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(54) **Downhole tool**

(57) A downhole tool has a tubular valve housing (102,104,106,108), a valve closure member movable (132) between an open and a closed position, an axially movable opening flow tube (124,130) for opening the valve closure member (132). Hydraulic pressure from a control line (114) is used to move a first piston (118), which in turn moves the axially movable flow tube (124,130) through the closure member (132). A balance line (116) can be used to provide a hydrostatic pressure against a second piston (120). The downhole tool can be used as a subsurface safety valve.

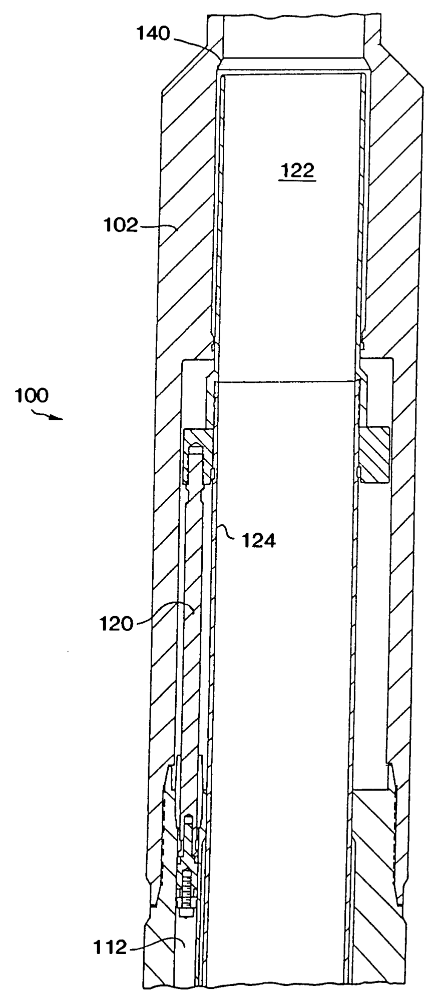

FIG. 4A

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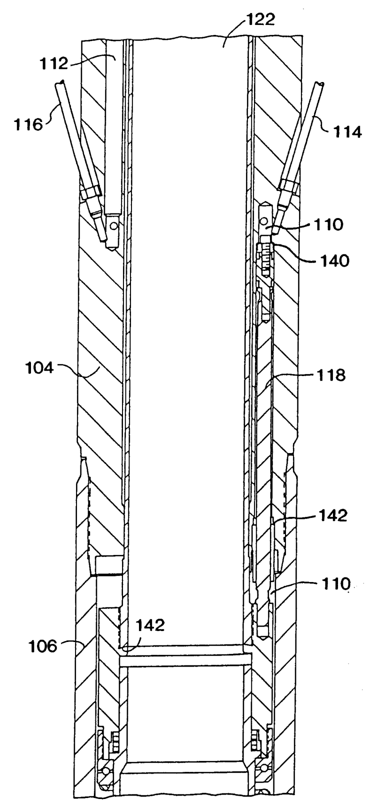
122
112
116
114
110
140
104
118
142
110
142
106

FIG. 4B

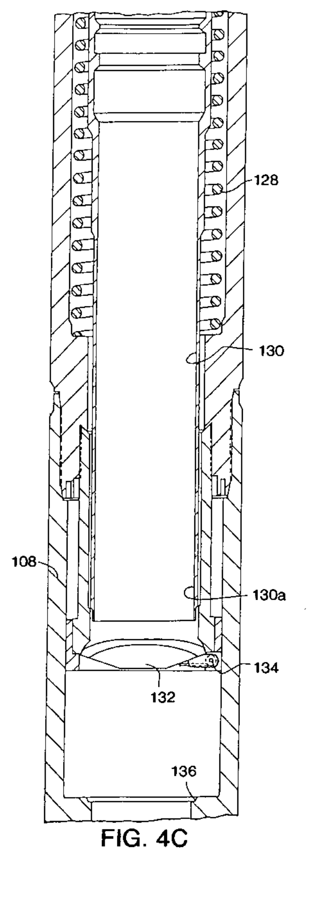
128
130
108
130a
134
132
136

FIG. 4C

Description

[0001] The present invention relates to a downhole tool such as a subsurface safety valve and, more particularly, to a downhole tool utilising opposed pistons. More specifically, the invention relates to a subsurface safety valve having a tubular housing and an axially shiftable flow tube used to manipulate a valve closure member.

[0002] Subsurface safety valves (SSSVs) are used within well bores to prevent the uncontrolled escape of well bore fluids, which if not controlled could directly lead to a catastrophic well blowout. Certain styles of safety valves are called flapper type valves because the valve closure member is in the form of a circular disc or in the form of a curved disc. These flappers can be opened by the application of hydraulic pressure to a piston and cylinder assembly to move an opening prong against the flapper. The opening prong is biased by a helical spring in a direction to allow the flapper to close in the event that hydraulic fluid pressure is reduced or lost.

[0003] Figures 1a and 1b illustrate a standard safety valve configuration wherein a safety valve 10 is interposed in a tubing string 12. A control line 16 is used to open the valve. The valve 10 includes a tubular valve housing 14 with an axial passage 20. When hydraulic pressure is applied through port 22, the pressure forces a piston 24 to engage an axially shiftable control rod 26 which is coupled to an opening prong 30. As the pressure forces the piston downward, the opening prong 30 engages the closure member 32 and pushes the member into an open position. A spring 28 opposes the motion of the piston so that when the hydraulic pressure is released, the piston and opening prong 30 are returned to a first position. The weight of the hydraulic fluid produces a hydrostatic "head" force against the piston, and thus is a factor in sizing the spring 28. In general, the pressure required to close the valve 10 is given by:

$$\text{Pressure}_{\text{closing}} = \text{Force}_{\text{spring}}/\text{Area}_{\text{piston}}$$

Setting subsurface safety valves deeper is typically just a matter of ensuring sufficient closing pressure to offset the hydrostatic pressure acting to cause the valve to stay open. Increasing closing pressure is accomplished by increasing the $\text{Force}_{\text{spring}}$ term or decreasing the $\text{Area}_{\text{piston}}$ term.

[0004] As the valve closing pressure increases, so does the valve opening pressure. The surface capacity to provide operating pressure is a combination of the pressure needed to open the valve and the wellbore pressure:

$$\text{Pressure}_{\text{surface}} = \text{Pressure}_{\text{opening}} + \text{Pressure}_{\text{well}}$$

However, the umbilical line used to deliver the hydraulic pressure can limit the available surface operating pressure. Thus, if the surface pressure is fixed and the well pressure increases with depth, the opening pressure decreases with depth. To compensate for changes in pressure, the valve requires changes in the spring force or piston area in accordance with the above formulas, thus requiring customization of the valve depending on the depth at which it will be placed. Design considerations of the well, string, and tools involved can also make such valve designs impractical at lower well depths.

[0005] For these reasons, designs which operate independent of well pressure are required. Two well-known designs are the dome charges safety valves and balance lines safety valves. A balance line valve 40 having a piston 48 in a housing 42 is illustrated in Figure 2. Two hydraulic chambers are pressurized on opposite sides of the piston 48. A control line is coupled to a first port 44 while the balance line is coupled to a second port 46. Each hydraulic line is filled with the same type of fluid. Hydrostatic pressure above and below the piston is equal. Thus, there is no downward force on the spring as a result of the hydrostatic pressure. The valve is operated by pressurizing the upper chamber. This increases the downward force, displacing fluid from the lower chamber and compressing the spring 50 to open the valve. Well pressure only has access to the seal diameters with cross sectional areas A and A'.

[0006] Well pressure acts upwards on A' and downwards on A. A and A' are equal, therefore well pressure has no upward or downward force on the piston as long as the seals at A and A' remain intact. Control line pressure acts downward on B-A while balance line pressure acts upward on B-A'. Thus, the hydrostatic pressures on opposite sides of the piston 48 are equalized. If seal 52 fails, well pressure enters the balance pressure chamber, acting on B-A, and increasing F3. If the well pressure is great, it may be impossible to supply sufficient surface pressure to the control line to force the opening prong downward. Thus, the safety valve fails to a closed position. If seal 54 fails, well pressure would enter the control chamber and act on B-A', increasing F1. Without applying control line pressure, F1 could be greater than F2 + F3. If F1 is greater than F2 + F3, this imbalance causes the valve to fail in an open position. The valve can be closed by pressuring up the balance line so that F3 + F2 is greater than the well assisted F1. This is only possible if sufficient balance line pressure can be applied. Another failure mode occurs when gas in the well fluid migrates into the balance line, reducing the hydrostatic pressure applied by the balance line, i.e. reducing F3.

[0007] Another style of balance line safety valve is illustrated in Figure 3. The valve 60 has a piston 64 captured within a housing 62 and three hydraulic chambers 68, 70, and 72, two above and one below the valve piston 64. Two control lines are run to the surface. Well pressure acts on seals 74, 80. Since the piston areas A and A' are the same, well pressure has no influence on the pressure required to displace the piston. Control line and balance line hydrostatic pressures act on identical piston areas B-A' and B-A", so there is no net upward or downward force. If seal 74 leaks, well pressure accesses the balance line system. This pressure acts on area B-A", boosting force F3, which with F2 will overcome F1, to close the valve. If seal 76 leaks, communication between the control and balance lines will be established. F1 will always equal F3. Thus, F2 will be the only active force causing the valve to close. If seal 78 leaks, it has the same effect as seal 76 leaking. If seal 80 leaks, tubing pressure accesses the balance line system. This pressure acts to increase F3, overcoming F1 and closing the valve. Thus, if sufficient control line pressure is available and tubing pressure is relatively low, it may be possible to open the valve if seals 72 and/or 80 leak. Control line force F1 is greater than the tubing assisted balance force F3 with the spring force F2. In all modes of failure for this valve, the valve fails permanently to a closed position.

[0008] A dome charge safety valve uses a captured gas charge. The gas charge provides a heavy spring force to achieve an increased closing pressure. However, dome charge designs are complex and require specialized manufacturing and personnel. This increases the cost and decreases the reliability of the design because numerous seals are required. Also, industry standards favour metal-to-metal (MTM) sealing systems. Gas charges require the use of elastomeric seals.

[0009] A need exists for a safety valve suitable for deep setting depth applications and which is well pressure insensitive. Thus, it should incorporate the benefits of a balance line SSSV. Such a design should utilize a metal-to-metal sealing system for increased reliability and also allow for the application of balance line pressure to cycle the valve's flow tube, thus opening the valve. Further, the design should minimize operational friction to reduce the required spring force to close the valve.

[0010] In one aspect, the present invention relates to an improved method of actuating a downhole safety valve that uses a pair of opposed pistons connected to individual control lines that are run to the surface. The hydrostatic pressure in the control line and balance line affects both pistons equally, thereby cancelling out any net affect. The pistons are situated in the valve housing so that one will tend to ascend in reaction to the hydrostatic pressure, while the other piston will tend to descend. Both are coupled to a common axially movable member within the valve.

[0011] To open the valve, the control line attached to the first piston is pressurized. The increased pressure forces the piston downward until it rests against a downstop. The distal end of the piston is attached to an axially movable flow tube that pushes through the closure member of the valve thereby opening the valve's central passage. A compression spring opposes the motion of the piston. Therefore, when the opening pressure subsides, the compression spring will return the flow tube to its original position, allowing the closure member to close.

[0012] According to another aspect of the present invention there is provided a downhole tool having an element movable by a piston force between a first and second position comprising a valve housing, a first piston movable within the housing, and a second piston movable within the housing, wherein the first and second pistons are coupled to each other.

[0013] In an embodiment, the downhole tool according further comprises a valve closure member captured in the housing and movable between an open and closed position, and axially shiftable flow tube captured in the housing for opening the valve closure member.

[0014] According to another aspect of the present invention there is provided a safety valve for use in a well comprising a valve housing, a first piston movable within the housing, a second piston movable within the housing, the first and second pistons being coupled to each other, a valve closure member captured in the housing and movable between an open and closed position, and an axially shiftable flow tube captured in the housing for opening the valve closure member.

[0015] In an embodiment, the first piston is coupled to a control line and/or the second piston is coupled to a balance line.

[0016] In an embodiment, the downhole tool or safety valve further comprises a spring within the housing and opposing the motion of the axially shiftable flow tube.

[0017] In an embodiment, the first and second pistons are coupled to a movable member.

[0018] In an embodiment, the downhole tool or safety valve further comprises first and second control lines coupled to a surface pressure source.

[0019] In an embodiment, the valve housing comprises a first and second piston chamber for capturing the first and second pistons, and the control line and balance line are coupled to the valve housing to move the pistons in opposite directions.

[0020] In an embodiment, the valve housing comprises a first and second piston chamber for capturing the first and second pistons, and a hydrostatic pressure is applied by the balance line to the second piston which is substantially equal and offsetting to a hydrostatic pressure applied by the control line to the first piston.

[0021] According to another aspect of the invention there is provided a method of operating a downhole tool placed in the flow path of a well tubing string within a well, comprising the steps of coupling a control line to a first piston chamber having a first piston, coupling a balance line to a second piston chamber having a second piston, and coupling both the first and second pistons to a movable member.

[0022] In an embodiment, the method further comprises supplying a substantially equal hydrostatic pressure through both the control line and the balance line.

[0023] In an embodiment, the method further comprises supplying a sufficient pressure through the control line to move the first piston downward.

[0024] In an embodiment, the method further comprises overcoming an opposing spring force, and forcing an opening prong through a closure member.

[0025] The present invention allows for the isolation of the valve from effects of hydrostatic pressure and wellbore pressure. It also provides a method of positively closing the valve in the event of a failure. The present invention preferably also uses metal-to-metal and non-elastomeric sealing.

[0026] Reference is now made to the accompanying drawings, in which:

Figures 1a and 1b illustrate a prior art safety valve having a single control line;

Figure 2 illustrates a balance line safety valve having a balance line;

Figure 3 illustrates an improved prior art balance line safety valve;

Figures 4a, 4b and 4c are sectional views of an embodiment of the present invention with the closure member in the closed position; and

Figures 5a, 5b, and 5c are sectional views of an embodiment of the present invention with the closure member in an open position.

[0027] Figures 4a, 4b and 4c provide partial sectional views along the length of a safety valve 100 that embodies the present invention. The safety valve 100 has an outer tubular housing that defines a central passage 122. The outer housing can be constructed of several sections 102, 104, 106, and 108. Each section can be coupled by threaded connection during the construction of the valve 100. The housing defines a number of inner structures, including piston chambers 110 and 112. The piston chamber 110 is coupled to control line 114, while piston chamber 112 is coupled to balance line 116. Both the control line and the balance line can be coupled to a surface pressure source. The weight of the hydraulic fluid in the control line and the balance line produces a hydrostatic force within the chambers 110, 112.

[0028] Pistons 118 and 120 are captured in chambers 110, 112 respectively. In a static situation, the hydraulic fluid in the control line and the balance line should exert a substantially equal and offsetting force on the pistons. To open the valve, only control line 114 is pressurized. When sufficient pressure is applied, piston 118 moves downward compressing spring 128. The piston simultaneously acts on movable member 124 and opening prong 130. The pistons are both coupled to the movable member 124. Thus, when piston 118 descends in chamber 110, piston 120 also descends in chamber 112. Likewise, the distal end 130a of the opening prong 130 contacts the closure member 132 of the valve. The closure member 132 is hinged at 134, allowing it to pivot to an open position. The piston 118 can travel between upstop 140 and downstop 142.

[0029] Figures 5a, 5b, and 5c illustrate the closure member in the open position. Note that the spring 128 is shown in a compressed state. The closure member 132 is in an open position, allowing well fluids to pass through the central passage of the valve. The distal end 130a of the opening prong rests against a stop 136. In the event that the safety valve becomes stuck in an open state, pressure can be applied to the balance line 116, thus moving piston 120 upward in chamber 112. The movable member 124 and piston 118 also move upward in conjunction with the piston 120. The ability to cycle the motion of the valve through the use of the balance line is an improvement over prior art valves.

[0030] It will be appreciated that the invention described above may be modified. For example, the invention is applicable not only to tubing conveyed safety valves, but also to wireline-conveyed safety valves, sliding side door devices, and other downhole tools that are movable.

Claims

1. A downhole tool having an element movable by a piston force between a first and second position comprising a valve housing (102,104,106,108), and a first piston (118) movable within the housing (102,104,106,108), a second piston (120) movable within the housing (102,104,106,108), wherein the first and second pistons (118,120) are coupled to each other.

2. A downhole tool according to Claim 1, further comprising: a valve closure member (132) captured in the housing (102,104,106,108) and movable between an open and closed position, and axially shiftable flow tube (130) captured in the housing (102,104,106,108) for opening the valve closure member (132).

3. A downhole according to Claim 1 or 2, wherein the first piston (118) is coupled to a control line (114).

4. A downhole tool according to Claim 1, 2 or 3, wherein the second piston (120) is coupled to a balance line (116).

5. A method of operating a downhole tool placed in the flow path of a well tubing string within a well, comprising the steps of coupling a control line (114) to a first piston chamber (110) having a first piston (118), coupling a balance (116) line to a second piston chamber (112) having a second piston (120), and coupling both the first and second pistons (118,120) to a movable member (124).

6. A method according to Claim 5, further comprising supplying a substantially equal hydrostatic pres-

sure through both the control line (114) and the balance line (116).

7. A method according to Claim 5, further comprising supplying a sufficient pressure through the control line (114) to move the first piston (118) downward.

8. A safety valve for use in a well comprising a valve housing (102,104,106,108), a first piston (118) movable within the housing (102,104,106,108), a second piston (120) movable within the housing (102,104,106,108), the first and second pistons (118,120) being coupled to each other, a valve closure member (132) captured in the housing (102,104,106,108) and movable between an open and closed position, and an axially shiftable flow tube (130) captured in the housing (102,104,106,108) for opening the valve closure member (132).

9. A safety valve according to Claim 8, wherein the first piston (118) is coupled to a control line (114).

10. A safety valve according to Claim 8 or 9, wherein the second piston (120) is coupled to a balance line (116).

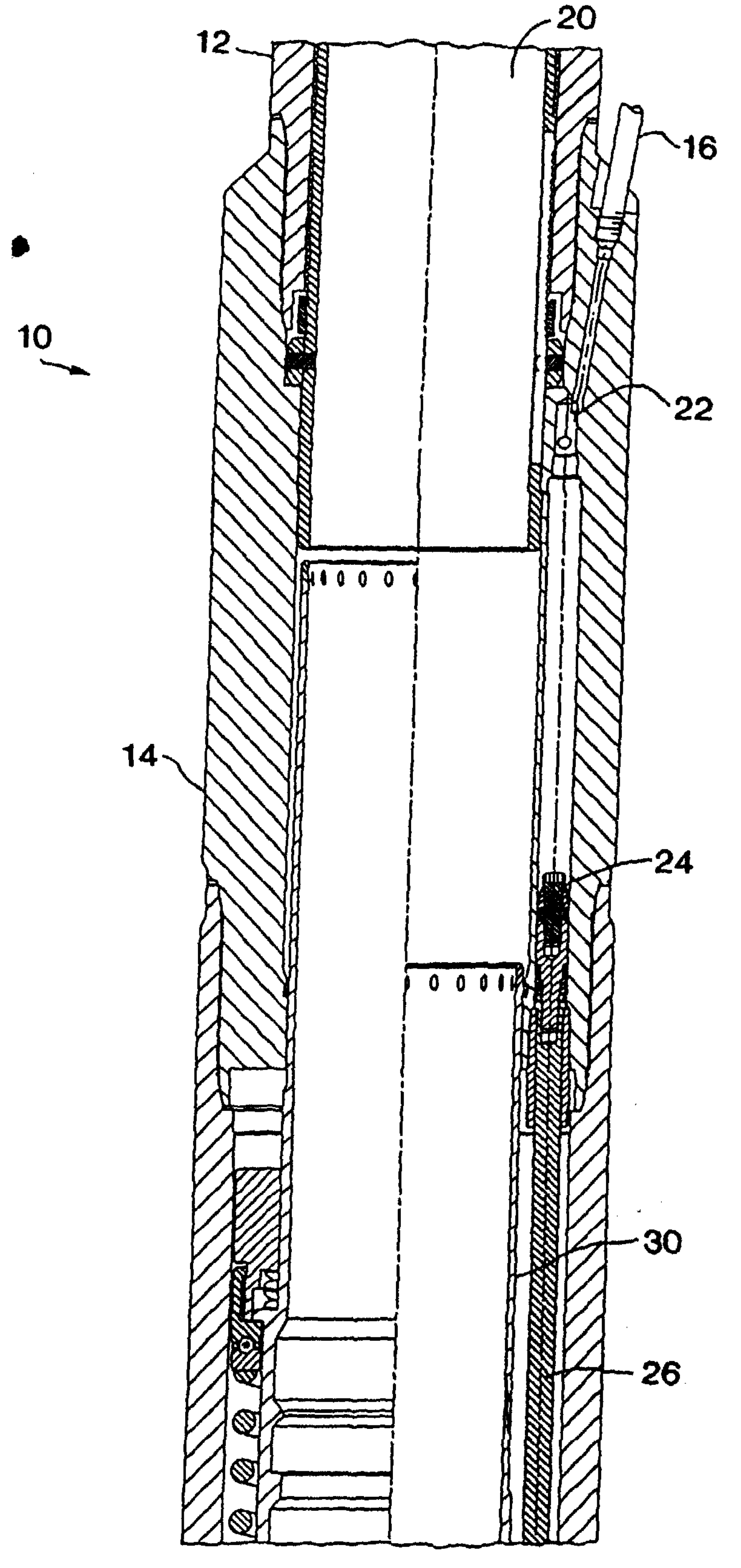

FIG. 1A
PRIOR ART

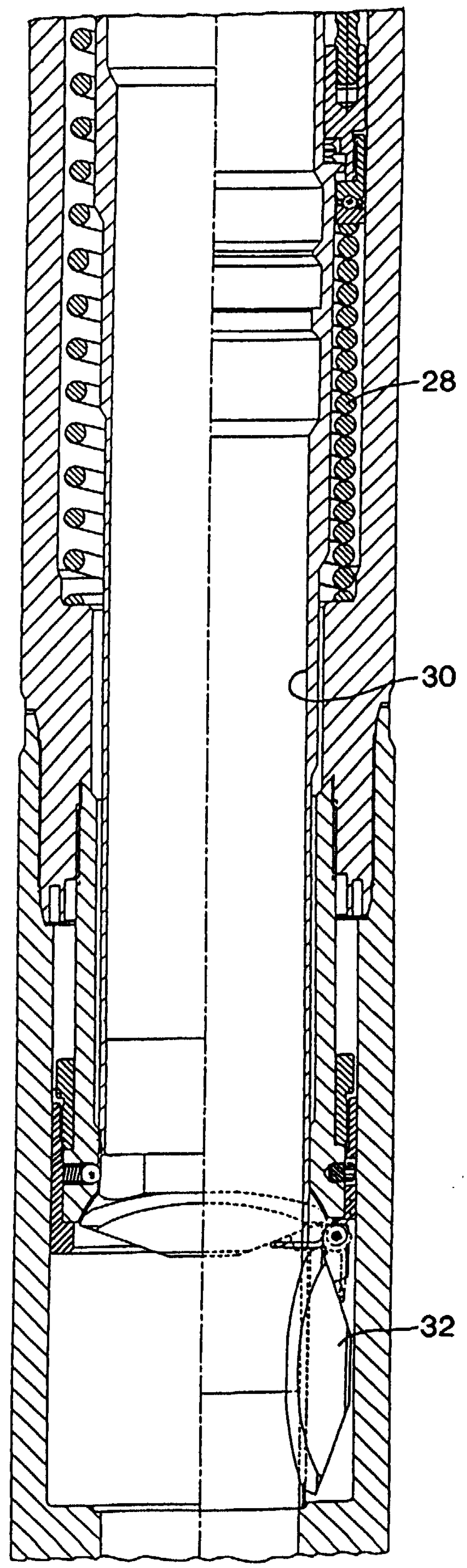

FIG. 1B
PRIOR ART

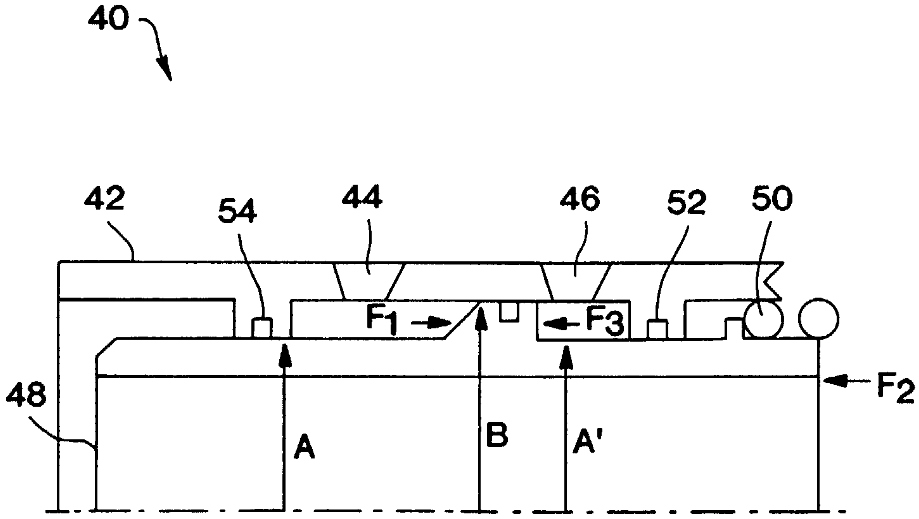

FIG. 2
PRIOR ART

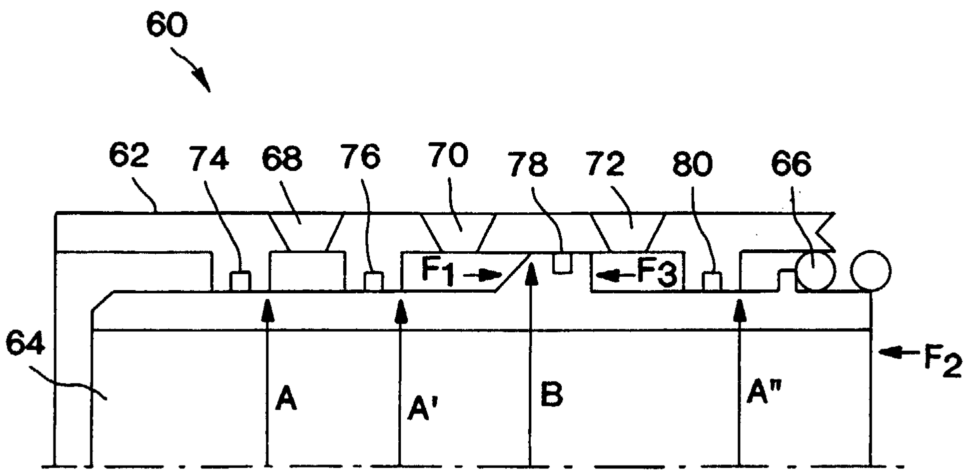

FIG. 3
PRIOR ART

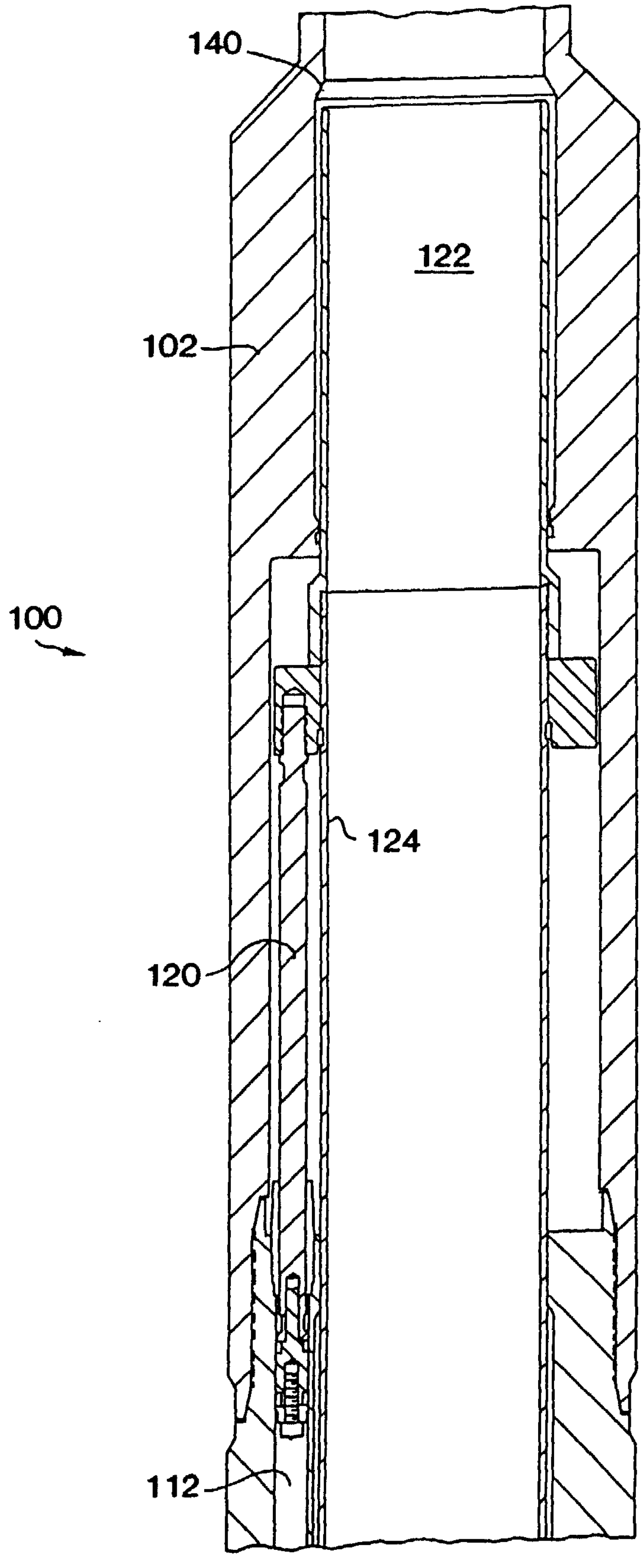

FIG. 4A

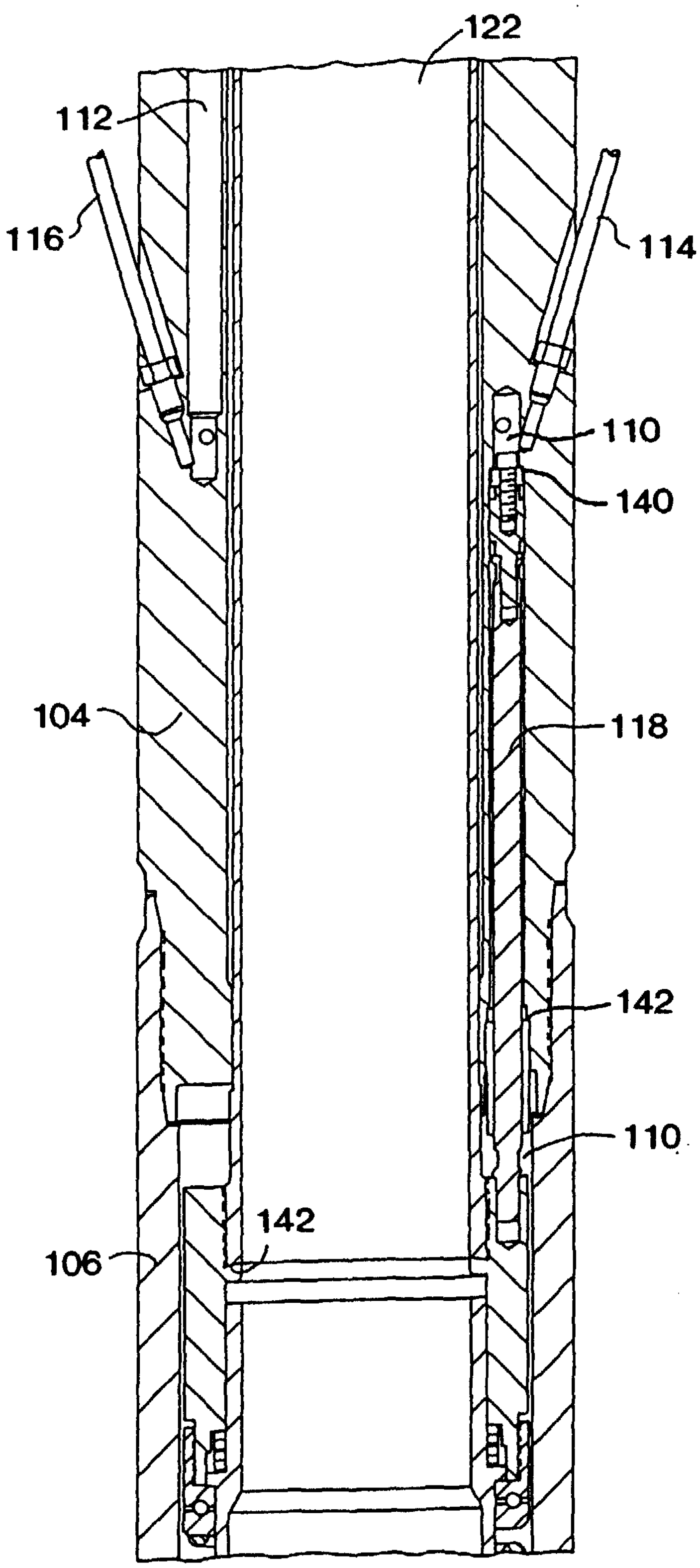

FIG. 4B

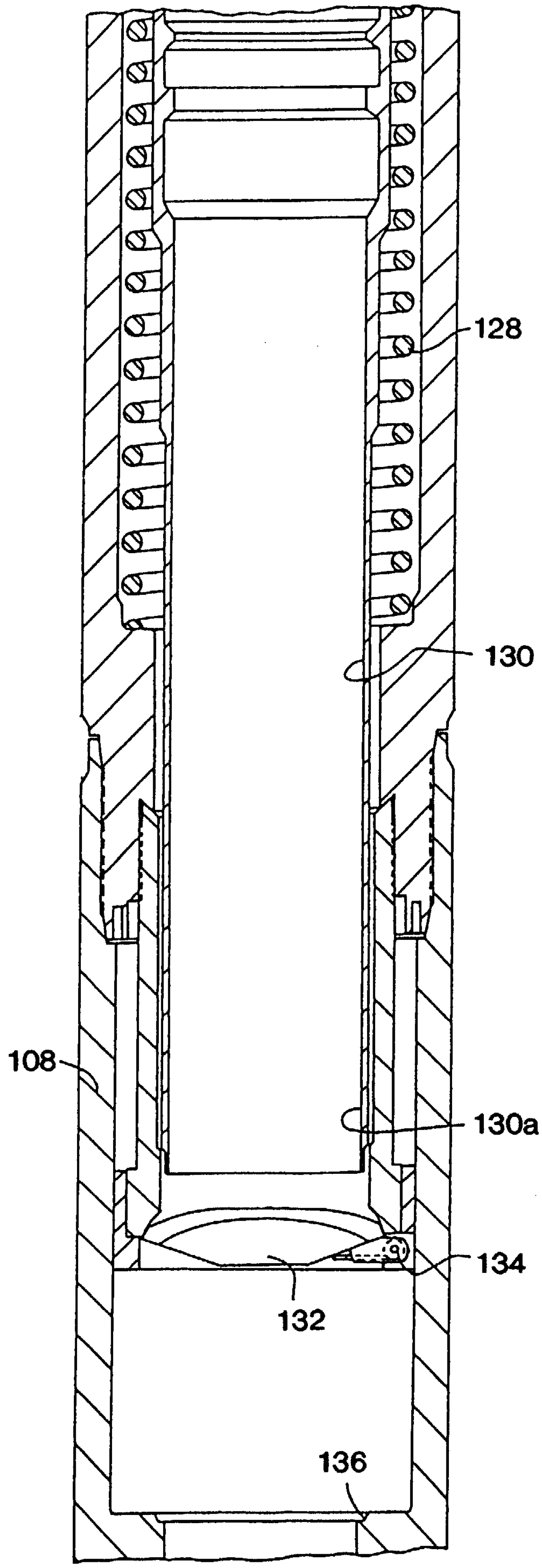

FIG. 4C

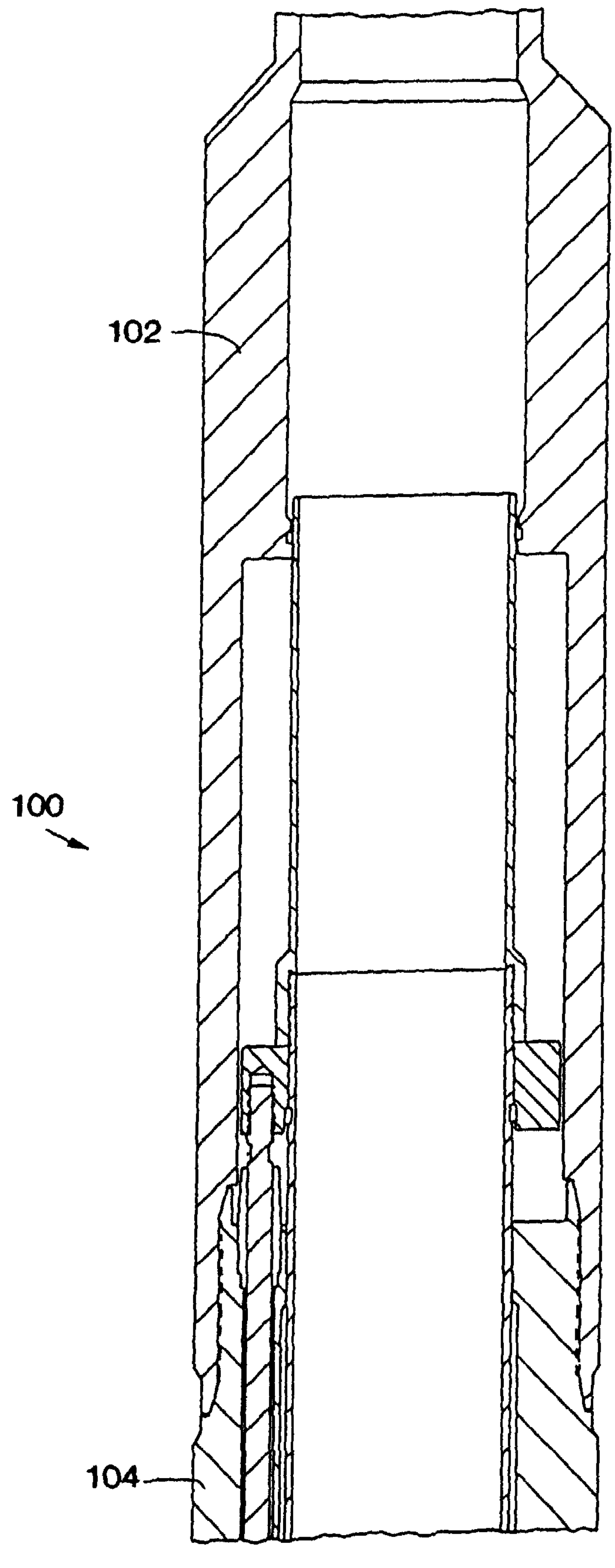

FIG. 5A

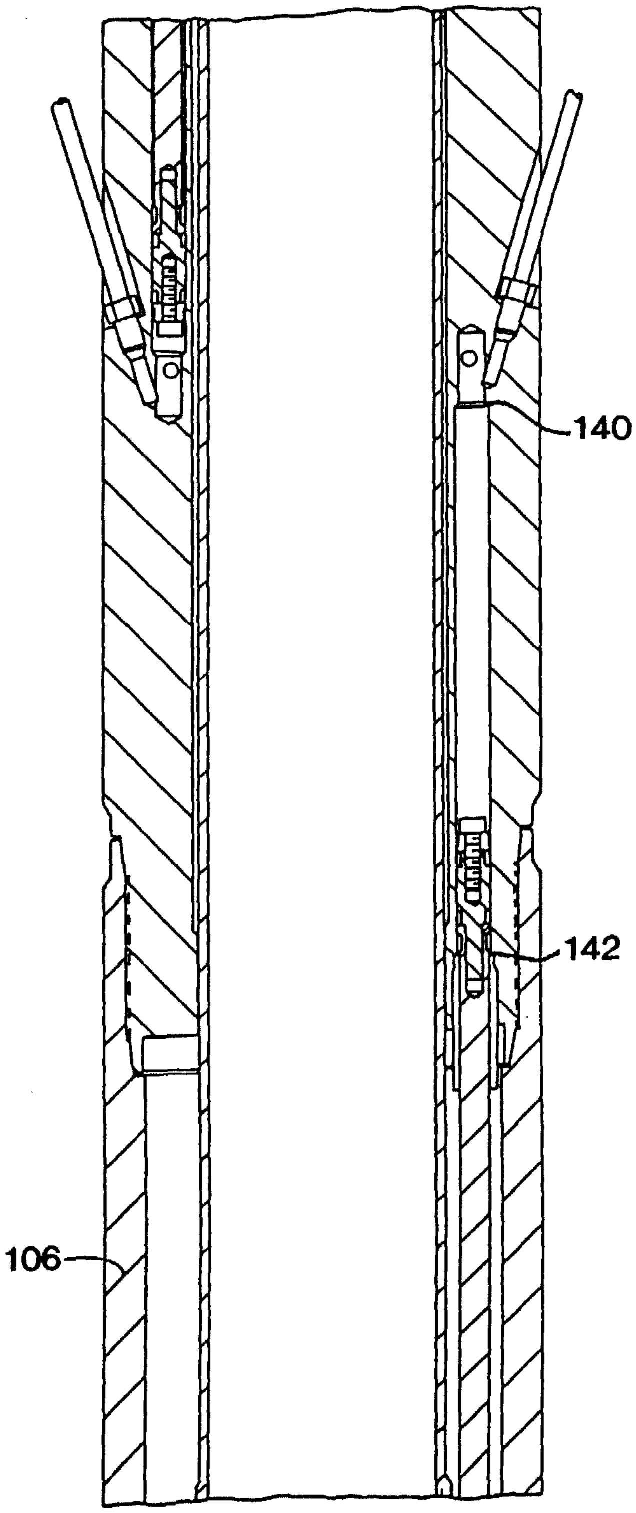

FIG. 5B

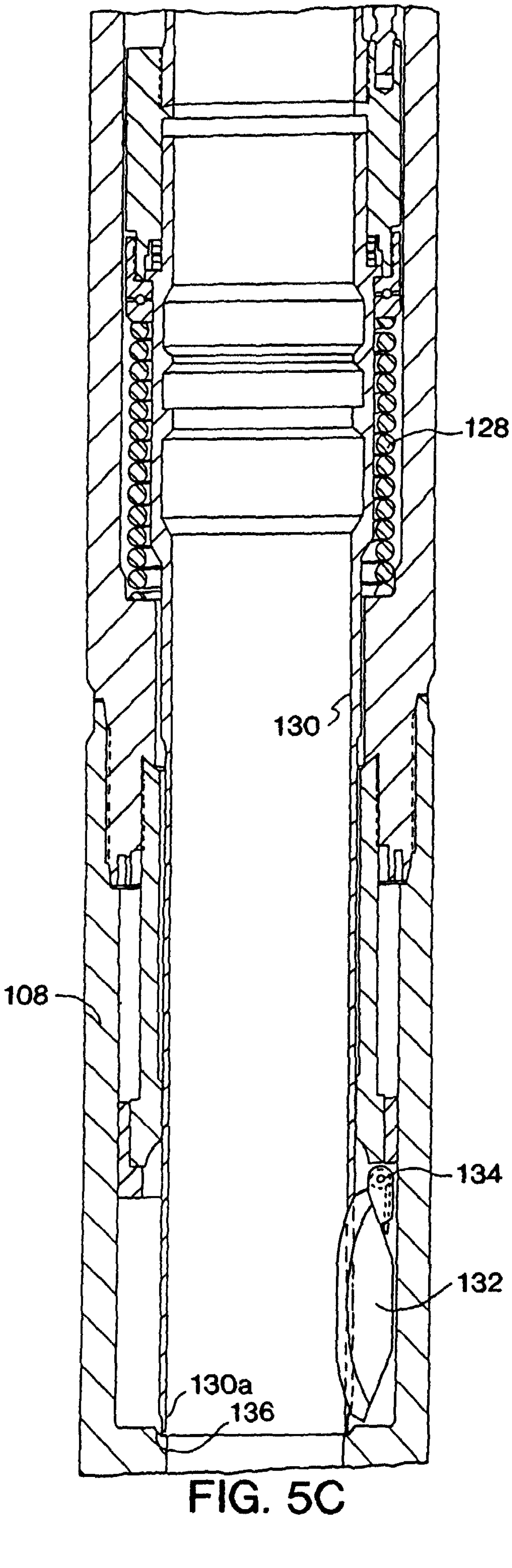

FIG. 5C