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(54) Title: PRESSURE COMPENSATOR FOR HYDROSTATICALLY-ACTUATED PACKERS

(57) Abstract: Devices and methods for operating a tool within a wellbore. A downhole tool includes a tool operation portion having a moveable tool member and a setting portion having a setting piston and setting chamber. A fluid pressure compensation reservoir is in fluid communication with the setting chamber and containing a pressurized fluid which offsets external hydrostatic pressure.

5                   **PRESSURE COMPENSATOR FOR HYDROSTATICALLY-  
                          ACTUATED PACKERS**

**BACKGROUND OF THE INVENTION**

10   **1. Field of the Invention**

**[0001]** The invention relates generally to downhole tools, including packer devices. In particular aspects, the invention relates to methods of actuating downhole tools.

15   **2. Description of the Related Art**

20   **[0002]** Some downhole tools use absolute well pressure activation to operate. They are also referred to as hydrostatically actuated tools. In absolute well pressure activation, the absolute pressure in the wellbore is the sum of the hydrostatic pressure and any additional pressure generated from the surface of the well. To use absolute pressure activation, the tool to be actuated is constructed to hold atmospheric air pressure in an atmospheric chamber. The tool is then run to depth. A rupture disc separates the atmospheric chamber from the wellbore fluid, which is under hydrostatic pressure. When the absolute pressure in the well exceeds the differential pressure rating of the rupture disc, the disc ruptures to permit fluid to enter the atmospheric chamber. Typically, the pressurized well fluid entering the actuation chamber is applied to a setting piston to set the packer device or otherwise actuate the downhole tool. Tools which can be operated using absolute well pressure activation are described in, for example, U.S. Patent No. 6,779,600.

### **SUMMARY OF THE INVENTION**

**[0003]** In preferred embodiments, the invention provides a design and method for operating downhole tools in response to absolute pressure. In a described embodiment, a well packer device is provided with a packer element and slip elements which are set by axial compression. The packer device has an actuation chamber which is in communication with a pressure compensator reservoir. The actuation chamber has a fluid communication port which allows fluid communication between actuation chamber and the annulus surrounding the packer device. The pressure compensator reservoir and actuation chamber are charged with a pressurized fluid, such as nitrogen. The fluid pressure within the pressure compensator reservoir and actuation chamber is higher than atmospheric pressure. The tool is actuated when the external wellbore pressure exceeds the burst pressure rating of the rupture disc plus the fluid pressure contained within the pressure compensator chamber and actuation chamber. When the actuation chamber is filled with wellbore fluid, a setting piston is moved by the pressure of the fluid to set the packer device. Pressure charging of the pressure compensator reservoir allows for the tool to be operated at greater depths and to remain operable under higher external pressures than possible if the actuation chamber was at atmospheric pressure.

**[0004]** Alternative embodiments are described which incorporate different actuation or setting chamber designs.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0005]** For a thorough understanding of the present invention, reference is made to the following detailed description of the preferred embodiments, taken in conjunction with the

accompanying drawings, wherein like reference numerals designate like or similar elements throughout the several figures of the drawings and wherein:

[0006] Figures 1A, 1B, 1C, 1D and 1E are a side, partial cross-sectional view of an exemplary packer device constructed in accordance with the present invention.

5 [0007] Figure 2 is a side, cross-sectional view of portions of an alternative packer device constructed in accordance with the present invention and in a run-in, unactuated position.

[0008] Figure 3 is a side, cross-sectional view of the packer device shown in Figure 2, now in an actuated position.

1 [0009] Figure 4 is a side, cross-sectional view of a further alternative device constructed  
0 in accordance with the present invention.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[0010] Figures 1A, 1B, 1C, 1D and 1E depict an exemplary packer device 10  
constructed in accordance with the present invention. The packer device 10 includes a  
central mandrel 12 having a threaded connection 14 at its upper axial end 16. The central  
15 mandrel 12 is formed of an upper central mandrel portion 18, middle central mandrel  
portion 20, and lower central mandrel portion 22, and a lower sub 24, which are  
interconnected with one another by threaded connections, in a manner known in the art.  
The lower sub 24 presents a lower threaded connection 26 at its lower axial end. The  
threaded connections 14, 26 are used for interconnection of the packer device 10 into a  
20 wellbore production or injection string (not shown), as is known in the art. The central  
mandrel 12 defines a central flowbore 28 along its length.

[0011] Beginning at the upper end 16 of the tool 10 and working downwardly, the packer  
device 10 generally features a debris barrier 30, a set of upper anchoring slips 32, an

elastomeric packer assembly 34, and a set of lower anchoring slips 36. The slip assemblies 32, 36 are set using axial compression of the assemblies with respect to the central mandrel 12 so as to cause the slip elements 38 of the slip assemblies 32, 36 to be urged radially outward, as is known in the art. As the construction and operation of such devices is well known, they will not be further described herein. A setting collar 42 and body lock ring assembly 44 are located axially below the lower slip assembly 36. The packer assembly 34 is set by axial compression as well so as to cause the elastomeric packer elements 40 to be extruded radially outward. Axial compression of the packer assembly 34 and slip assemblies 32, 36 is caused by upward axial movement of the setting collar 42 with respect to the central mandrel 12.

**[0012]** The lower portion of the packer device 10 includes a hydraulic setting section, generally shown at 46 and a hydrostatic setting assembly, generally shown at 48, which are used to generate the axial force to set the slip assemblies 32, 36 and the packer assembly 34.

**[0013]** The hydraulic backup setting piston 50 is moveably retained within a setting piston chamber 52 which is defined radially between the central mandrel 12 and an outer sleeve 54. The backup setting piston 50 includes a compression end 56, which abuts the compression collar 42. In addition, the piston 50 includes an enlarged sealing portion 58 with fluid seals 60 to provide fluid sealing against both the central mandrel 12 and the outer sleeve 54. The enlarged portion 58 presents a fluid pressure receiving surface 62. It is noted that an upper setting piston chamber 52 is in fluid communication with the annulus 53 surrounding the tool 10 via a port 15 while a lower setting piston chamber 52' is in fluid communication with the flowbore 28 via a radial port 64 disposed through the central

mandrel 12. Pressurized fluid may enter the lower setting piston chamber 52' via the port 64 and be applied against the surface 62. In the event that the absolute pressure setting technique, which will be described shortly, fails, the backup setting piston may be used to set the packer assembly 34 and slip assemblies 32, 36. To do this, the flowbore 28 is  
5 pressurized at the surface of the well to exude pressure upon the surface 62 of the backup setting piston 50. The backup setting piston 50 is axially moved to cause the compression end 56 of the piston 50 to urge the setting collar 42 against the lower slip assembly 36. As pressurized fluid enters the lower chamber 52' through port 64, and the piston 50 moved, fluid is expelled from the upper chamber 52 into the annulus 53 through port 15. Setting  
10 force is retained in slips 32, 36 and packer 34 by body lock ring assembly 44.

**[0014]** The primary setting assembly 48 includes a setting sleeve 66 which is attached by one or more set screws 68 to the compression collar 42. The lower end of the setting sleeve 66 is secured to outer sleeve 54. A pressure chamber 55 is formed radially between the lower sleeve 72 and the central mandrel 12 (see Figure 1D). The chamber 55  
15 is pressurized to a level above wellbore hydrostatic pressure. The lower end of the outer sleeve 54 is secured by securing ring 70 to lower sleeve 72. Annular fluid seals 57 ensure pressure integrity of the pressure chamber 55. A body lock ring assembly 74, of a type known in the art for ensuring one-way relative axial movement between components, is incorporated between the outer sleeve 54 and the central mandrel 12, as depicted in  
20 Figure 1D. The lower end of the lower sleeve 72 is affixed by a threaded connection 74 to an interlock assembly housing 76. The interlock assembly housing 76 overlies the lower sub 24 without being affixed to it. Seals 80 provide fluid sealing between the interlock assembly housing 76 and the lower sub 24.

**[0015]** A setting chamber 82 and an interlock assembly, generally indicated at 84, are retained radially between the interlock assembly housing 76 and the central mandrel 12. A number of features of the interlock assembly 84 are described in U.S. Patent No. 6,779,600 entitled "Labyrinth Lock Seal for Hydrostatically Set Packer" issued to King et al.

5 That patent is owned by the assignee of the present application and is hereby incorporated by reference in its entirety. The interlock assembly 84 includes a lock sleeve 86 that is moveably disposed within the setting chamber 82. The lock sleeve 86 is affixed by shear pin 88 to an interlock piston 90. The interlock piston 90 is secured by a locking dog 92 to the lower central mandrel portion 22.

10 **[0016]** A fluid pressure compensator reservoir 94 is defined within the lower sub 24. In a currently preferred embodiment, the fluid pressure compensator reservoir 94 contains pressurized nitrogen. A fluid communication passage 96 extends between the reservoir 94 and the setting chamber 82. A fluid communication port 98 (see Fig. 1E) is disposed through the interlock assembly housing 76 to permit fluid communication from the exterior  
15 annulus 100 into the setting chamber 82. The port 98 is initially closed off by a frangible rupture disc 102.

**[0017]** Prior to running the packer device into a wellbore, the reservoir 94 is filled with pressurized nitrogen or another pressurized fluid. The reservoir 94 is pressurized to a pressure that is greater than atmospheric pressure. The level of pressure within the  
20 reservoir 94 is set based upon the external wellbore pressure that the tool 10 is expected to be exposed to. In a presently preferred embodiment, the reservoir 94 is pressurized to a level that approximates the expected exterior pressure. Therefore, the tool 10 may be actuated by increasing pressure within the annulus by an amount approximately equal to

the burst rating of the rupture disc 102. A fill port 104 is disposed through the exterior wall of the lower sub 24 to permit fluid to be communicated into the reservoir 94. The fill port 104 is closed off with a removable plug. The pressure within the reservoir 94 will be communicated to the setting chamber 82 via the passage 96. One advantage of  
5 pressurizing the setting chamber 82 is that, at great depths, outer housing components, including the interlock assembly housing 76 will not be deformed or deflected radially inwardly, or very minimally so, by the significant hydrostatic wellbore pressure, so that the operational movement of members within the setting chamber 82 is not impeded by this deformation.

10 **[0018]** In operation, the fluid pressure compensator reservoir 94 is filled with pressurized fluid at the surface prior to running the tool 10 into a wellbore. The packer device 10 is incorporated into a production tubing string in a manner known in the art. The production tubing string and packer device 10 are then disposed into a wellbore and lowered to a desired depth.

15 **[0019]** When the desired depth of setting is reached in the wellbore, the annulus 100 is sufficiently pressurized at the surface of the wellbore so that the rupture disc 102 will burst and allow high pressure wellbore fluid to flow from the annulus 100 into the setting chamber 82. As the wellbore fluid enters the setting chamber 82, it urges the lock sleeve 86 axially upwardly within the chamber 82. Movement of the lock sleeve 86 causes shear  
20 member 88 to rupture and releases the locking dog 92 from engagement with the central mandrel 12. Once the locking dog 92 is released, the interlock assembly housing 76 and lower sleeve 72 are free to move axially with respect to the central mandrel 12.

**[0020]** Increased fluid pressure within the annulus 100 will also cause the packer device 10 to be set. The increased fluid pressure will bear upon the lower end 106 of the interlock assembly housing 76 and urge the interlock assembly housing 76, the affixed lower sleeve 72, outer sleeve 54 and setting sleeve 66 and compression collar 64 axially upwardly with respect to the central mandrel 12. The interlock assembly housing 76, lower sleeve 72, outer sleeve 54, and setting sleeve 66 serve as a primary setting piston for setting of the packer device 10. Because the locking dog 92 has been released, the primary setting piston may now move freely with respect to the central mandrel 12. The compression collar 64 is urged against the lower slip assembly 36 causing the slip assemblies 32, 36 and the packer assembly 34 to be set. The chamber 55 collapses.

**[0021]** Pressurization of the compensator reservoir 94 provides an increase in internal pressure for the setting chamber 82. This allows the packer device 10 to be run to deeper depths and resulting higher hydrostatic pressures before actuation occurs. The amount of external fluid pressure required to destroy the rupture disc 102 is determined by adding the internal pressure of the compensator reservoir 94 to the burst rating of the rupture disc 102. For example, if the rupture disc 102 is designed to rupture at approximately 10,000 psi, and the compensation reservoir 94 contains fluid that is pressurized to 2,000 psi, the absolute external pressure applied to the tool 10 must exceed 12,000 psi in order to rupture the disc 102 and actuate the tool 10.

**[0022]** Referring now to Figures 2 and 3, there is depicted an alternative packer assembly 200 wherein there is a single piston with balanced or nearly balanced atmospheric chambers which urge the piston up and down more or less equivalently. The upper portions (not shown) of the packer assembly 200 may have the identical construction

as the packer device 10 described previously. The packer assembly 200 includes a central mandrel 202 and a bottom sub 204. A setting cylinder 206 surrounds the central mandrel 202 above the bottom sub 204. The setting cylinder 206 presents a radially-inwardly projecting piston 208 which contacts the outer radial surface 210 of the mandrel 202. O-ring seals 212 provide fluid sealing across the piston 208. The setting cylinder 206 is initially affixed to the bottom sub 204 by frangible shear pins 214.

**[0023]** A first setting chamber, indicated generally at 216, is defined below the piston 208 and radially between the central mandrel 202 and the bottom sub 204. The lower end of the first setting chamber 216 is closed off by fluid seals 218. A fluid port 220 is disposed through the lower sub 204 to provide fluid communication between the first setting chamber 216 and the surrounding annulus 222. The port 22 is initially closed off by a frangible rupture disc 224.

**[0024]** A second setting chamber 226 is located above the piston 208 and defined radially between the setting cylinder 206 and the mandrel 202. The upper end of the second setting chamber 226 is closed off by a radial projection 228 from the central mandrel 202 and fluid seals 230. The second setting chamber 226 is in fluid communication with the first setting chamber 216 via a weep hole 232 or other restrictive fluid path, which is disposed through the piston 208.

**[0025]** A fluid pressure compensator reservoir 234 is defined within the bottom sub 204. The reservoir 234 is similar in structure and function to the fluid pressure compensator reservoir 94 described earlier. In a currently preferred embodiment, the fluid pressure compensator reservoir 234 contains pressurized nitrogen. A fluid communication passage 236 extends between the reservoir 234 and the first setting chamber 216. A chamber fill

port 238 is preferably provided for readily filling the reservoir 234. Prior to running the packer device 200 into a wellbore, the reservoir 234 is charged with fluid that is pressurized greater than atmospheric pressure, thereby enabling the packer assembly 200 to be run in deeper wells containing greater hydrostatic pressure. The greater-than-atmospheric pressure from the reservoir 234 is transmitted through the passage 236 to the first setting chamber 216 and through the weep hole 232 to the second setting chamber 226.

**[0026]** To activate the packer assembly 200, the annulus 222 is pressurized to rupture the rupture disc 224. Fluid from the annulus 222 will pass through the port 220 and enter the first setting chamber 216. The increased fluid pressure will bear against the lower side 238 of the piston 208 and cause the shear pins 214 to shear. When the pins 214 are sheared, the setting cylinder 206 is released and moves upwardly with respect to the central mandrel 202. The second setting chamber 226 is collapsed, and the setting cylinder 206 will set the associated packer and slip elements (not shown) in the manner described previously with regard to packer device 10.

**[0027]** Figure 4 illustrates an exemplary alternative packer device 300 incorporating an improved setting assembly in accordance with the present invention. In the depicted device 300, the packer element 302 is located above the setting assembly 304 while a slip anchoring assembly 306 is located below the setting assembly 304. The setting assembly 304 includes an upper setting cylinder 308 and a lower setting sleeve 310. An upper setting chamber 312 is defined radially between the central mandrel 314 and the upper setting cylinder 308. The upper setting chamber 312 is bounded on its lower end by shoulder 316 and at its upper end by setting piston 318. A charging port 320 is disposed

through the setting cylinder 308 to permit the upper setting chamber 312 to be charged with a fluid. The charging port 320 is closed off by a plug, as is known in the art.

**[0028]** A lower setting chamber 322 is defined radially between the central mandrel 314 and the lower setting sleeve 310. The lower setting chamber 322 is bounded at its upper end by a fluid seal 324 between the lower setting sleeve 310 and the central mandrel 314. At its lower end, the lower setting chamber 322 is bounded by a lower setting piston 326. A fluid port 328 is disposed through the lower setting piston 310 to permit the lower setting chamber 322 to be charged with a fluid. The fluid port 328 is closed off by a closure plug, as is known in the art. A shear screw 330 secures the lower setting sleeve 326 to the upper setting sleeve 308.

**[0029]** Prior to running the packer device 300 into a wellbore, the upper and lower setting chambers 312, 322 are charged with a fluid at a pressure that exceeds atmospheric pressure. This permits the packer device 300 to be run to deeper depths with higher hydrostatics within a wellbore. In this embodiment, the fluid pressure compensation reservoir is integrated into the setting chambers 312, 322. However, the packer device 300 might also be constructed so as to have one or more separate fluid compensation reservoirs which is/are maintained separately from the setting chambers 312, 322.

**[0030]** When it is desired to set the packer device 300, the annulus surrounding the packer device 300 is pressurized from the surface to a predetermined level. The increased fluid pressure acts upon the outer radial surfaces of the upper setting cylinder 308 and the lower setting sleeve 310 and particularly at the point 332 where the cylinder 308 and sleeve 310 meet and causes the shear screw 330 to rupture, thereby releasing the cylinder 308 from the sleeve 310. The increased annular fluid pressure then causes the upper and

lower setting chambers 312, 322 to collapse. As the chambers 312, 322 collapse, the upper setting cylinder 308 is moved axially upwardly with respect to the central mandrel 314, thereby setting the packer element 302. The lower setting sleeve 310 is moved axially downwardly with respect to the central mandrel 314, thereby setting the slip  
5 anchoring assembly 306. Body lock ring 332 maintains the axial compression force in packer element 302 and slip anchoring assembly 306.

**[0031]** Those of skill in the art will recognize that numerous modifications and changes may be made to the exemplary designs and embodiments described herein and that the invention is limited only by the claims that follow and any equivalents thereof.

**CLAIMS**

1

What is claimed is:

2

1. A tool for operation within a wellbore comprising:

3

a tool operation portion having a moveable tool member;

4

a setting portion comprising:

5

a primary setting piston operably associated with the tool member such that movement of the setting piston in response to absolute well pressure moves the tool member;

6

8

a setting chamber associated with the primary setting piston to release the primary setting piston to move the tool member;

9

10

a fluid pressure compensation reservoir in fluid communication with the setting chamber and containing a pressurized fluid to offset hydrostatic pressure within the wellbore.

11

2

2. The tool of claim 1 further comprising a fluid communication port disposed

3

between the setting chamber and an annulus of the wellbore, the port being releasably

3

closed to selectively block fluid flow between the annulus and the setting chamber.

1

3. The tool of claim 1 wherein the tool operation portion comprises a packer

2

assembly and the tool member comprises a packer element.

1

4. The tool of claim 1 further comprising a backup setting piston that is actuated by

2

hydraulic pressure from a central flowbore to move the tool member.

1 5. The tool of claim 1 wherein the fluid pressure compensation reservoir is filled  
2 with pressurized nitrogen.

1 6. The tool of claim 1 wherein the fluid compensation reservoir is pressurized to a  
2 level of pressure above atmospheric pressure.

1 7. The tool of claim 1 further comprising a locking dog disposed within the setting  
2 chamber, the locking dog releasably securing the primary setting piston to a central  
3 mandrel and releasing the primary setting piston from the central mandrel portion when  
4 the setting chamber is filled with fluid from the annulus.

1 8. The tool of claim 7 further comprising a lock sleeve associated with the locking  
2 dog, the lock sleeve being moveable within the setting chamber in response to the  
3 setting chamber being filled with fluid from the annulus.

1 9. The tool of claim 2 wherein the fluid communication port is releasably blocked by  
2 a frangible rupture member.

2 10. A packer assembly for use in creating a seal within a wellbore, the packer  
assembly comprising:

3 a central mandrel defining a central flowbore along its length;

4 a packer assembly surrounding the central mandrel and axially compressible to  
5 selectively form a fluid seal with a surrounding wellbore wall;

a primary setting portion for selectively axially compressing the packer assembly,  
7 the setting assembly comprising:  
8

9 a primary setting piston operably associated with the packer assembly  
10 such that movement of the primary setting piston with respect to the central  
11 mandrel compresses the packer assembly, the primary setting piston being  
12 moveable in response to absolute well pressure;  
13

14 a setting chamber associated with the setting piston such that filling of the  
15 setting chamber with fluid will free the primary setting piston to move with respect  
16 to the central mandrel; and  
17

18 a fluid pressure compensation reservoir in fluid communication with the  
19 setting chamber and containing a fluid that is pressurized at a pressure greater  
20 than atmospheric pressure.

21 11. The packer assembly of claim 10 further comprising a fluid communication port  
22 disposed between the setting chamber and an annulus of the wellbore, the port being  
23 releasably closed to selectively block fluid flow between the annulus and the setting  
24 chamber.

25 12. The packer assembly of claim 10 further comprising a set of anchoring slips  
26 associated with the setting portion to be set by movement of the setting piston.

27 13. The packer assembly of claim 10 wherein the fluid within the compensation  
28 reservoir comprises nitrogen.

1 14. The packer assembly of claim 10 further comprising a backup setting piston that  
2 is actuated by hydraulic pressure from the central flowbore to set the packer assembly.

1 15. The packer assembly of claim 10 wherein the fluid communication port is  
2 releasably closed by a frangible rupture member.

16. A method of operating a tool within a wellbore, comprising the steps of:

3 a) providing a tool for operation within a wellbore, the tool comprising:  
4 a tool operation portion having a settable tool member;  
5 a primary setting portion comprising:

6 a primary setting piston operably associated with the tool member  
7 such that movement of the setting piston sets the tool member, the  
8 primary setting piston being moveable in response to absolute well  
9 pressure;

10 a setting chamber associated with the primary setting piston such  
11 that filling of the setting chamber with fluid will free the primary setting  
12 piston to move to set the tool member;

13 a fluid pressure compensation reservoir in fluid communication with  
14 the setting chamber; and

15 b) filling the fluid pressure compensation reservoir with a fluid that is  
16 pressurized at a pressure above atmospheric pressure;

17 c) disposing the tool within a fluid-filled wellbore;

d) lowering the tool to a desired depth for operation; and

3) moving the primary setting piston under impetus of absolute well pressure  
18 to set the tool member.

1 17. The method of claim 16 wherein the tool operation portion comprises a packer  
2 assembly and the tool member comprises a packer element.

1 18. The method of claim 16 wherein the fluid pressure compensation chamber is  
2 filled with nitrogen.

1 19. The method of claim 16 wherein a fluid communication port to permit fluid  
2 access to the setting chamber is releasably closed by a rupture member that is ruptured  
3 by absolute well pressure.

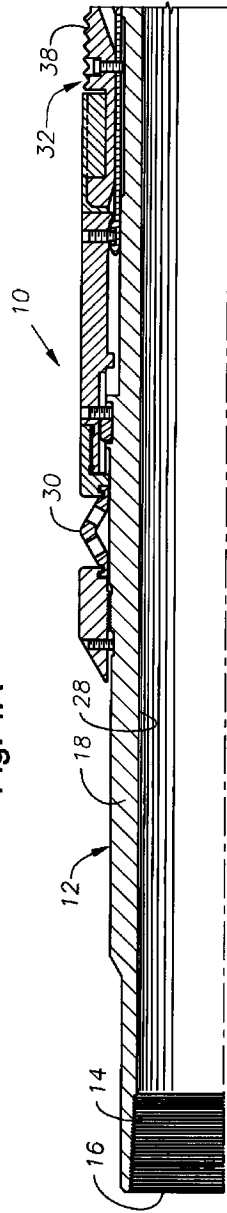
1 20. The method of claim 19 wherein the rupture member is ruptured by pressurizing  
2 the surrounding wellbore from the surface.

1 21. The method of claim 16 further comprises the step of flowing wellbore fluid into  
2 the setting chamber to free the primary setting piston.

22. The method of claim 21 wherein the step of flowing wellbore fluid into the setting  
2 chamber further comprises the step of moving a lock sleeve with the wellbore fluid to  
3 release the primary setting piston to be moved by absolute well pressure.

- 1 23. The method of claim 16 further comprising the step of actuating a backup setting
- 2 piston to set the tool member.

Fig. 1A



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Fig. 1B

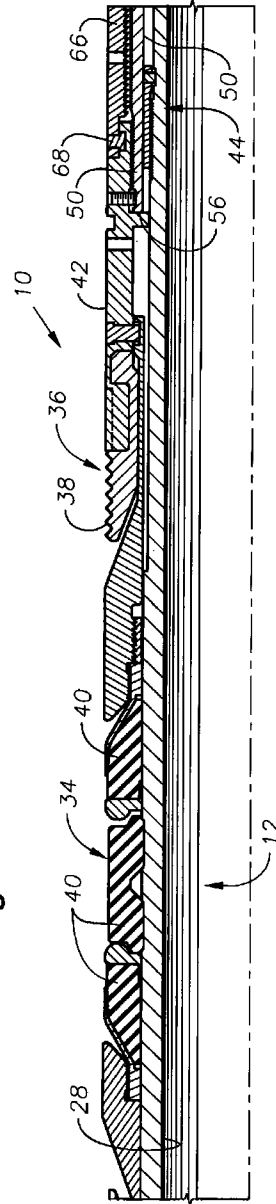
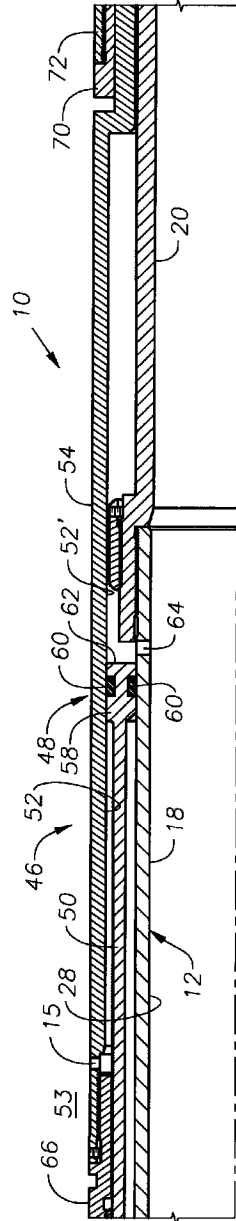


Fig. 1C



2/6

Fig. 1D

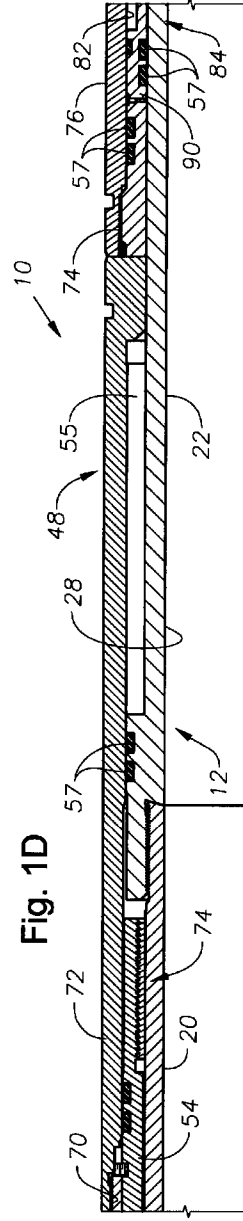


Fig. 1E

