Description

The present invention relates generally to annulus pressure responsive downhole tools utilizing a liquid spring chamber.

One operation which is often performed on a well is to flow test the well by lowering a tester valve into the well connected to a testing string, with the tester valve in the closed position until it reaches its final location within the well. Then the packer is set and the tester valve is opened by annulus pressure to allow the formation to produce through the test string. Quite often, these tester valves are constructed so that they are operated in response to changes in annulus pressure.

A typical annulus pressure responsive tester valve of the prior art is shown, for example, in U.S. Patent No. 3,856,085, and another somewhat modified example is shown at pages 3310—3311 of "Halliburton Services Sales and Service Catalog—No. 39", and designated as "APR Ball Valve Tester". Both of these tester valves utilize a chamber containing pressurized nitrogen gas as a spring chamber to bias the power piston in a direction opposite the direction in which it is biased by increased annulus pressure.

Also, it has been proposed in connection with a circulation valve to utilize such a compressed nitrogen gas chamber in combination with a floating shoe which transmits the pressure from the compressed nitrogen gas to a non-compressible liquid-filled chamber, which liquid-filled chamber is communicated with a well annulus through a pressurizing and depressurizing passage, each of which includes a fluid flow restriction means and a back pressure valve, to trap annulus pressure. This is shown in U.S. Patent No. 4,113,012.

One significant disadvantage of all these nitrogen gas-filled valves, is that the nitrogen chamber must be filled with pressurized nitrogen gas under extremely high pressures while the valve is still located at the surface, and before it is lowered into the well. This creates safety problems due to the difficulties of containing the high pressure gas.

In U.S. Patents Nos. 4109724 and 4109725 it has been proposed to utilise liquid springs using silicone liquid in downhole tools.

We have devised a liquid spring downhole tool apparatus, particularly a valve tool apparatus, which is described in our co-pending European patent application EP—A—83300882.4 (0088550) from which the present application is divided.

In U.S. 4109725 the tool apparatus has a mechanical spring supplementing the liquid spring. In accordance with the present invention we use only a liquid spring but also provide a booster piston to aid in initially overcoming any frictional resistance to movement of the operating element.

According to the present invention there is provided a downhole tool apparatus, comprising: a housing; an operating element disposed in said housing; a power piston disposed in said housing, one side of said power piston being communicated with a power source of pressurized fluid, said power piston being operably associated with said operating element so that said operating element is moved between first and second positions in response to movement of said power piston between an initial position and a final position; a first chamber disposed in said housing and filled at least partially with a compressible liquid, a second side of said power piston being in fluid communication with said first chamber so that pressure from said compressible liquid is transmitted to said second side of said power piston, said first chamber and said compressible liquid providing a compressible liquid spring means for resiliently opposing motion of said power piston in a first direction from its initial position toward its final position and for providing a restoring force to move said power piston back to its initial position; characterised in that said power piston includes: a main piston having a first differential area acted upon by a pressure differential between said power source and said first chamber; and a booster piston, operably associated with said main piston, for initially providing an additional differential area to said first differential area of said main piston and for thereby providing an additional initial force for moving said operating element through a first portion of its travel from its first position toward its second position.

In the downhole tools of the invention, the said operating element may be any of a number of such elements, including, for example, a valve element.

One embodiment of the invention provides such a valve element, which is a flow valve, wherein: said first and second positions of said flow valve are closed and open positions, respectively; and said first portion of travel of said flow valve corresponds to movement of said flow valve from its said closed position to a partially open position whereby a pressure differential across said flow valve is relieved, thereby reducing a frictional force opposing continued movement of said flow valve to its open second position.

In one preferred embodiment, the invention provides a valve comprising: an outer housing including: an upper housing adapter; a valve housing section connected to said upper housing adapter; an upper filler nipple connected to said valve housing section; a power housing section connected to said upper filler nipple; a liquid spring chamber connector connected to said power housing section; a liquid spring chamber housing section connected to said liquid spring chamber connector; a lower filler nipple connected to said liquid spring chamber housing section; a lower housing section connected to said lower filler nipple; and a lower housing adapter connected to said lower housing section; valve means, disposed in said valve housing section, and movable between open and closed

positions; power mandrel means, disposed in said outer housing, and including a power piston of the invention received within a cylindrical inner bore of said power housing section, said power mandrel means being operatively associated with said valve means for movement of said valve means between its open and closed positions upon movement of said power piston within said power housing section, a lower end of said power mandrel means being slidably and sealingly received within a central bore of said liquid spring chamber connector; a power port disposed through a wall of said power housing section and arranged to be in fluid communication with an upper side of said power piston; a liquid spring chamber mandrel means having an upper end connected to said liquid spring chamber connector and a lower end received in a bore of said lower filler nipple, said liquid spring chamber mandrel means being spaced radially inward from said liquid spring chamber housing section so as to define an annular main spring chamber which is in fluid communication with a lower side of said power piston; a lower mandrel having an upper end connected to said lower filler nipple and a lower end sealingly received in a bore of said lower housing adapter, said lower mandrel being spaced radially inward from said lower housing section to define an annular equalizing chamber; a metering cartridge disposed between said lower housing section and said lower mandrel at an upper end of said equalizing chamber; pressurizing passage means, disposed through said lower filler nipple and said metering cartridge, for communicating said main spring chamber with said equalizing chamber; a pressurizing back pressure check valve disposed in said pressurizing passage means within said metering cartridge, for allowing liquid to flow from said equalizing chamber to said main spring chamber; a first time delay liquid flow restriction disposed in said pressurizing passage means within said metering cartridge; a depressurizing passage means, disposed through said lower filler nipple and said metering cartridge for communicating said main spring chamber with said equalizing chamber; a depressurizing back pressure check valve, disposed in said depressurizing passage means within said metering catridge, for allowing liquid to flow from said main spring chamber to said equalizing chamber; a second time delay liquid flow restriction disposed in said depressurizing passage means within said metering cartridge; an equalizing port disposed through a wall of said lower housing section; and a floating piston means, disposed in said equalizing chamber above said equalizing port.

The invention further provides a method of flow testing a well, said method comprising the steps of: lowering a flow tester valve of the invention into said well, the tester valve being an annulus pressure operated flow tester valve having a liquid spring means for returning said valve to its closed position, said liquid spring means being at substantially atmospheric pressure as said lowering is begun; transmitting annulus fluid pressure from an annulus of said well to said liquid spring means as said flow tester valve is lowered into said well; locating said flow tester valve within said well at a final depth; pressurizing said annulus an additional amount, above a hydrostatic pressure therein, sufficient to open said flow tester valve; transmitting at least a portion of said additional amount of annulus pressure to said liquid spring means; depressurizing said annulus to a final annulus pressure; as said annulus is depressurized, trapping a portion of the pressure in said liquid spring means in excess of said final annulus pressure sufficient to close said flow tester valve so that a trapped amount of liquid pressure energy trapped in said liquid spring means in excess of an amount of liquid pressure energy within said liquid spring means when said liquid spring means was at substantially atmospheric pressure is entirely obtained from transmittal of liquid pressure energy from said well annulus to said liquid spring means; and closing said flow tester valve, upon depressurizing of said annulus, by use of said trapped liquid pressure energy.

In preferred tester valves of the invention, a silicone liquid spring chamber is utilised. Significant safety advantages are provided as compared to the nitrogen-filled units of the prior art since the safety problems of dealing with high pressure nitrogen are eliminatd. Additionally, the structure for, and manner of operating and controlling the pressure within, the silicone liquid spring chamber are improved in numerous respects as compared to the two prior silicone liquid filled tools referred to above.

The valve apparatus of the present invention generally includes a housing with a flow valve means disposed therein for opening and closing a flow passage of the housing. A power mandrel means is disposed in the housing and includes a power piston. The power mandrel means is connected to the flow valve means. A power passage transmits well annulus pressure to the top side of the power piston. A first chamber is disposed in the housing and filled at least partially with compressible liquid. The lower side of the power piston is in communication with this first chamber. A second chamber is also disposed in the housing and has a floating piston means disposed therein dividing the second chamber into a first zone and a second zone. An equalizing passage is disposed through the housing for transmitting well annulus pressure to the second zone of the second chamber. Both a pressurizing passage and a depressuring passage each communicate the first chamber with the first zone of the second chamber. A first back pressure check valve means and a first fluid flow restriction are placed in the pressurizing passage for fluid communication from the first zone of the second chamber to the first chamber. A second back pressure check valve means and a second fluid flow restriction are placed in the depressurizing

passage, in reverse order of those just described, for fluid communication from the first chamber to the first zone of the second chamber. This arrangement provides a means for trapping a portion of the well annulus fluid in the first chamber so as to provide liquid pressure energy for returning the power mandrel and the flow valve to the closed position upon depressurizing of the well annulus.

In the present invention, the power piston includes a main piston and a booster piston. The booster piston aids in initially overcoming the frictional resistance of the ball valve to opening.

In order that the invention may be more fully understood, reference is made to the accompanying drawings, wherein:

Figure 1 is a schematic elevation view of a representative offshore installation which may be employed for formation testing purposes, and illustrates a formation testing string or tool assembly in position in a submerged well bore extending upwardly to the floating operating and testing station.

Figures 2A—2J comprise an elevational section view of a tester valve of the type devised for the present invention, but which does not include the present invention.

Figure 3 is a view similar to Figure 2G illustrating an alternative embodiment of the tool of Figures 2A—2J wherein a second floating piston is provided in the first chamber.

Figure 4 is an elevational section view of a locater tool for initially positioning the lower floating piston within the equalizing chamber.

Figures 5C and 5D are similar to Figures 2C and 2D except that they include features of the present invention. Thus the power piston of Figures 5C and 5D includes a main piston and a booster piston. The releasable holding means of Figure 2D has been eliminated.

During the course of drilling an oil well, the borehole is filled with a fluid known as drilling fluid or drilling mud. One of the purposes of this drilling fluid is to contain in intersected formations any fluid which may be found there. To contain these formation fluids the drilling mud is weighted with various additives so that the hydrostatic pressure of the mud at the formation depth is sufficient to maintain the formation fluid within the formation without allowing it to escape into the borehole.

When it is desired to test the production capabilities of the formation, a testing string is lowered into the borehole to the formation depth and the formation fluid is allowed to flow into the string in a controlled testing program. Lower pressure is maintained in the interior of the testing string as it is lowered into the borehole. This is usually done by keeping a valve in the closed position near the lower end of the testing string. When the testing depth is reached, a packer is set to seal the borehole thus closing in the formation from the hydrostatic pressure of the drilling fluid in the well annulus.

The valve at the lower end of the testing string is then opened and the formation fluid, free from the restraining pressure of the drilling fluid, can flow into the interior of the testing string.

A typical arrangement for conducting a drill string test offshore is shown in Figure 1. Such an arrangement would include a floating work station 10 stationed over a submerged well site 12. The well comprises a well bore 14 typically lined with a casing string 16 extending from the work site 12 to a submerged formation 18. The casing string 16 includes a plurality of perforations 20 at its lower end which provide communication between the formation 18 and the interior 22 of the well bore 14.

At the submerged well site is located a wellhead installation 23 which includes blowout preventer mechanisms. A marine conductor 24 extends from the wellhead installation to the floating work station 10. The floating work station 10 includes a work deck 26 which supports a derrick 28. The derrick 28 supports a hoisting means 30. A wellhead closure 32 is provided at the upper end of the marine conductor 24. The wellhead closure 32 allows for lowering into the marine conductor and into the well bore 14 a formation testing string 34 which is raised and lowered in the well by the hoisting means 30.

A supply pump conduit 36 is provided which extends from a hydraulic pump 38 on the work deck 26 of the floating station 10 and extends to the wellhead installation 23 at a point below the blowout preventers to allow the pressurizing of a well annulus 40 surrounding the testing string 34.

The testing string 34 includes an upper conduit string portion 42 extending from the work deck 26 to the wellhead installation 23. A hydraulically operated conduit string test tree 44 is located at the lower end of the upper conduit string 42 and is landed in the wellhead installation 23 to thus support the lower portion of the formation testing string 34.

The lower portion of the formation testing string 34 extends from the test tree 44 to the formation 18. A packer mechanism 46 isolates the formation 18 from fluids in the well annulus 40. A perforated tail piece 48 is provided at the lower end of the formation testing string 34 to allow fluid communication between the formation 18 and the interior of the tubular formation testing string 34.

The lower portion of the formation testing string 34 includes intermediate conduit portion 50 and torque transmitting pressure and volume balance slip joint means 52. An intermediate conduit portion 54 is provided for imparting packer setting weight to the packer mechanism 46 at the lower end of the formation testing string 34.

A circulation valve 56 is located near the lower end of the formation testing string 34. Also near the lower end of the formation testing string 34 below the circulation valve 56 is located a tester valve 58 of the present invention which is described in more detail below.

A pressure recording device 60 is located below the tester valve 58.

The testing string 34 may also include numerous other items of related equipment which is known to those skilled in the art.

Figures 2A—2J show a cross-section elevation view of a tester valve apparatus 58 of the type devised for the present invention.

The valve apparatus 58 includes an outer housing 62. The outer housing 62 itself includes an upper housing adapter 64, a valve housing section 66, an upper filler nipple 68, a power housing section 70, a liquid spring chamber connector 72, a liquid spring chamber housing section 74, a lower filler nipple 76, a lower housing section 78, and a lower housing adapter 80.

A holder mandrel 82 has an externally threaded upper end 84 threadedly connected to internally threaded surface 86 of a lower end of upper housing adapter 64.

The valve housing section 66 has an upper inner cylindrical surface 88 in which is closely received a lower outer cylindrical surface 90 of upper housing adapter 64. A resilient seal 92 is provided between surfaces 88 and 90, and a resilient seal 94 is provided between upper adapter 64 and holder mandrel 82.

The valve housing section 66 includes a plurality of radially inward extending splines 96 which are meshed with a plurality of radially outward extending splines 98 of holder mandrel 82.

Holder mandrel 82 includes a radially outward extending upward facing ledge 100 which is located below the radially outward extending splines 98 and engages lower ends 102 of the radially inward extending splines 96 so that the valve housing section 66 is held longitudinally and rotationally fixed relative to the upper housing adapter 64 by means of the holder mandrel 82.

An upper seat holder 104 has an upper cylindrical outer surface 106 closely received in a lower bore 108 of holder mandrel 82. A resilient seal 110 is provided between upper seat holder 104 and the bore 108.

Upper seat holder 104 includes a first annular groove 112 in a lower end thereof, within which is received an upper annular resilient seat 114. An upper seat retainer 116 is threadedly attached to upper seat holder 104 to hold the upper seat 114 in the groove 112.

A cylindrical collar 118 has an internally threaded upper end 120 attached to an outer threaded surface 122 of holder mandrel 82. Collar 118 has a radially inward extending lip 124 at a lower end thereof.

A lower seat holder 126 has a radially outward extending downward facing surface 128 engaging an upper side of the lip 124 of collar 118.

A second annular seat receiving groove 130 is disposed in the upper end of lower seat holder 126 and has a lower annular resilient seat 132 received therein. A lower seat retainer 134 is threadedly attached to the lower seat holder 126 to hold the lower seat 132 in the groove 130.

A ball valve 136, which may also be referred to as a full opening ball flow valve means, is spherical in shape and has a central bore 138 therethrough. The flow valve means 136 is shown in Figure 2B in its closed position wherein its bore 138 is isolated from a longitudinal axial flow passage 140 of the tester valve apparatus 58 by the upper and lower seats 114 and 132. The flow valve means 136 sealingly engages the upper and lower resilient seats 114 and 132.

An operating means 142 includes a pin 144 which extends through a longitudinal opening in the collar 118 into an eccentric hole 146 of the flow valve means 136. Although only two small portions of the collar 118 are shown in Figures 2A and 2B, the collar 118 is generally an elongated cylinder in shape having a continuous upper end which shows in cross section like the upper end 120 and having a continuous lower end which shows in cross section like the lip 124 with those upper and lower ends being connected by a thin cylinder which has two longitudinal openings therein.

Actually, there are two pins such as 144 which are eccentrically located on opposite sides of the bore 138 in a manner known to those skilled in the art. When the operating means 142 is moved longitudinally downward relative to the housing 62 from the position shown in Figure 2B, the flow valve means 136 is rotated within the seats 114 and 132 to an open position wherein the bore 138 thereof is aligned with the axial flow passage 140 of the tester valve apparatus 58.

A power mandrel means 148 includes a top power mandrel section 150 and a bottom power mandrel section 152 which are threadedly connected together at 154. Formed on the bottom power mandrel section 152 is a power piston 156 which is received within a cylindrical inner bore 158 of power housing section 70.

Top power mandrel section 150 includes radially outward extending splines 160 which mesh with radially inward extending splines 162 of the lower end of upper filler nipple 68 to prevent relative rotation therebetween.

An intermediate portion of top power mandrel section 150 is closely and sealingly received within a bore 164 of upper filler nipple 68 and a seal therebetween is provided by seals 166.

A power mandrel cap 168 is threadedly attached to the upper end of top power mandrel section 150.

A connector assembly 170 includes an upper connector piece 172 and a lower connector piece 174 threadedly connected together at 176.

The upper connector piece 172 includes a groove 178 within which is received a lip 180 of operating means 142 so that operating means 142 and upper connector piece 172 move together longitudinally within the housing 62.

The power mandrel cap 168 is held between upward and downward facing surfaces 182 and 184 of connector assembly 170 so that upon longitudinal movement of power mandrel means 148, the connector assembly 170 moves longitudinally therewith which also moves the oper-

ating means 142 longitudinally therewith so as to operate the closure valve means 136.

A lower end of bottom power mandrel section 152 is closely slidably and sealingly received within a central bore 186 of liquid spring chamber connector 72. The seals therebetween are provided by seals 188 and 190.

A power port 192 is disposed through a wall of power housing section 70 and arranged to be in fluid communication with an upper side 194 of power piston 156.

A seal is provided between piston 156 and bore 158 at 196.

A releasable holding means 198 includes a radially resilient collet sleeve 200 held in place within the housing 62 by upper and lower collet retainer pieces 202 and 204 which are threadedly connected together at 206. The assembled upper and lower collect retainer pieces 202 and 204 are held between a downward facing ledge 208 of power housing section 70 and an upper end 210 of liquid spring chamber connector 72.

Releasable holding means 198 also includes a shoulder piece 212 threadedly connected to bottom power mandrel section 152 at threaded connection 214. Shoulder piece 212 includes thereon a plurality of radially outward extending shoulders 216.

Collet sleeve 200 includes upper and lower tapered surfaces 218 and 220, and shoulder 216 includes upper and lower tapered surfaces 222 and 224 arranged so that when shoulder 216 moves past sleeve 200 one of said tapered surfaces of the shoulder 216 engages one of the tapered surfaces of the sleeve 200 and causes the sleeve 200 to expand radially to allow the shoulder 216 to pass therethrough.

A liquid spring chamber mandrel means 226 includes an upper spring chamber mandrel piece 228 and a lower spring chamber mandrel piece 230 connected together at threaded connection 232.

An upper end of upper spring chamber mandrel piece 228 is threadedly connected to liquid spring chamber connector 72 at threaded connection 234.

A lower end 236 of lower spring chamber mandrel piece 230 is closely received within a bore 238 of lower filler nipple 76 and a seal therebetween is provided by seal 240.

Liquid spring chamber mandrel means 226 is spaced radially inward from liquid spring chamber housing section 74 so as to define an annular main spring chamber 242. Main spring chamber 242 communicates with a lower side 244 of power piston 156 through a connecting bore 246 disposed through liquid spring chamber connector 72 and an annular space 248 between power housing section 70 and bottom power mandrel section 152.

A lower mandrel 250 has an upper end connected to lower filler nipple 76 at threaded connection 252 and a lower end sealingly received in a bore 254 of lower housing adapter 80. A seal is provided between lower mandrel 250 and bore 254 by seal 256.

The lower mandrel 250 is spaced radially inward from lower housing section 78 to define an annular equalizing chamber 258.

A cylindrical metering cartridge 260 is disposed between lower housing section 78 and lower mandrel 250 at an upper end of equalizing chamber 258.

A pressurizing passage means 262 includes an upper portion 264 disposed in lower filler nipple 76 and a lower portion 266 disposed in metering cartridge 260. Pressurizing passage means 266 communicates main spring chamber 242 with equalizing chamber 258.

Pressurizing back pressure check valve 268 is disposed in lower portion 266 of pressurizing passage means 262 for allowing liquid to flow from equalizing chamber 258 to the main spring chamber 242.

A first time delay liquid flow restriction 270 is disposed in lower portion 266 of pressurizing passage means 262. Also, a filter 271 is disposed in lower portion 266 of pressurizing passage means 262.

A depressurizing passage means 272 includes an upper portion 274 disposed in lower filler nipple 76 and a lower portion 276 disposed in metering cartridge 260. Depressurizing passage means 272 also communicates main spring chamber 242 with equalizing chamber 258.

A depressurizing back pressure check valve 278 is disposed in lower portion 276 of depressurizing passage means 272. A second time delay liquid flow restriction 280 is disposed in lower portion 276 of depressurizing passage means 272. Also, a filter 281 is disposed in lower portion 276 of depressurizing passage means 272.

A floating piston means 282 is disposed in equalizing chamber 258 between lower housing section 78 and lower mandrel 250. Seals 284 and 286 are provided between piston 282 and lower housing section 78. Seals 288 and 290 are provided between floating piston 282 and lower mandrel 250.

An equalizing port 292 is disposed through a wall of lower housing section 78 near a lower end thereof.

Upper filler nipple 68 has a fill port 294 disposed therethrough which is closed by a threaded plug 296.

Lower filler nipple 76 includes a fill port 298 closed by a plug 300. Lower filler nipple 76 also includes a second filler port 302 closed by a plug 304.

Lower housing section 78 includes a filler port 306 closed by a plug 308.

Thus, the valve apparatus 58 may generally be said to include the housing 62 having the flow passage 140 disposed therethrough.

Flow valve means 136 is disposed in the housing 62 and is movable between a closed position as shown in Figure 2B wherein the flow passage 140 is closed, and an open position

wherein the bore 138 of flow valve means 136 is aligned with flow passage 140 so that the flow passage 140 is open.

The power mandrel means 148 is disposed in the housing 62 and includes the power piston 156. The power mandrel means 148 is operatively associated with the flow valve means 136 for moving the flow valve means 136 from its closed position to its open position in one continuous movement simultaneous with movement of the power mandrel means 148 longitudinally downwardly within the housing 62 in one continuous motion from the first position illustrated in Figs. 2B—2E whereupon a lower end 310 of lower connector piece 174 engages an upper end 312 of upper filler nipple 68. The valve means 136 thus snaps open, rather than opening slowly or in incremental steps, and this minimizes fluid erosion problems.

The power port 192 may be described as a power passage means 192 disposed in the housing 62 for transmitting pressure from the well annulus 40 external of the housing 62 to the upper or first side 192 of power piston 156.

A liquid spring chamber, which may also be generally referred to as a first chamber disposed in the housing 62, includes the entire space communicating the bottom or second side 244 of power piston 156 with the fluid flow restrictors 270 and 280 disposed in the metering cartridge 260. This first chamber includes a number of the spaces previously defined such as the annular space 248, the bore 246, the main spring chamber 242, and the upper portion 264 of equalizing passage 262 as well as all the other liquid spaces communicated therewith.

In the valve apparatus shown in Figures 2A—2E, this entire first chamber is filled with a compressible liquid which is preferably a silicone oil such as that sold under the trademark DOW CORNING 200. The basic properties of that compressible fluid and its changing compressibility characteristics with changes in pressure and temperature are described in detail in U.S. Patent No. 4,109,724 and U.S. Patent No. 4,109,725.

Also disposed in the housing 62 is the equalizing chamber 258 which may also generally be referred to as a second chamber. The equalizing chamber 258 is divided into a first zone 314 and a second zone 316 by the floating piston means 282 seen in Figure 2I. The equalizing port 292 may generally be described as an equalizing passage means disposed in the housing 62 for transmitting pressure from the well annulus 40 external of the housing 62 to the second zone 316 of the equalizing chamber 258.

The pressurizing passage means 262 and the depressurizing passage means 272 both communicate the main spring chamber portion 242 of the first chamber with the first zone 314 of the second or equalizing chamber 258.

The pressurizing back pressure check valve means 268 allows liquid to flow from the first zone 314 of the equalizing chamber 258 through the pressurizing passage 262 into the main spring chamber portion 242 when a pressure in the first zone 314 of equalizing chamber 258 exceeds a pressure of the compressible liquid in the main spring chamber 242 by a first predetermined value. The pressurizing back pressure check valve means 268 prevents liquid from flowing from the main spring chamber 242 through the pressurizing passage 262 to the first zone 314 of equalizing chamber 258.

The depressurizing back pressure check valve means allows liquid to flow from the main spring chamber 242 through the depressurizing passage 272 into the first zone 314 of equalizing chamber 258 when the pressure in the main spring chamber 242 exceeds the pressure in the first zone 314 of equalizing chamber 258 by a second predetermined value. This second predetermined value is greater than the first predetermined value. The depressurizing back pressure check valve means 278 prevents liquid from flowing from the first zone 314 of equalizing chamber 258 through the depressurizing passage means 272 into the main spring chamber 242.

In the valve apparatus shown in Figures 2A—2E, the entire first chamber, including all of the main spring chamber 242, is completely filled with the compressible liquid and also the first zone 314 of equalizing chamber 258 is completely filled with compressible liquid so that it is the compressible liquid which flows through the metering cartridge 260. However, in certain installations, wherein the amount of flow back and forth through the flow restricting orifices 270 and 280 is particularly great, there may be a problem of foaming of a compressible liquid such as silicone oil, and in that situation an alternative arrangement is preferable wherein a second floating piston 318 is provided in the main spring chamber 242 such as shown in Figure 3. This is described and claimed in our copending European patent application No. 83300882.4.

This second floating piston divides the main spring chamber 242 into an upper first zone 320 and a lower second zone 322. The first zone 320 is completely filled with the compressible silicone oil liquid. The second zone 322 of the main spring chamber 242 and the first zone 314 of equalizing chamber 258 are both filled with a substantially noncompressible liquid, such as hydraulic oil, which will not present any foaming problem as it passes back and forth through the fluid flow restrictions.

With this one modification, the valve apparatus of Figure 3 is otherwise the same as the valve apparatus of Figures 2A—2J.

Continuing with the description of the valve apparatus of Figures 2A—2J, it is necessary that an initial volume of the first chamber when the power mandrel means is in its first position, as illustrated in Figures 2A—2J, be sufficiently large that the amount of compressible silicone oil liquid in the first chamber may be compressed into a final volume of the first chamber as the power mandrel means 148 moves rapidly downward from its first position to its second position

wherein the surfaces 310 and 312 engage. This requires that the silicone oil have sufficient compressibility at the pressures and temperatures involved during the operation of the tester valve apparatus 58 that it can be compressed by a volume at least as great as the volume displaced by the power piston 156 when it moves from its first position shown in Figures 2C—2E to its second position wherein the surfaces 310 and 312 engage as previously described.

A specific detailed example of such a construction is given in U.S. Patent No. 4,109,724, at column 10, line 52—column 11, line 13 thereof, to which reference should be made for further details.

The back pressure check valves 268 and 278 are constructed such that the second predetermined value of the depressurizing back pressure check valve 278 exceeds the first predetermined value of the pressurizing back pressure check valve 268 by an amount sufficient that when a pressure differential of such amount is applied across power piston 156 from the second side 244 toward the first side 194 thereof, when the power mandrel means 148 is in its second position with the surfaces 310 and 312 engaged, a sufficient force is exerted on the power piston 156 to move the power mandrel means 148 back to its first position illustrated in Figures 2C—2E.

The first flow restrictor 270 which may also be referred to as a flow impedance means 270, is disposed in the pressurizing passage means 262 and impedes the flow of liquid through the pressurizing passage 262 so that upon rapid pressurization of the well annulus 40 an annulus fluid pressure in the annulus 40 will increase faster than the annulus fluid pressure can be transmitted through the pressurizing passage 262 to the main spring chamber 242, thereby creating a pressure differential across the power piston 156 from the upper first side 194 toward the lower second side 244 thereof sufficient to move the power mandrel means 148 from its first position shown in Figures 2C—2E to its said second position previously described with surfaces 310 and 312 engaged to thereby open the flow valve means 136.

The second liquid flow restrictor 280 which may be generally described as a second flow impedance means 280, disposed in the depressurizing passage 272, impedes flow of liquid through the depressurizing passage 272 so that when the power mandrel means 148 is in its said second position with the surfaces 310 and 312 engaged, and the well annulus 40 is rapidly depressurized, an annulus fluid pressure in annulus 40 will decrease faster than the pressure of the compressible liquid in the main spring chamber 242 will decrease, thereby creating a pressure differential across the power piston 156 from the lower second side 244 thereof toward the upper first side 194 thereof. This pressure differential is greater than an amount by which the second predetermined value of the depressurizing back pressure check valve 278 exceeds the first predetermined value of the pressurizing back pressure check valve 268. In other words, upon rapid depressurization of the well annulus, there is for a period of time a pressure trapped in the main spring chamber 242 due to the time delay provided by the liquid flow restrictor 280 which exceeds the difference in operating pressure between the check valves 268 and 278.

The releasable holding means 198 is operably associated with the housing 62 and the power mandrel means 148, for holding the power mandrel means in its first position until a pressure differential across the power piston 156 from the upper first side 194 thereof toward the lower second side 244 thereof exceeds a third predetermined value, and for then holding the power mandrel means 148 in its said second position with the surfaces 310 and 312 engaged until a pressure differential across the power piston 156 from its second side 244 toward its first side 194 thereof exceeds a fourth predetermined value, which fourth predetermined value is less than the difference between the first predetermined value of pressurizing back pressure check valve 268 and the second predetermined value of depressurizing back pressure check valve 278. In other words, the pressure differential required across the power piston 156 to force the shoulders 216 attached to the bottom power mandrel section 152 through the collet sleeve 200 is less than the minimum pressure which will be trapped within the main spring chamber 242 due to the different operating pressures of the check valves 268 and 278, thus assuring that even if the well annulus 40 is depressurized very slowly, sufficient pressure will be trapped within the main spring chamber 242 to move the power mandrel means back upward to its first position to close the flow valve means 136.

It will be appreciated that the floating piston means 282 in the equalizing chamber 258 may move in either of two opposite directions relative to the housing 62, i.e., either upward or downward, to either increase or decrease a volume of the first zone 314 of equalizing chamber 258 to allow for either expansion or contraction of the compressible silicone oil liquid due to pressure and temperature changes as the tester valve apparatus 58 is lowered into the well bore 14.

It is important that the floating shoe 282 be initially located at the proper position within equalizing chamber 258 to allow sufficient movement both upward and downward to accommodate all possible volume changes of the compressible liquid encountered during the lowering of the tester valve apparatus 58 into any particular well 14. Accurate positioning of the floating piston 282 is accomplished by means of a positioning tool 324 shown in Figure 4.

Positioning tool 324 includes an upper threaded portion 326 which threadedly engages an internal lower threaded portion 328 of floating piston 282.

The positioning tool 324 also includes a second threaded portion 330 which threadedly engages the threads 332 of the lower end of lower housing

section 78. When the upward facing shoulder 334 of positioning tool 324 engages the lower end 336 of lower housing section 78 the floating piston 282 will be properly located within the equalizing chamber 258. Then the locating tool 324 is unthreaded from the piston 282 and the lower housing section 78 thus leaving the piston 282 in its proper place within the equalizing chamber 258.

The general manner of flow testing a well utilizing the flow tester valve of the present invention with the improved silicone oil liquid spring is as follows. First, a flow pressure valve like the flow tester valve apparatus 58 is provided.

Prior to placing the valve apparatus 58 in the well 14, the liquid spring means, i.e., the compressible fluid located in the first chamber, is maintained at substantially atmospheric pressure. Thus, the danger encountered with prior art tools wherein the compressible fluid, namely nitrogen gas thereof, must be initially placed under high pressures with its accompanying safety hazards to personnel handling the tool is eliminated.

Then the flow tester valve apparatus is lowered into the well bore 14 with the liquid spring means initially still at substantially atmospheric pressure as the lowering is begun.

As the flow tester valve apparatus 58 is lowered into the well bore 14, annulus fluid pressure from the annulus 40 is transmitted to the liquid spring means through the equalizing chamber 258 and the pressurizing passage 262.

In a preferred embodiment of the present invention, the pressurizing back pressure check valve 268 is set to open at a pressure differential of 80 psi (0.55 MPa) and the liquid flow restrictor 270 provides a two-minute time delay such that any liquid pressure differential takes two minutes to be completely transmitted therethrough. Thus, as the flow tester valve 58 is lowered into the well bore 14, the pressure in the main spring chamber 242 lags the pressure in the equalizing chamber 258 by 80 psi (0.55 MPa) plus an amount corresponding to a time lag of two minutes.

This time lag is set to be long anough so that the pressure in main spring chamber 242 will not be effected by rapid changes in annulus pressure, and short enough so that with normal rates of lowering a stand of drill pipe into the well the increase in hydrostatic head as the tester valve 58 is lowered into the well will not occur sufficiently fast to prematurely actuate the flow valve means 136.

The flow tester valve is lowered until it is located within the well bore 14 at a final depth wherein the packer 46 is set against the casing 16.

Then the annulus 40 is rapidly pressurized an additional amount above the hydrostatic pressure which is already present therein sufficient to open the flow valve means 136 of the apparatus 58.

When the annulus 40 is rapidly pressurized this increased pressure is communicated to the upper end 194 of power piston 156 through the power port 192, but is not initially transmitted to the main spring chamber 242 because of the two-minute time delay provided by flow restrictor 270 in the pressurizing passage 262. Thus the pressure on the top of power piston 156 exceeds the pressure communicated with the lower side 244 of power piston 156 and the power piston 156 is moved downward compressing the compressible liquid located within the first chamber and particularly within the main spring chamber 242.

This pressure differential must be sufficient to push the shoulder 216 through the collet sleeve 200 and to compress the compressible silicone liquid located in the first chamber. This opens the flow valve means 136 so that its bore 138 is aligned with the flow passage 140 of the apparatus 58. In a preferred embodiment of the present invention, a pressure differential of 450 psi (3.10 MPa) across the power piston 156 is required to force shoulder 216 through collet sleeve 200, thus the third and fourth predetermined values mentioned above are each equal to 450 psi (3 · 10 MPa).

The well annulus pressure is maintained at this high level while the flow test is performed. After a period of two minutes, the pressure within the main spring chamber 242 will reach a value 80 psi (0.55 MPa) less than the well annulus pressure.

Thus, at least a portion of the additional amount of annulus pressure provided to the well annulus 40 when it was rapidly pressurized is transmitted to the liquid spring means in the first chamber.

When it is desired to close the flow valve means 136, the well annulus 40 is rapidly depressurized to a final annulus pressure much less than the prior high annulus pressure.

As the annulus 40 is depressurized rapidly, this pressure change is not immediately seen in the main spring chamber 242 because the liquid flow restrictor 280 in the depressurizing passage means 272 prevents the rapid flow of liquid from the main spring chamber 242 into the first zone 314 of the equalizing chamber 258, thus trapping the pressure in the liquid spring means for a period of time after the annulus 40 is depressurized. Thus, upon initial depressurization, the pressure trapped within the main spring chamber 242 greatly exceeds the pressure in the well annulus 40 and thus a pressure differential is directed upward against the power piston 156 thus moving the power mandrel means 148 upward to its first position and moving the flow valve means 136 to its closed position.

The value of the pressure differential at which the depressurizing back pressure check valve 278 operates is higher than the first predetermined value of the pressurizing back pressure check valve 268, and in a preferred embodiment is 600 psi (4.14 MPa), so that even after more than two minutes have passed since the depressurization of the annulus 40, a minimum portion of the pressure in the main spring chamber 242 which has remained trapped is at least 600 psi±80 psi (4.14±0.6 MPa) or a total of 520 psi (3.59 MPa) which will always remain trapped in the main spring chamber 242.

The releasable holding means 198 is constructed to be overcome by a pressure differential of only 450 psi (3.10 MPa) so that this minimum trapped pressure, namely, 520 psi (3.59 MPa), provides sufficient force to move the power piston 156 and the power mandrel means 148 back upward to the first position of the power mandrel means 148.

Also, it has been determined that in some circumstances it is not necessary to provide a releasable holding means such as 198, but rather the inherent frictional forces opposing movement of the valve means 136 and the attached structure may be relied upon to prevent premature operation of the valve means 136.

This may be described in terms of the liquid pressure energy which is trapped within the first chamber by means of compression of the compressible fluid therein. It may generally be said that a trapped amount of liquid pressure energy trapped in the liquid spring means, in excess of the liquid pressure energy which was present in the liquid spring means when the liquid spring means was at substantially atmospheric pressure, is entirely obtained from transmittal of liquid pressure energy from the well annulus 40 to the liquid spring means while the apparatus 58 is being lowered into the well bore 14. This means that all of the liquid pressure energy present to reclose the flow valve means 136 was provided from the annulus 40 and none of it was initially provided by any initial pressurization of the compressible liquid prior to placing the tool in the well. This is in contrast to prior art wherein much of the fluid pressure energy contained in a nitrogen-filled tool is placed in the nitrogen chamber prior to the time that the tool is placed in the well bore.

This trapped liquid pressure energy is utilized to close the flow valve means 136 upon depressurizing of the well annulus 40 as previously described.

Referring now to Figures 5C—5D, an embodiment of the present invention is thereshown. In this preferred embodiment, the power piston includes a main piston and a booster piston, and the releasable holding means has been eliminated.

Figures 5C and 5D are similar to Figures 2C and 2D with the modifications mentioned.

Elements of the structure shown in Figures 5C and 5D which are identical to the similar elements of Figures 2C and 2D are designated with the same part numbers as shown in Figures 2C and 2D. Elements of the structure of Figures 5C and 5D which are similar to but somewhat modified from the structure of Figures 2C and 2D are indicated with a suffix A. New parts are given new numbers.

The overall valve apparatus which includes the structure of Figures 5C and 5D is identical to the apparatus shown in Figures 2A—2J except for the changes shown in Figures 5C and 5D. It will therefore be understood that the upper portions of the apparatus partially illustrated in Figures 5C and 5D would be identical to the structure shown in Figures 2A and 2B. It will also be understood that the lower portions of the apparatus including the structure shown in Figures 5C and 5D will be identical to the structure shown in Figures 2E—2J.

The modified apparatus of Figures 5C and 5D includes a power piston 156A. The power piston 156A includes a main piston 400 and a booster piston means 402.

Main piston 400 is an integral part of bottom power mandrel section 152A.

Booster piston means 402 is an annular booster piston concentrically disposed about main piston 400. Booster piston means 402 has an upper end 404 and a lower end 406.

A first annular resilient sliding seal means 408 is provided between main piston 400 and booster piston means 402.

A second annular resilient sliding seal means 410 is provided between booster piston means 402 and bore 158 of power housing section 70A.

At the upper end 404 of booster piston means 402 an engagement lug 412 extends radially inward over and engages an upper end 414 of main piston 400.

The power housing section 70A includes an annular stop lug 416 extending radially inwardly therefrom for engagement with the lower end 406 of booster piston means 402. The stop lug 416 provides a limit means for limiting movement of the booster piston means 402 in a downward direction and for allowing the main piston 400 to continue moving downward.

A lower end 418 of upper filler nipple 68 of outer housing 62 provides a second limit means for limiting movement of the booster piston means 402 in an upward direction when booster piston 402 returns to its initial position and its upper end 404 engages second limit means 418.

During the testing of a tester valve apparatus like that shown in Figures 2A—2J, it became evident that very high pressures were required in the well annulus 40 to open the ball valve 136. Examination of the operating pressures showed that the annulus pressure required to initially crack open the ball valve 136 peaked after a relatively short portion of the total travel required to move the ball valve from its fully closed to its fully open position. The pressure required to continue the opening operation of the ball valve after the ball valve was initially cracked open was in most cases less than one-half of the peak operating pressure.

It is believed that this peak operating pressure and the rapid drop-off in operating pressure is due to the frictional forces within the ball valve assembly which oppose the initial opening of the ball valve because of a differential pressure in the flow passage 140 across the ball valve 136. Prior to the opening of the ball valve 136, the pressure in passage 140 below the ball valve is much greater than the pressure above the ball valve, and thus the ball valve 136 is pushed upward against the resilient seat 114 creating a high frictional force which must be overcome to turn the ball valve 136 against the resilient seat 114.

As soon as the ball valve 136 is cracked open, this pressure differential is released through the bore 138 of the ball valve 136, so that the force

required to further move the ball valve 136 relative to the seat 114 is very much reduced.

One way in which the required annulus operating pressure could be reduced, would be to increase the differential area of the power piston. A fixed travel of the power mandrel is, however, required in order to open the ball valve 136. Thus, if the differential area of the power piston 156 were merely increased, and the travel remained the same, the volume displaced by the power piston 156 would be substantially increased thus increasing the necessary volume of silicone fluid in the main spring chamber 242.

By the present invention, the use of the booster piston means 402 initially provides a power piston 156A having a differential area equal to the combined differential areas of main piston 400 and booster piston 402. This provides a large differential area for the power piston during the initial portion of its travel during which the ball valve 136 is cracked open.

After the booster piston 402 and the main piston 400 have moved downward a sufficient distance to crack the ball valve 136 open, the lower end 406 of booster piston 402 engages the stop lug 416 to stop the downward movement of the booster piston 402. At this point, the operating pressure necessary to continue the opening of the ball valve 136 is very much reduced, and the differential area provided by main piston 400 is sufficient to provide sufficient force to continue moving the power mandrel downward until the ball valve 136 is fully opened.

The additional volume of silicone oil displaced by booster piston 402 was originally expected to raise the pressure of the silicone oil during the initial travel of power piston 156A. Operating tests have shown, however, that very little additional compressibility of the silicone oil is required. It is believed that this is a result of air trapped in the silicone oil.

Furthermore, tests have shown that the booster piston 402 functions in a surprising manner much different from what was expected.

It was originally expected that the booster piston 402 would engage stop lug 416 and remain abutted against stop lug 416 until such time as the well annulus pressure was reduced to reclose ball valve 136. It was assumed that this would be the case because the well annulus pressure would be greater than the silicone oil pressure thus maintaining a downward acting pressure differential across booster piston 402.

Operating tests have shown, however, that during the downward opening stroke of power piston means 156A, after lower end 406 of booster piston 402 engages stop lug 416 and as the main piston 400 continues to move rapidly downward further compressing the silicone oil, the booster piston 402 moves back upward to its initial position abutting second limit means 418. It is believed that this is a result of the momentum of the rapidly downward moving power mandrel means 148 causing a pressure surge in the silicone oil such that for a short period of time the silicone oil pressure actually exceeds the well annulus pressure. This pressure surge causes an upward acting pressure differential across the booster piston means 402 moving it back upward to its initial position.

One significant advantage provided by this unexpected phenomenon is that the decrease in silicone oil volume due to the initial downward movement of booster piston 402 is restored when booster piston 402 returns to its initial position, thus reducing the required compressibility of the silicone oil. As a result, the initial added opening force of the larger diameter booster piston 402 is provided without any significant requirement of additional silicone oil compressibility that normally would be associated with an increase in piston diameter.

Claims

1. A downhole tool apparatus, comprising: a housing (62); an operating element (136) disposed in said housing; a power piston (156A) disposed in said housing, one side of said power piston being communicated with a power source of pressurized fluid, said power piston being operably associated with said operating element so that said operating element is moved between first and second positions in response to movement of said power piston between an initial position and a final position; a first chamber (242) disposed in said housing and filled at least partially with a compressible liquid, a second side of said power piston being in fluid communication with said first chamber so that pressure from said compressible liquid is transmitted to said second side of said power piston, said first chamber and said compressible liquid providing a compressible liquid spring means for resiliently opposing motion of said power piston in a first direction from its initial position toward its final position and for providing a restoring force to move said power piston back to its initial position; characterised in that said power piston includes: a main piston (400) having a first differential area acted upon by a pressure differential between said power source and said first chamber; and a booster piston (402), operably associated with said main piston, for initially providing an additional differential area to said first differential area of said main piston and for thereby providing an additional initial force for moving said operating element through a first portion of its travel from its first position toward its second position.

2. Apparatus according to claim 1, further comprising limit means (416), operably associated with said booster piston, for limiting movement of said booster piston in said first direction when said operating element has been moved through said first portion of its travel from its first position toward its second position and for allowing said main piston to continue moving in said first direction.

3. Apparatus according to claim 2, wherein: said limit means (416) is a stop lug extending

required to further move the ball valve 136 relative to the seat 114 is very much reduced.

One way in which the required annulus operating pressure could be reduced, would be to increase the differential area of the power piston. A fixed travel of the power mandrel is, however, required in order to open the ball valve 136. Thus, if the differential area of the power piston 156 were merely increased, and the travel remained the same, the volume displaced by the power piston 156 would be substantially increased thus increasing the necessary volume of silicone fluid in the main spring chamber 242.

By the present invention, the use of the booster piston means 402 initially provides a power piston 156A having a differential area equal to the combined differential areas of main piston 400 and booster piston 402. This provides a large differential area for the power piston during the initial portion of its travel during which the ball valve 136 is cracked open.

After the booster piston 402 and the main piston 400 have moved downward a sufficient distance to crack the ball valve 136 open, the lower end 406 of booster piston 402 engages the stop lug 416 to stop the downward movement of the booster piston 402. At this point, the operating pressure necessary to continue the opening of the ball valve 136 is very much reduced, and the differential area provided by main piston 400 is sufficient to provide sufficient force to continue moving the power mandrel downward until the ball valve 136 is fully opened.

The additional volume of silicone oil displaced by booster piston 402 was originally expected to raise the pressure of the silicone oil during the initial travel of power piston 156A. Operating tests have shown, however, that very little additional compressibility of the silicone oil is required. It is believed that this is a result of air trapped in the silicone oil.

Furthermore, tests have shown that the booster piston 402 functions in a surprising manner much different from what was expected.

It was originally expected that the booster piston 402 would engage stop lug 416 and remain abutted against stop lug 416 until such time as the well annulus pressure was reduced to reclose ball valve 136. It was assumed that this would be the case because the well annulus pressure would be greater than the silicone oil pressure thus maintaining a downward acting pressure differential across booster piston 402.

Operating tests have shown, however, that during the downward opening stroke of power piston means 156A, after lower end 406 of booster piston 402 engages stop lug 416 and as the main piston 400 continues to move rapidly downward further compressing the silicone oil, the booster piston 402 moves back upward to its initial position abutting second limit means 418. It is believed that this is a result of the momentum of the rapidly downward moving power mandrel means 148 causing a pressure surge in the silicone oil such that for a short period of time the silicone oil pressure actually exceeds the well annulus pressure. This pressure surge causes an upward acting pressure differential across the booster piston means 402 moving it back upward to its initial position.

One significant advantage provided by this unexpected phenomenon is that the decrease in silicone oil volume due to the initial downward movement of booster piston 402 is restored when booster piston 402 returns to its initial position, thus reducing the required compressibility of the silicone oil. As a result, the initial added opening force of the larger diameter booster piston 402 is provided without any significant requirement of additional silicone oil compressibility that normally would be associated with an increase in piston diameter.

Claims

1. A downhole tool apparatus, comprising: a housing (62); an operating element (136) disposed in said housing; a power piston (156A) disposed in said housing, one side of said power piston being communicated with a power source of pressurized fluid, said power piston being operably associated with said operating element so that said operating element is moved between first and second positions in response to movement of said power piston between an initial position and a final position; a first chamber (242) disposed in said housing and filled at least partially with a compressible liquid, a second side of said power piston being in fluid communication with said first chamber so that pressure from said compressible liquid is transmitted to said second side of said power piston, said first chamber and said compressible liquid providing a compressible liquid spring means for resiliently opposing motion of said power piston in a first direction from its initial position toward its final position and for providing a restoring force to move said power piston back to its initial position; characterised in that said power piston includes: a main piston (400) having a first differential area acted upon by a pressure differential between said power source and said first chamber; and a booster piston (402), operably associated with said main piston, for initially providing an additional differential area to said first differential area of said main piston and for thereby providing an additional initial force for moving said operating element through a first portion of its travel from its first position toward its second position.

2. Apparatus according to claim 1, further comprising limit means (416), operably associated with said booster piston, for limiting movement of said booster piston in said first direction when said operating element has been moved through said first portion of its travel from its first position toward its second position and for allowing said main piston to continue moving in said first direction.

3. Apparatus according to claim 2, wherein: said limit means (416) is a stop lug extending

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radially inward from said housing for engaging said booster piston and preventing further movement thereof in said first direction.

4. Apparatus according to claim 2 or 3, further comprising: second limit means (418), operably associated with said booster piston, for limiting movement of said booster piston in a second direction opposite said first direction, when said booster piston returns to an initial position thereof.

5. Apparatus according to claim 1, 2, 3 or 4, wherein: said operating element is a flow valve; said first and second positions of said flow valve are closed and open positions, respectively; and said first portion of travel of said flow valve corresponds to movement of said flow valve from its said closed position to a partially open position whereby a pressure differential across said flow valve is relieved thereby reducing a frictional force opposing continued movement of said flow valve to its open second position.

6. Apparatus according to any of claims 1 to 5, wherein: said first chamber, when said power piston is in its initial position, is sufficiently large that said compressible liquid therein may be compressed into a final volume as said power piston moves rapidly from its initial position to its final position.

7. Apparatus according to any of claims 1 to 6, wherein: said booster piston is an annular booster piston disposed concentrically about said main piston; said power piston includes a first annular resilient sliding seal means (408) between said main piston and said booster piston, and a second annular resilient sliding seal means (410) between said booster piston and an internal bore of said housing; and said annular booster piston includes an engagement means (412) for engaging said main piston and transferring to said main piston a force resulting from said pressure differential between said power source and said first chamber acting across said additional differential area of said annular booster piston, when a pressure of said power source exceeds pressure in said first chamber and when said power piston is in its initial position.

8. Apparatus according to claim 1, further characterised in that said downhole tool apparatus (58) is a valve apparatus (58); in that the housing (62) is an outer housing (62); in that said outer housing includes an upper housing adapter (64); a valve housing section (66) connected to said upper housing adapter, an upper filler nipple (68) connected to said valve housing section, a power housing section (70) connected to said upper filler nipple, a liquid spring chamber connector (72) connected to said power housing section, a liquid spring chamber housing section (74) connected to said liquid spring chamber connector, a lower filler nipple (76) connected to said liquid spring chamber housing section, a lower housing section (78) connected to said lower filler nipple, and a lower housing adapter (80) connected to said lower housing section; in that the operating element (136) is a valve (136), disposed in said valve housing section, and movable between open and closed positions; in that a power mandrel (148) is provided, disposed in said outer housing, and including said power piston (156A) received within a cylindrical inner bore (158) of said power housing section, the power piston of said power mandrel including said main piston (400) and an annular booster piston (402) disposed concentrically about said main piston; in that a first annular resilient sliding seal means (408) is provided, disposed between said main piston and said booster piston; in that a second annular resilient sliding seal means (410) is provided, disposed between said booster piston and said cylindrical inner bore of said power housing section; in that an engagement means (412) is provided, disposed on said annular booster piston, for engaging said main piston and transferring to said main piston a force developed by a differential pressure acting across said booster piston; in that a stop lug (416) is provided extending radially inward from said power housing section, for engaging said booster piston and preventing further movement thereof, after said valve is partially opened; in that a lower end of said power mandrel is slidably and sealingly received within a central bore (186) of said liquid spring chamber connector; in that a power port (192) is provided, disposed through a wall of said power housing section and arranged to be in fluid communication with an upper side of said power piston; in that a liquid spring chamber mandrel (226) is provided having an upper end (228) connected to said liquid spring chamber connector and a lower end (236) received in a bore (238) of said lower filler nipple, said liquid spring chamber mandrel being spaced radially inward from said liquid spring chamber housing section so as to define the annular main spring chamber (242) which is in fluid communication with a lower side (244) of said power piston; in that a lower mandrel (250) is provided having an upper end connected to said lower filler nipple and a lower end sealingly received in a bore (254) of said lower housing adapter, said lower mandrel being spaced radially inward from said lower housing section to define an annular equalising chamber (258); in that a metering cartridge (260) is provided, disposed between said lower housing section and said lower mandrel at an upper end of said equalising chamber; in that a pressurizing passage (262) is provided, disposed through said lower filler nipple and said metering cartridge, for communicating said main spring chamber with said equalising chamber; in that a pressurizing back pressure check valve (268) is provided, disposed in said pressurizing passage within said metering cartridge, for allowing liquid to flow from said equalising chamber to said main spring chamber; in that a first time delay liquid flow restriction (270) is provided, disposed in said pressurizing passage within said metering cartridge; a depressurizing passage (272), disposed through said lower filler nipple and said metering cartridge for communicating said main spring

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chamber with said equalising chamber; in that a depressurizing back pressure check valve (278) is provided, disposed in said depressurizing passage within said metering cartridge, for allowing liquid to flow from said main spring chamber to said equalising chamber; in that a second time delay liquid flow restriction (280) is provided disposed in said depressurizing passage within said metering cartridge; in that an equalising port (292) is provided, disposed through a wall of said lower housing section; and in that a floating piston means (282) is provided, disposed in said equalising chamber above said equalising port.

9. A valve according to claim 8, further comprising: a limit means (418), operably associated with said booster piston, for limiting upward movement of said booster piston when said booster piston returns to an initial position thereof.

10. A method of flow testing a well using apparatus incorporating a tester valve as claimed in claim 5, 8 or 9, said method comprising the steps of: lowering a flow tester valve into said well, wherein the liquid spring means for returning said valve to its closed position is at substantially atmospheric pressure as said lowering is begun; transmitting annulus fluid pressure from an annulus of said well to said liquid spring means as said flow tester valve is lowered into said well; locating said flow tester valve with said well at a final depth; pressurizing said annulus an additional amount, above a hydrostatic pressure therein, sufficient to open said flow tester valve; transmitting at least a portion of said additional amount of annulus pressure to said liquid spring means; depressurizing said annulus to a final annulus pressure; as said annulus is depressurized, trapping a portion of the pressure in said liquid spring means in excess of said final annulus pressure sufficient to close said flow tester valve, so that a trapped amount of liquid pressure energy trapped in said liquid spring means in excess of an amount of liquid pressure energy within said liquid spring means when said liquid spring means was at substantially atmospheric pressure is entirely obtained from transmittal of liquid pressure energy from said well annulus to said liquid spring means; and closing said flow tester valve, upon depressurizing of said annulus, by use of said trapped liquid pressure energy.

Patentansprüche

1. Ein Bohrgerät, enthaltend: ein Gehäuse (62); ein Arbeitsglied (136) das in dem besagten Gehäuse angeordnet ist; ein Antriebskolben (156A), der in dem besagten Gehäuse angeordnet ist, wobei eine Seite des besagten Antriebskolbens mit einer Antriebsquelle aus unter Druck stehendem Druckmittel verbunden ist und der besagte Antriebskolben mit dem besagten Arbeitsglied wirksam verbunden ist, so daß das besagte Arbeitsglied sich zwischen einer ersten und einer zweiten Stellung bewegt, in Abhängigkeit von der Bewegung des besagten Antriebskolbens zwischen einer Ausgangsstellung und einer Endstellung; eine erste Kammer (242), die in dem besagten Gehäuse angeordnet ist und wenigstens zum Teil mit einer kompressiblen Flüssigkeit gefüllt ist, wobei eine zweite Seite des besagten Antriebskolbens mit der besagten ersten Kammer in Druckmittelverbindung steht, so daß Druck von der besagten kompressiblen Flüssigkeit auf die besagte zweite Seite des besagten Antriebskolbens übertragen wird, wobei die besagte erste Kammer und die besagte kompressible Flüssigkeit Federmittel aus kompressibler Flüssigkeit darstellen, die der Bewegung des besagten Antriebskolbens in einer ersten Richtung von seiner Ausgangsstellung zu seiner Endstellung, elastisch entgegenwirken und eine Rückstellkraft lieferen, so daß der besagte Antriebskolben zurück in seine Ausgangstellung bewegt wird; dadurch gekennzeichnet, daß der besagte Antriebskolben einschließt: einen Hauptkolben (400), der eine erste Differenzfläche aufweist, auf die eine Druckdifferenz zwischen der besagten Antriebsquelle und der besagten ersten Kammer wirkt; und einen Hilfskolben (402), der mit dem Hauptkolben in Wirkverbindung ist, so daß anfänglich eine zusätzliche Differenzfläche zu der besagten ersten Differenzfläche des besagten Hauptkolbens zur vorhanden ist, und so daß anfänglich dadurch eine zusätzliche Kraft zur Verfügung steht, um das besagte Arbeitsglied über einen ersten Teil seines Weges von seiner ersten Stellung zu seiner zweiten Stellung zu bewegen.

2. Gerät nach Anspruch 1, weiterhin Begrenzungsmittel (416) enthaltend, die in Wirkverbindung mit dem besagten Hilfskolben sind, so daß, wenn das besagte Arbeitsglied über den ersten Teil seiner Bewegung von seiner ersten Stellung zu seiner zweiten Stellung bewegt worden ist, die Bewegung des besagten Hilfskolbens in die besagte erste Richtung begrenzt wird und der besagte Hauptkolben weiter in die besagte erste Richtung bewegbar ist.

3. Gerät nach Anspruch 2, bei welchem das besagte Begrenzungsmittel (416) eine Anschlagnase ist, die von dem besagten Gehäuse radial nach innen vorspringt, so daß sie an dem besagten Hilfskolben zur Anlage kommt und dessen weitere Bewegung in die besagte erste Richtung verhindert.

4. Gerät nach Anspruch 2 oder 3, weiterhin enthaltend: zweite, mit dem Hilfskolben in Wirkverbindung stehende Begrenzungsmittel (418), so daß, wenn der besagte Hilfskolben zu seiner Ausgangsstellung zurückkehrt, die Bewegung des besagten Hilfskolbens in eine zweite, der ersten Richtung entgegengesetzte Richtung begrenzt wird.

5. Gerät nach Anspruch 1, 2, 3 oder 4 bei welchem: das besagte Arbeitsglied ein Strömungsventil ist; die erste Stellung und die zweite Stellung des besagten Strömungsventils der Schließstellung bzw. der Offenstellung entsprechen; und der besagte erste Teil der Bewegung des besagten Strömungsventils einer Bewegung des besagten Strömungsventils von seiner besagten Schließstellung zu einer teilweise geöffneten

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Stellung entspricht, wodurch eine Druckdifferenz an dem besagten Strömungsventil abgelassen wird und dadurch eine Reibungskraft vemindert wird, die der fortgeführten Bewegung des besagten Strömungsventils zu seiner zweiten Offenstellung entgegenwirkt.

6. Gerät nach einem der Ansprüche 1 bis 5, bei welchem: die besagte erste Kammer, wenn sich der besagte Antriebskolben in seiner Ausgangsstellung befindet, ausreichend groß ist, daß, wenn der besagte Antriebskolben sich zügig von seiner Ausgangsstellung zu seiner Endstellung bewegt, die besagte, darin befindliche kompressible Flüssigkeit auf ein endgültiges Volumen komprimiert werden kann.

7. Gerät nach einem der Ansprüche 1 bis 6, bei welchem: der besagte Hilfskolben ringförmig ist und konzentrisch um den besagten Hauptkolben herum angeordnet ist; der besagte Antriebskolben ein erstes ringförmiges, elastisches Gleitdichtungsmittel (408) zwischen dem besagten Hauptkolben und dem besagten Hilfskolben, sowie ein zweites ringförmiges, elastisches Gleitdichtungsmittel (410) zwischen dem besagten Hilfskolben und einer inneren Bohrung des besagten Gehäuses einschließt; und der besagte ringförmige Hilfskolben Anlagemittel (412) einschließt zur Anlage an den besagten Hauptkolben und zur Übertragung einer Kraft auf den besagten Hauptkolben, die sich ergibt aus der besagten Druckdifferenz zwischen der besagten Antriebsquelle und der ersten Kammer, die auf die besagte Differenzfläche des besagten ringförmigen Hilfskolbens wirkt, wenn ein Druck der besagten Antriebsquelle den Druck in der besagten ersten Kammer übersteigt und wenn sich der besagte Antriebskolben in seiner Ausgangstellung befindet.

8. Gerät nach Anspruch 1, weiterhin dadurch gekennzeichnet, daß das besagte Bohrgerät (58) ein Ventilgerät (58) ist; das Gehäuse (62) ein äußeres Gehäuse (62) ist; das besagte äußere Gehäuse ein oberes Gehäuseanpassungsteil (64) einschließt; ein Ventilgehäuseabschnitt (66) mit dem besagten oberen Gehäuseanpassungsteil verbunden ist, ein oberer Einfüllnippel (68) mit dem besagten Gehäuseabschnitt verbunden ist, ein Antriebsgehäuseabschnitt (70) mit dem besagten oberen Einfüllnippel verbunden ist, ein Verbindungsteil für die Flüssigkeitsfederkammer (72) mit dem besagten Antriebsgehäuseabschnitt verbunden ist, ein Gehäuseabschnitt der Flüssigkeitsfederkammer (74) mit dem besagten Verbindungsteil für die Flüssigkeitsfederkammer verbunden ist, ein unterer Einfüllnippel (76) mit dem besagten Gehäuseabschnitt der Flüssigkeitsfederkammer verbunden ist, ein unterer Gehäuseabschnitt (78) mit dem besagten unteren Einfüllnippel verbunden ist, und ein unterer Gehäuseanpassungsteil (80) mit dem besagten unteren Gehäuseabschnitt verbunden ist; das Arbeitsglied (136) ein Ventil (136) ist, das in dem besagten Ventilgehäuseabschnitt angeordnet ist und zwischen einer Offenstellung und einer Schließstellung bewegbar ist; daß ein Antriebsinnenteil (148) vorgesehen das, der in dem besagten äußeren Gehäuse angeordnet ist und den besagten Antriebskolben (156A) einschließt, der in einer zylindrischen inneren Bohrung (158) des besagten Antriebsgehäuseabschnitts aufgenommen ist, der Antriebskolben des besagten Antriebsinnenteils den besagten Hauptkolben (400) und einen ringförmigen, konzentrisch über dem besagten Hauptkolben angeordneten Hilfskolben (402) einschließt; daß ein erstes ringförmiges, elastisches Gleitdichtungsmittel (408) zwischen dem besagten Hauptkolben und dem besagten Hilfskolben angeordnet ist; daß ein zweites ringförmiges, elastisches Gleitdichtungsmittel (410) zwischen dem besagten Hilfskolben und der besagten zylindrischen inneren Bohrung des besagten Antriebsgehäuseabschnitts angeordnet ist; daß Anlagemittel (412) vorgesehen sind, die auf dem besagten ringförmigen Hilfskolben angeordnet sind, so daß der besagte Hauptkolben zur Anlage kommt und auf den besagten Hauptkolben eine Kraft übertragen wird, die sich aus einer an dem besagten Hilfskolben wirksamen Druckdifferenz entwikkelt; daß eine Anschlagnase (416) vorgesehen ist, die sich von dem besagten Antriebsgehäuseabschnitt radial nach innen erstreckt, so daß sie an dem besagten Hilfskolben zur Anlage kommt und, nachdem dieses Ventil teilweise geöffnet ist, dessen weitere Bewegung verhindert; daß ein unteres Ende des besagten Antriebsinnenteils gleitbar und dicht in einer zentralen Bohrung (186) in dem besagten Anschluß der Flüssigkeitsfederkammer aufgenommen ist; daß ein Antriebsanschluß (192) vorgesehen ist, der in einer Wand des besagten Antriebsgehäuseabschnitts verläuft und mit einer oberen Seite des besagten Antriebskolbens in Druckmittelverbindung steht; daß eine Flüssigkeitsfederkammer-Innenteil (226) vorgesehen ist, das ein oberes, mit dem besagten Anschluß der Flüssigkeitsfederkammer verbundenes Ende (228) aufweist sowie ein unteres Ende (236) aufweist, das in einer Bohrung (238) des besagten unteren Einfüllnippels aufgenommen ist, wobei das besagte Flüssigkeitsfederkammer-Innenteil im Abstand radial einwärts von dem Abschnitt der Flüssigkeitsfederkammer angeordnet ist, so daß die ringförmige, mit einer unteren Seite (244) des besagten Antriebskolbens in Druckmittelverbindung stehende Hauptfederkammer (242) gebildet wird; daß ein unteres Innenteil (250) vorgesehen ist, mit einem oberen Ende, das mit dem besagten unteren Einfüllnippel verbunden ist, und einem unteren Ende, das dicht in einer Bohrung (254) des besagten unteren Gehäuseanpassungsteil aufgenommen ist, wobei das besagte untere Innenteil radial nach innen, im Abstand von dem besagten unteren Gehäuseabschnitt angeordnet ist, so daß eine ringförmige Ausgleichskammer (258) gebildet wird; daß eine Dosierpatrone (260) vorgesehen ist, die zwischen dem besagten unteren Gehäuseabschnitt und dem besagten unteren Innenteil an einem oberen Ende der besagten Ausgleichskammer angeordnet ist; daß ein Druckübertragungskanal (262) vorgesehen ist, der durch den besagten unteren Füllnippel und die besagte Dosierpatrone ver-

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läuft, so daß eine Verbindung zwischen der besagten Federkammer und der besagten Ausgleichskammer besteht; daß ein druckübertragendes Rückschlagventil (268) vorgesehen ist, das in dem besagten Druckübertragungskanal in der Dosierpatrone angeordnet ist, so daß es möglich ist, daß Flüssigkeit von der besagten Ausgleichskammer zu der besagten Hauptfederkammer strömt; daß eine erste zeitverzögernde Flüssigkeitsströmungsdrossel (270) vorgesehen ist, die in dem besagten Druckübertragungskanal in der besagten Dosierpatrone angeordnet ist; ein Druckabbaukanal (272), der durch den besagten unteren Füllnippel und die besagte Dosierpatrone verläuft, so daß eine Verbindung zwischen der besagten Federkammer und der besagten Ausgleichskammer besteht; daß ein druckabbauübertragendes Rückschlagventil (278) vorgesehen ist, das in dem besagten Druckübertragungskanal in der Dosierpatrone angeordnet ist, so daß es möglich ist, daß Flüssigkeit von der besagten Ausgleichskammer zu der besagten Hauptfederkammer strömt; daß eine zweite zeitverzögernde Flüssigkeitsströmungsdrossel (280) vorgesehen ist, die in dem besagten Druckabbaukanal in der besagten Dosierpatrone angeordnet ist; daß ein Ausgleichsanschluß (292) vorgesehen ist, der in einer Wand des unteren Gehäuseabschnitts verläuft; und daß schwimmende Kolbenmittel (282) in der besagten Ausgleichskammer über dem besagten Ausgleichsanschluß vorgesehen sind.

9. Ein Ventil nach Anspruch 8, weiterhin enthaltend: Begrenzungsmittel (418), die mit dem besagten Hilfskolben in Wirkverbindung sind, so daß, wenn der besagte Hilfskolben in seine Ausgangsstellung zurückkehrt, die Aufwärtsbewegung des besagten Hilfskolbens begrenzt wird.

10. Ein Verfahren zur Strömungsprüfung in einem Bohrloch unter Verwendung eines Gerätes das ein Prüfventil gemäß Anspruch 5, 8 oder 9 beinhalted, wobei das besagte Verfahren die Schritte aufweist: Absenken eines Strömungsprüfventils in das besagte Bohrloch, wobei, falls mit dem Absenken begonnen wird, die Flüssigkeitsfedermittel zur Rückführung des besagten Ventils in seine geschlossene Stellung im wesentlichen unter Atmosphärendruck stehen; Übertragen des Ringraumflüssigkeitsdrucks von einem Ringraum des besagten Bohrlochs auf die besagten Flüssigkeitsfedersmittel, während das besagte Strömungsprüfventil in das besagte Bohrloch abgesenkt wird; Placieren des besagten Strömungsprüfventils in dem besagten Bohrloch in einer endgültigen Tiefe; Unterdrucksetzen des besagten Ringraumes mit einer bestimmten Menge, die ausreichend ist das besagte Strömungsprüfventil zu öffnen, über den vorhandenen hydrostatische Druck; Übertragen, wenigstens eines Teils der besagten zusätzlichen Ringraumdrucks, auf die besagten Flüssigkeitsfedermittel; Entlasten des besagten Ringraums auf einen endgültigen Ringraumdruck; wenn der besagte Ringraum entlastet wird, Einschließen eines Teils des, im Vergleich zu dem besagten endgültigen Ringraumdruck, überschüssigen Drucks in den besagten Flüssigkeitsfedermitteln, der ausreicht das besagte Strömungsprüfventil zu schließen, so daß eine eingeschlossene Menge an Flüssigkeitsdruckenergie, die in den besagten Flüssigkeitsfedermitteln eingeschlossen ist über die Flüssigkeitsdruckenergie in den Flüssigkeitsdruckmitteln bei im wesentlichen Atmosphärendruck hinaus, vollständig durch die Übertragung von Flüssigkeitsdruckenergie von dem besagten Bohrlochringraums auf die besagten Flüssigkeitsfedermittel zurückerhalten wird; und Schließen des besagten Strömungsüberprüfungsventils, nach Entlasten des besagten Ringraums unter Verwendung der eingeschlossenen Flüssigkeitsdruckenergie.

Revendications

1. Outillage de fond de puits, comprenant: une enveloppe (62); un élément actif (136) disposé dans cette enveloppe; un piston de commande (156A) disposé dans l'enveloppe, l'une des faces de ce piston de commande communiquant avec une source de commande de fluide sous pression, ce piston de commande étant associé fonctionnellement à l'élément actif d'une façon telle que cet élément actif est déplacé entre une première et une seconde positions sous l'influence d'un déplacement du piston de commande entre une position initiale et une position finale; une première chambre (242) disposée dans l'enveloppe et remplie au moins partiellement d'un liquide compressible, une seconde face du piston de commande étant en liaison de communication de fluide avec la première chambre de sorte qu'une pression provenant du liquide compressible est transmise à cette seconde face du piston de commande, la première chambre et le liquide compressible constituant un dispositif de ressort hydraulique à liquide compressible destiné à s'opposer élastiquement à un déplacement du piston de commande dans un premier sens, de sa position initiale vers sa position finale, et à fournir une force de rappel permettant de ramener le piston de commande vers sa position initiale, caractérisé en ce que le piston de commande comprend: un piston principal (400), offrant une première section différentielle sur laquelle agit une différence de pression se présentant entre la source de commande et la première chambre; et un piston d'amplification (402) associé de manière fonctionnelle à ce piston principal de façon à offrir initialement une section différentielle s'ajoutant à la première section différentielle du piston principal et à fournir ainsi une force initiale supplémentaire permettant de déplacer l'élément actif suivant une première partie de sa course s'étendant de sa première position vers sa seconde position.

2. Outillage suivant la revendication 1, comprenant en outre un moyen de limitation (416), associé fonctionnellement au piston d'amplification, qui est destiné à limiter le déplacement de ce piston d'amplification dans ledit premier sens lorsque l'élément actif a été déplacé suivant ladite

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première partie de sa course allant de sa première position vers sa seconde position, et à permettre au piston principal de poursuivre son déplacement dans ledit premier sens.

3. Outillage suivant la revendication 2, dans lequel le moyen de limitation (416) est une nervure d'arrêt s'étendant radialement vers l'intérieur à partir de l'enveloppe et destinée à offrir un contact au piston d'amplification et à empêcher celui-ci de continuer de se déplacer dans ledit premier sens.

4. Outillage suivant la revendication 2 ou 3, comprenant en outre un second moyen de limitation (418), associé fonctionnement au piston d'amplification, qui est destiné à limiter un déplacement de ce piston d'amplification dans un second sens opposé audit premier sens lorsque ce piston d'amplification retourne vers une position initiale qui lui est affectée.

5. Outillage suivant la revendication 1, 2, 3 ou 4, dans lequel l'élément actif est un obturateur d'écoulement, lesdites première et seconde positions de cet obturateur d'écoulement sont des positions respectivement fermée et ouverte, et la première partie de la course de cet obturateur d'écoulement correspond à un déplacement de ce dernier de sa position fermée à une position partiellement ouverte, de sorte qu'une différence de pression se présentant entre les deux côtés de cet obturateur d'écoulement est annulée, réduisant ainsi la force de frottement qui s'oppose à la poursuite du déplacement de cet obturateur jusqu'à sa seconde position, ouverte.

6. Outillage suivant l'une quelconque des revendications 1 à 5, dans lequel la première chambre est suffisamment grande, lorsque le piston de commande est dans sa position initiale, pour que le liquide compressible qui y est contenu puisse être comprimé, jusqu'à offrir un volume final, pendant que le piston de commande se déplace rapidement de sa position initiale à sa position finale.

7. Outillage suivant l'une quelconque des revendications 1 à 6, dans lequel: le piston d'amplification est un piston d'amplification annulaire disposé d'une manière concentrique autour du piston principal; le piston de puissance comporte un premier joint glissant d'étanchéité (408), annulaire et élastique, entre le piston principal et le piston d'amplification, et un second joint glissant d'étanchéité (410), annulaire et élastique, entre le piston d'amplification et un alésage intérieur de l'enveloppe; et le piston d'amplification annulaire comporte un moyen de venue en contact (412) destiné à venir au contact du piston principal et à transférer à ce piston principal une force résultant de la différence de pression existant entre la source de commande et la première chambre et agissant de part et d'autre de la section différentielle supplémentaire du piston d'amplification annulaire, lorsque la pression de la source de commande excède la pression régnant dans la première chambre et lorsque le piston de commande est dans sa position initiale.

8. Outillage suivant la revendication 1, caractérisé en outre en ce que cet outillage de fond de trou (58) est une soupape (58); en ce que l'enveloppe (62) est une enveloppe extérieure (62); en ce que cette enveloppe extérieure comprend un adaptateur supérieur d'enveloppe (64), une section d'enveloppe de soupape (66) reliée à cet adaptateur supérieur d'enveloppe, un raccord supérieur de remplissage (68) relié à cette section d'enveloppe de soupape, une section d'enveloppe de commande (70) reliée à ce raccord supérieur de remplissage, un connecteur de chambre de ressort hydraulique (72) relié à cette section d'enveloppe de commande, une section d'enveloppe de chambre de ressort hydraulique (74) reliée à ce connecteur de chambre de ressort hydraulique, un raccord inférieur de remplissage (76) relié à cette section d'enveloppe de chambre de ressort hydraulique, une section inférieure d'enveloppe (78) reliée à ce raccord inférieur de remplissage, et un adaptateur inférieur d'enveloppe (80) relié à cette section inférieure d'enveloppe; en ce que l'élément actif (136) est un obturateur (136) disposé dans la section d'enveloppe de soupape et mobile entre des positions ouverte et fermée; en ce qu'il est prévu un mandrin de commande (148) disposé dans l'enveloppe extérieure et comprenant ledit piston de commande (156A), qui est logé à l'intérieur d'un alésage intérieur cylindrique (158) de la section d'enveloppe de commande, le piston de commande du mandrin de commande comprenant ledit piston principal (400) et un piston d'amplification annulaire (402) disposé de manière annulaire concentrique autour de ce piston principal; en ce qu'il est prévu un premier joint glissant d'étanchéité (408), annulaire et élastique, disposé entre le piston principal et le piston d'amplification; en ce qu'il est prévu un second joint glissant d'étanchéité (410), annulaire et élastique, disposé entre le piston d'amplification et l'alésage intérieur cylindrique de la section d'enveloppe de commande; en ce qu'il est prévu un moyen de venue en contact (412) disposé sur le piston d'amplification annulaire, destiné à recevoir le contact du piston principal et à transférer à ce piston principal une force résultant d'une différence de pression s'exerçant de part et d'autre du piston d'amplification; en ce qu'il est prévu une nervure d'arrêt (416) s'étendant radialement vers l'intérieur à partir de la section d'enveloppe de commande et destinée à recevoir le contact du piston d'amplification et à empêcher celui-ci de se déplacer plus loin, une fois que l'obturateur est partiellement ouvert; en ce qu'une extrémité inférieure du mandrin de commande est logée de façon coulissante et de manière étanche dans un alésage central (186) du connecteur de chambre de ressort hydraulique; en ce qu'il est prévu un orifice de commande (192) ménagé à travers une paroi de la section d'enveloppe de commande et agencé de façon à être en liaison de communication de fluide avec une face supérieure du piston de commande; en ce qu'il est prévu un mandrin de chambre de ressort hydraulique (226) comportant une extrémité supérieure (228), reliée au

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connecteur de chambre de ressort hydraulique; et une extrémité inférieure (236) logée dans un alésage (238) du raccord inférieur de remplissage, ce mandrin de chambre de ressort hydraulique étant espacé radialement vers l'intérieur par rapport à la section d'enveloppe de chambre de ressort hydraulique de façon à délimiter la chambre principale annulaire de ressort (242) qui est en liaison de communication de fluide avec une face inférieure (244) du piston de commande; en ce qu'il est prévu un mandrin inférieur (250) comportant une extrémité supérieure, reliée au raccord inférieur de remplissage, et une extrémité inférieure logée de manière étanche dans un alésage (254) de l'adaptateur inférieur d'enveloppe, ce mandrin inférieur étant espacé radialement vers l'intérieur par rapport à la section inférieure d'enveloppe de façon à délimiter une chambre annulaire d'égalisation (258), en ce qu'il est prévu une cartouche de calibrage (260) disposée entre la section inférieure d'enveloppe et le mandrin inférieur, à une extrémité supérieure de la chambre d'égalisation; en ce qu'il est prévu un passage de mise sous pression (262) ménagé à travers le raccord inférieur de remplissage et la cartouche de calibrage et destiné à faire communiquer la chambre principale de ressort avec la chambre d'égalisation; en ce qu'il est prévu un clapet anti-retour de mise sous pression (268) disposé dans ce passage de mise sous pression, à l'intérieur de la cartouche de calibrage, et destiné à permettre au liquide de s'écouler de la chambre d'égalisation vers la chambre principale de ressort; en ce qu'il est prévu un premier étranglement d'écoulement de liquide (270), à fonction de retard, disposé dans le passage de mise sous pression, à l'intérieur de la cartouche de calibrage; un passage de délestage de pression (272) ménagé à travers le raccord inférieur de remplissage et la cartouche de calibrage et permettant de faire communiquer la chambre principale de ressort avec la chambre d'égalisation; en ce qu'il est prévu un clapet anti-retour de délestage de pression (278) disposé dans ce passage de délestage de pression, à l'intérieur de la cartouche de dosage, et servant à permettre au liquide de s'écouler de la chambre principale de ressort vers la chambre d'égalisation; en ce qu'il est prévu un second étranglement de liquide (280), à fonction de retard, disposé dans la passage de délestage de pression, à l'intérieur de la cartouche de calibrage; en ce qu'il est prévu un orifice d'égalisation (292) ménagé à travers une paroi de la section inférieure de l'enveloppe; et en ce qu'il est prévu un piston flottant (282) disposé dans la chambre d'égalisation au-dessus de cet orifice d'égalisation.

9. Soupape suivant la revendication 8, comprenant en outre un moyen de limitation (418), associé fonctionnellement au piston d'amplification, destiné à limiter un déplacement de ce piston d'amplification vers le haut lorsque ce dernier retourne vers une position initiale qui lui est affectée.

10. Procédé permettant de soumettre un puits à un essai de production, en utilisant un outillage dont fait partie une soupape de tester suivant l'une quelconque des revendications 5, 8 ou 9, ce procédé comprenant les étapes suivantes: faire descendre dans le puits une soupape de tester, ou d'essai de production, dans laquelle le ressort hydraulique permettant de ramener la soupape dans sa position fermée est pratiquement à la pression atmosphérique lorsque la descente commence; transmettre la pression de fluide d'annulus de l'annulus du puits au ressort hydraulique pendant qu'on fait descendre la soupape de tester dans le puits; positionner la soupape de tester dans ce dernier à une profondeur finale; accroître la pression de l'annulus d'une valeur supplémentaire, au dessus d'une pression hydrostatique qui y règne, suffisante pour faire s'ouvrir la soupape de tester; transmettre au moins une partie de cette valeur supplémentaire de pression d'annulus au ressort hydraulique, délester la pression de l'annulus jusqu'à la pression finale d'annulus; emprisonner, dans le ressort hydraulique, pendant qu'on réalise ce délestage de la pression de l'annulus, une partie de la pression qui est en excès par rapport à la pression finale de l'annulus, cette partie étant suffisante pour faire se fermer la soupape de tester, de sorte qu'une valeur emprisonnée d'énergie de pression hydraulique emprisonnée dans le ressort hydraulique, excédant une valeur d'énergie de pression hydraulique se trouvant dans le ressort hydraulique lorsque ce dernier était pratiquement à la pression atmosphérique, est entièrement obtenue à partir d'une transmission d'énergie de pression hydraulique de l'annulus du puits vers le ressort hydraulique; et fermer la soupape de tester, lors du délestage de la pression de l'annulus, grâce à l'utilisation de cette énergie de pression hydraulique emprisonnée.

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