to --assembly--.
- Column 22, line 20: change "withdrawl" to --withdrawal--.  
line 25: cancel "of" and substitute --to--.

Signed and Sealed this

second Day of September 1975

[SEAL]

Attest:

RUTH C. MASON  
Attesting Officer

C. MARSHALL DANN  
Commissioner of Patents and Trademarks