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[54] **HYDRAULICALLY OPERABLE VALVES**
17 Claims, 9 Drawing Figs.

[52] U.S. Cl..... 166/128,
166/226

[51] Int. Cl..... E21b

[50] Field of Search..... 23/00, E21b 33/12

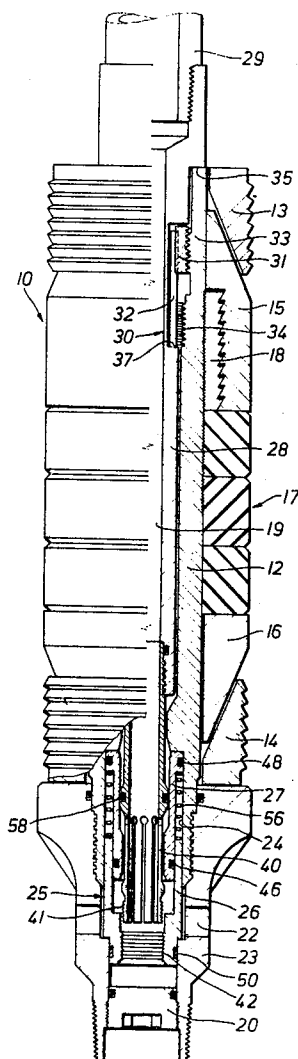
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128, 133, 148, 224—226

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ABSTRACT: A well packer apparatus including a body having a flow passage and check valve means movable upwardly and downwardly in said flow passage between positions opening and closing said flow passage to fluid flow, a hydraulically operable piston member engageable with said body member in response to fluid pressure tending to close said check valve means and with said check valve means in response to fluid pressure tending to open said check valve means and functioning to prevent opening movement of said check valve means, and means for selectively isolating said piston member from said last-mentioned fluid pressure to enable opening movement of said check valve means.



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3 Sheets-Sheet 1

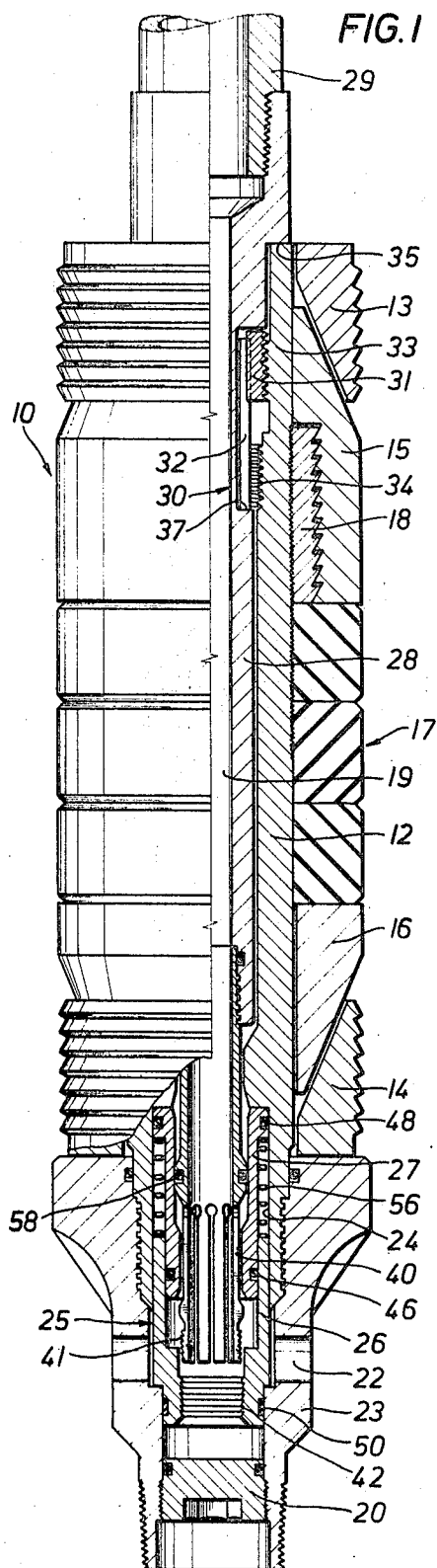
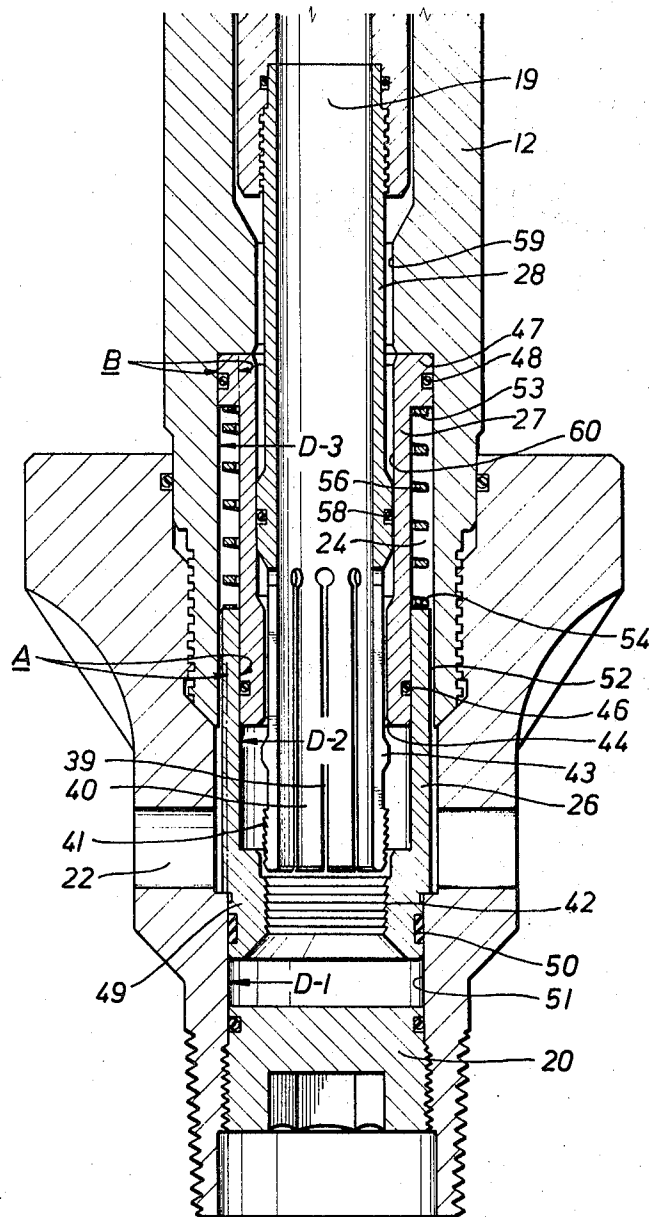


FIG. 2

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FIG. 3

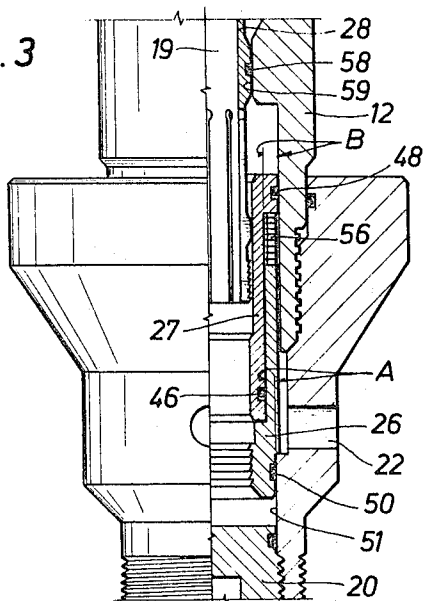


FIG. 4

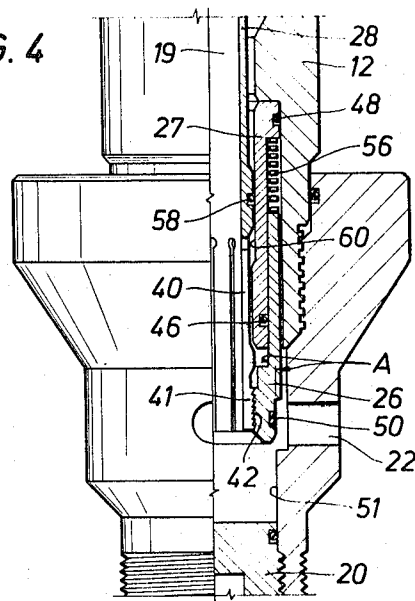


FIG. 5

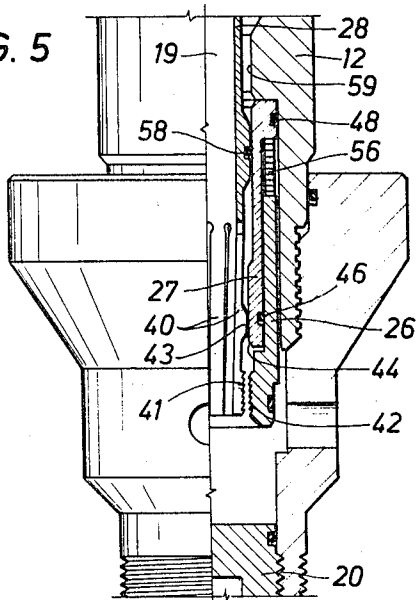
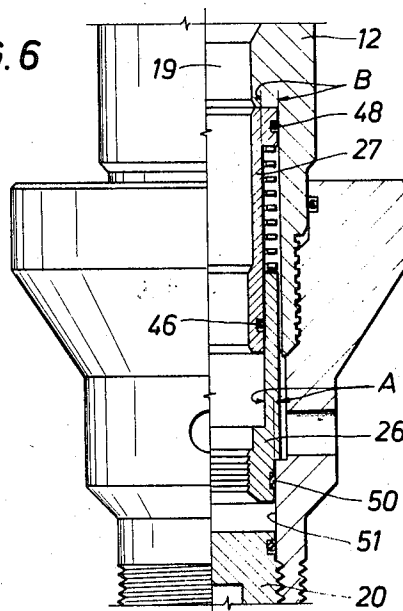


FIG. 6



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FIG. 7

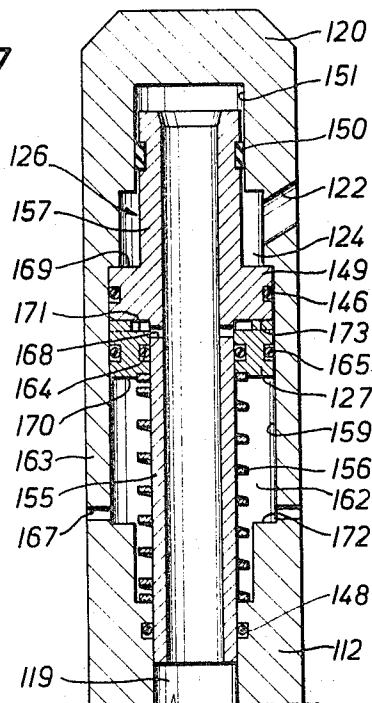
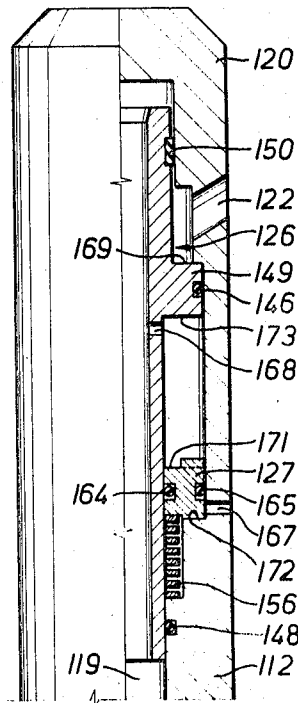
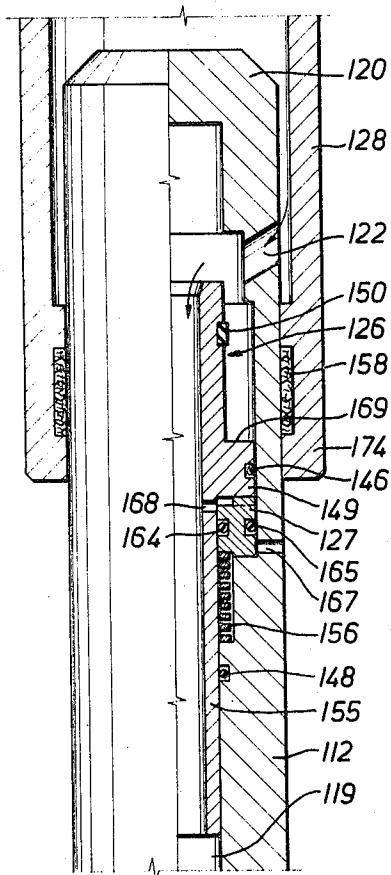


FIG. 8

FIG. 9



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HYDRAULICALLY OPERABLE VALVES

This invention relates generally to well tools used in well bores, and more specifically to hydraulically operated valves for use in controlling fluid flow through a well packer.

Valved well packers such as squeeze retainers generally include a central mandrel having a flow passage and some type of valve arrangement for opening and closing the flow passage. When the valve is open, fluids such as cement slurry, acid or hydraulic fracturing fluids can be forced under pressure into the well bore below the packer, and the valve can be closed in order to trap the fluids at developed pressures.

Several types of valve constructions have been used in the past. U.S. Pat. No. 2,196,661, for example, discloses a floating ball check valve which is forced open by fluids flowing downwardly through the mandrel, and when the flow is stopped, the ball will seat and is held closed by pressure trapped below the packer. Although this type of valve is relatively simple, it is subject to the disadvantage that should pressure subsequently be applied to a region above the packer, the ball will unseat and allow fluid flow. Another type of valve construction is shown in U.S. Pat. No. 3,306,363, which relates to a valve sleeve movable upwardly and downwardly by a mechanical member in order to open and close lateral ports in the mandrel. This type of valve has the advantage that it can be constructed to be insensitive to fluid pressure and will remain closed regardless of pressure. However, the mechanical coupling between the member and valve sleeve may be somewhat complex and subject to operational problems in a well bore. Moreover, a mechanically operable valve may be difficult to move when cement slurry has been pumped through it and the valve held open for even a short length of time before an attempt is made to close it.

It is an object of the present invention to provide a new and improved valve construction for use in controlling fluid flow through a well packer, which has the advantage of simplicity found in hydraulically operated check valves, yet which will remain closed even though pressure is imposed from either side.

This and other objects are attained in accordance with the principles of the present invention by a well packer apparatus including a body member having a flow passage and carrying normally retracted slips and packing means for providing an anchored packoff in a well bore. A check valve means is movable in said flow passage between positions opening and closing said flow passage and is provided with a transverse pressure surface which is subject to the pressure of fluids in the flow passage as well as below the packing means. A hydraulically operable force-transferring means is movable between spaced positions of alternate engagement with the body member and the check valve means, said transferring means having a transverse pressure area greater in size than the pressure area of said check valve means. The force transferring means is arranged to engage the body member in response to a fluid pressure acting to close said check valve means, and to engage said check valve means in response to a fluid pressure acting to open said check valve means, and providing a net force on said check valve means to maintain it in closed position. According to one embodiment of the present invention, a flow conductor is telescopically movable in said flow passage and has a seal element which is selectively engageable with said body member to enable fluid pressure to act on said force-transferring means and to maintain said check valve means closed, and with said transferring means itself to isolate said transferring means from the pressure of fluids in said flow passage, whereby a predominance of fluid pressure in said flow passage can act on said check valve means to cause opening movement thereof. In accordance with another embodiment of the present invention, a flow conductor is cooperable with the body member to isolate the transferring means from the fluid pressure acting to move said check valve means to open position, thus enabling movement of the check valve means to open position.

The present invention has other objects and advantages which will become more clearly apparent in connection with the following detailed description of several embodiments taken in conjunction with the appended drawings, in which:

FIG. 1 is a longitudinal sectional view, with portions in side elevation, of a well packer including the valve assembly of the present invention;

FIG. 2 is an enlarged cross section view showing greater detail of the valve assembly;

FIG. 3 is a sectional view showing the valve assembly during testing of the pipe string for leaks;

FIG. 4 is a sectional view showing the valve assembly opened and held open to enable flow of fluids in either direction;

FIG. 5 is a sectional view showing release of the latch mechanism to permit the valve assembly to close;

FIG. 6 is a sectional view of the valve assembly with the flow conductor removed;

FIG. 7 is a cross-sectional view of a modified form of valve assembly in accordance with the present invention with the valve closed in response to pressure from above;

FIG. 8 shows the valve remaining closed in response to fluid pressure from below; and

FIG. 9 shows a flow conductor telescoped over the body member and the valve opened to fluid flow in a downward direction.

Referring initially to FIG. 1, a well packer 10 is shown which can be set in a cased well bore. The well packer 10 includes a central mandrel or body member 12 which carries normally retracted upper and lower slips 13 and 14 and companion expander cones 15 and 16. An elastomeric, expansible packing structure 17 which can be constituted by several annular rings is mounted around the mandrel 12 between the expander cones. In conventional fashion, when the mandrel 12 is forced upwardly and the upper slip 13 is forced downwardly, the slips 13 and 14 will be shifted outward by the respective expander cones 15 and 16 into gripping engagement with a well casing wall, and the packing structure 17 will be compressed between expander cones and expanded outwardly to pack-off casing. A conventional one-way clutch ring 18 can be used to trap the slips and packing in set positions. Other conventional elements such as shear pins and antiextrusion rings can be provided but are not shown.

The body member 12 has a central bore providing a flow passage 19 which is closed at its lower end by a plug 20. Several ports 22 extend radially through the wall portion 23 of the body member in order to communicate with the well bore below the packing 17. An internal annular recess 24 is formed in the body portion 23 adjacent the ports 22 and is arranged to receive a valve assembly generally indicated at 25. The valve assembly 25 includes a valve sleeve 26 and a force-transferring piston member 27 to be fully described hereafter, the valve sleeve 26 being movable between longitudinally-spaced positions to effect opening and closing of the flow passage 19 to fluid flow.

Telescopically received within the bore 19 of the body member 12 is a flow conductor or "stinger" 28. The flow conductor 28 is coupled to the lower end of a pipe string 29 which extends upwardly to the top of the well bore, and through which fluids under pressure can be pumped into the well bore below the packer 10. A suitable mechanical stop assembly 30 is provided to limit longitudinal movement of the flow conductor 28 in longitudinally-spaced positions. Although the stop assembly can take many forms, the structure illustrated is constituted by an annular, split stop ring 31 which is slidably and corotatively secured to the flow conductor 28 by a spline 32 which engages in the split in the ring. The ring 31 is radially expansible and contractable and is cooperable with longitudinally-spaced thread portions 33 and 34 formed on the inner periphery of the mandrel 12. When the ring 31 engages the upper thread portion 33 as shown in FIG. 1, the flow conductor 28 can be reciprocated by the pipe string 29 between a lower position where an annular shoulder 35 engages an upper

end surface of the mandrel 12, and an upper position where an upwardly facing shoulder 37 on the flow conductor engages the stop ring 31. The stop ring 31 can be selectively engaged and disengaged from the mandrel by appropriate manipulation of the pipe string, and further details of the stop assembly 30 are described in U.S. Pat. No. 3,433,304 which is assigned to the assignee of the present invention.

As shown in greater detail in FIG. 2, the lower end portion of the flow conductor 28 is longitudinally slotted, the slots 39 dividing the lower portion into a plurality of elongated fingers 40 having a degree of lateral flexibility. A section of upwardly facing buttress-type threads 41 are formed on the outer periphery of each finger 40, the threads being mateable with internal threads 42 formed on the valve sleeve 26. An upward movement of the valve sleeve 26 when the flow conductor 28 is in its lower position will cause the threads 41 on the fingers 40 to ratchet into the threads 42, thereby coupling the flow conductor 28 and valve sleeve 26 together with the valve sleeve in its upper or open position. The fingers 40 can be released from the valve sleeve 26 by pulling the flow conductor upwardly until annular projections 43 formed on each finger engage an inclined surface 44 on the member 27. This will cause the fingers 40 to resile inwardly and release the threads 41 from the valve sleeve threads 42, enabling the valve sleeve 26 to return to closed position.

As previously mentioned, the valve assembly 25 includes a transfer piston member 27 and a valve sleeve 26. The piston member 27 and the valve sleeve 26 are telescopically movable relative to each other, and a seal ring 46 prevents any fluid leakage between them. The piston member 27 has an annular flange portion 47 which is sealed against the wall of the recess 24 by a seal ring 48, whereas the lower portion 49 of the valve sleeve 26 is reduced somewhat in diameter and is sealed by a suitable packing ring 50 against a seal surface 51 on the body member 12. The outer periphery of the valve sleeve 26 is sized relative to the recess 24 such that a space 52 is provided therebetween to communicate at all times the lower face 53 of the flange portion 47, as well as the upper face 54 of the valve sleeve 26, with the fluid pressure in the well bore below the packing element 17 via the side ports 22. A coil spring 56 is positioned to surround the piston member 27 and is arranged to press upwardly on the flange portion 47 and downwardly on the upper end of the valve sleeve 26. The spring 56 functions to yieldably retain the valve sleeve 26 in the position shown in FIG. 2, but will foreshorten and enable either the piston member 27 to shift downwardly, or the valve sleeve 26 to shift upwardly.

The various seals 46, 48 and 50 engage on different diameters, the seal diameter $D-1$ for the packing ring 50 being intermediate the respective seal diameters $D-2$ and $D-3$ for the rings 46 and 48. In this manner, the valve sleeve 26 has an effective pressure area A equal to the difference in cross-sectional or transverse areas defined by the seal diameters $D-1$ and $D-2$ whereas the piston member 27 has an effective pressure area B equal to the difference in transverse areas defined by the seal diameters $D-2$ and $D-3$. The area B, as shown, is somewhat larger than the area A. The flow conductor 28 carries a seal ring 58 which can sealingly engage either a body member seal surface 59, or the inner peripheral surface 60 of the piston member 27. When the seal ring 58 engages the surface 59, the area B is exposed to fluid pressure in the flow passage 19; when the seal ring 58 engages the surface 60, the area B is isolated from fluid pressure in the flow passage 19. The seal packing 58 is engageable with the body member seal surface 59 when the flow conductor 28 is in its upper limit position as previously described, and with the inner surface 60 of the sleeve member 27 when the flow conductor is placed in its lower limit position.

In operation, the packer 10 can be set in a conventional manner by a wire line or a mechanical setting tool, such tools being well known to those skilled in the art. The upper and lower slips 13 and 14 are anchored to respectively prevent upwardly and downwardly movement, and the packing structure

17 seals off the well annulus between the body member 12 and the surrounding well casing wall. In case the packer 10 has been previously set on wire line, the flow conductor 28 can be lowered into the well bore and at the end of the pipe string 29 and inserted into the bore 19 of the body member 12, after which a pressure operation can be performed. If it is desired to pressure test the pipe string 29 for leaks prior to performance of a pressure operation, this can be accomplished by properly positioning the flow conductor 28 within the body member 12 such that the seal packing 58 is against the body seal surface 59 as shown in FIG. 3. This position can correspond to the upper limit position of the flow conductor 28 where the shoulder 37 engages the stop ring 31. With a predominance of fluid pressure applied in the flow passage 19, the pressure will act downwardly over the area B and upwardly over the area A, causing the piston member 27 to shift downwardly, as shown in FIG. 3, compressing the spring 56 and transferring the pressure force imposed upon it to the valve sleeve 26. Since the area B is larger than the area A, the resultant force on the valve sleeve 26 is directed downwardly to maintain the packing ring 50 sealed against the seal surface 51. Accordingly the valve sleeve 26 remains in closed position with respect to the side ports 22, and the pipe string 29 can be tested for leaks.

In order to pump fluids into the well bore below the packer 10, the flow conductor 28 is moved downwardly to its lower limit position where the seal packing 58 engages the inner surface 60 of the piston member 27 as shown in FIG. 4. Now the upper end surfaces of the piston member 27 are isolated from fluid pressure in the flow passage 19, and such fluid pressure cannot act downwardly thereon. Thus, a predominance of fluid pressure in the flow passage 19 will cause the valve sleeve 26 to respond like a check valve, that is to say, the pressure will act upwardly on the area A and shift the valve sleeve upwardly and disengage the packing ring 50 from the seal surface 51. This mode of operation is shown in FIG. 4, with fluid flowing outwardly through the side ports 22 holding the valve sleeve 26 in an upper position.

When the valve sleeve 26 shifts upwardly, the teeth 42 are ratcheted over the corresponding teeth 41 on the fingers 40, coupling the valve sleeve temporarily against downward movement. Thus, the valve sleeve 26 is held open, so that an operator at the surface can check for "flowback." In pressure operations such as squeeze cementing, it is sometimes desirable to check for flowback, that is to say, to hold the valve open and discover by observing surface flow conditions whether or not the cement slurry is being forced back into the well bore through the perforations. This occurrence would indicate that the slurry has not hardened or set up sufficient to conclude the operation, or perhaps an acceptable cement squeeze has not been obtained. In any event, since the valve sleeve 26 is being held open, a flow of fluids from the running-in string at the surface will indicate that the cement slurry is being forced back into the casing, and that a successful squeeze is yet to be obtained.

When it is desired to close the valve sleeve 26, the flow conductor 28 is again moved to its upper position, such upward movement causing the annular projections 43 on the latch fingers 40 to engage the inclined surface 44 on the piston member 27, resulting in inward flexing of the fingers and release of the threads 41 and 42 as shown in FIG. 5. The spring 56 can now function to push the valve sleeve 26 downwardly to the closed position shown in FIG. 2. With the flow conductor 28 removed as shown in FIG. 6, the valve sleeve 26 will remain in closed position whether pressure is imposed from above or below. A greater pressure from below will act through the ports 22 and downwardly on the area A to bias the valve closed. A greater pressure from above will act downwardly on the area B of the piston member 27 and upwardly on the area A of the valve sleeve 26. Since the area B is greater than the area A, the net result is a downward force on the valve sleeve 26 with the piston member shifting downwardly and engaging the valve sleeve as shown in FIG. 3.

Referring now to FIG. 7, a modified form of the present invention is illustrated. In the previously described embodiment, the bore of the mandrel or body member was closed at its lower end and the valve assembly and side ports located below the packing structure. In this embodiment, however, the flow passage 119 of the body member 112 is closed by a partition 120 at its upper end, and side ports 122 communicate with the well bore above the packing (not shown). The body member 112 has a stepped internal recess 124, and movably received in the flow passage 119 is a valve sleeve 126 having an upper packing ring 150 engageable with a seal surface 151 above the ports 122, and an enlarged flange portion 149 carrying a seal ring 146 which is engageable with the wall surface 159 below the ports. The valve sleeve 126 has a depending skirt 155 with a smaller outer diameter than the upper portion 157 of the valve sleeve, fluid leakage between the skirt 155 and the body member 112 being prevented by a seal ring 148.

A transfer piston 127 is movably received in the annular cavity 162 between the skirt 155 and the mandrel wall portion 163. Inner and outer rings 164 and 165 seal respectively against the skirt 155 and the wall surface 159 of the portion 163. The cavity space below the piston 127 is communicated with the well bore by one or more ports 167, whereas the cavity space above the piston is communicated with the flow passage 119 via one or more ports 168 through the skirt 155 below the flange portion 149. A suitable coil spring 156 is arranged to urge the transfer piston 127 upwardly, and, in the valve position shown in FIG. 7, to bias the valve sleeve 126 upwardly toward closed position.

The valve system will remain in closed position against pressure imposed from above or below in the following manner. In response to a greater fluid pressure in the well bore above the packer, the pressure will act through ports 122 downwardly on the packer, the pressure will act through ports 122 downwardly on the upwardly facing transverse surface 169 of the valve sleeve. However, the pressure will also act through the ports 167 upwardly on the downwardly facing surface 170 of the transfer piston 127. Inasmuch as the transverse area of the transfer piston 127 is greater than the transverse area of the flange portion 149, the net force due to greater pressure from above is directed upwardly on the valve sleeve 127 to maintain it in closed position as shown in FIG. 7.

In response to greater fluid pressure in the well bore below the packer, the valve sleeve 126 will remain in closed position as shown in FIG. 8. The greater pressure will act via the skirt ports 168 on the upper face 171 of the transfer piston 127, shifting it downwardly and against the body shoulder 172. The same pressure also acts upwardly on the lower face 173 of the flange portion 149. Inasmuch as the lesser fluid pressure is communicated via the ports 122 to the upper face 169 of the flange portion 149, an upward force is applied to the valve sleeve 126 to maintain it in closed position as shown in FIG. 8.

In order to pump fluid under pressure through the flow passage 119 and into the well bore below the packer, a flow conductor 128 is positioned in the well bore and telescoped over the body member 112 as shown in FIG. 9. The flow conductor 128 has an inwardly extending annular portion 174 carrying a seal packing 158 which engages the body member below the ports 122 and prevents fluid leakage. Fluid pressure inside the flow conductor 128 will act through the side ports 122 and on the upper face 169 of the flange portion 149 to force the valve sleeve 126 downwardly to its open position as shown. The seal packing 158, of course, confines the greater pressure to the passage 119 and prevents the greater pressure from acting via the ports 167 on the lower side of the transfer piston 127. Fluids flowing past the valve sleeve 126 will maintain it in open condition until the flow is discontinued, whereupon the spring 156 will force the valve sleeve upwardly to its closed position as illustrated in FIG. 7.

Certain new and improved well packer valve systems have been disclosed, the valve systems having the simplicity of a check valve, yet being constructed and arranged to hold pressure from above or below. According to one embodiment, the

valve can be held open to check for backflow of fluids, and the surface manipulations required to operate the valve are constituted primarily by simple upward and downward movement of the pipe string. Since certain changes and modifications will become apparent to those skilled in the art in view of the foregoing disclosure without departing from the inventive concepts involved, it is the aim of the appended claims to cover all such changes and modifications falling within the true spirit and scope of the present invention.

I claim:

1. A well packer apparatus comprising: a body member having a flow passage; a valve sleeve movable upwardly and downwardly in said flow passage between position opening and closing said flow passage, said valve sleeve having a transverse pressure area subject to the pressure of fluids in the well bore on one side of the well packer and to the pressure of fluids in said flow passage; and hydraulic means having a transverse pressure area of greater size than said transverse pressure area of said valve sleeve, said hydraulic means being shiftable between longitudinally-spaced positions of alternate abutting engagement with said mandrel and said valve sleeve, said hydraulic means engaging said mandrel in response to fluid pressure acting to close said valve sleeve, said hydraulic means engaging and opposing movement of said valve sleeve in response to fluid pressure acting to open said valve sleeve in order to provide a net force on said valve sleeve to maintain it in closed position.

2. The well packer apparatus of claim 1 further including a flow conductor for supplying fluid under pressure to said flow passage, said flow conductor having seal means for selectively isolating and subjecting said hydraulic means to fluid pressure to correspondingly permit and prevent opening movement of said valve sleeve.

3. The well packer apparatus of claim 2 wherein said seal means is engageable with said body member to prevent fluid pressure from causing engagement of said valve sleeve by said hydraulic means, thereby enabling opening movement of said valve sleeve.

4. The well packer apparatus of claim 2 wherein said seal means is engageable with said hydraulic means to prevent fluid pressure from causing engagement of said valve sleeve by said hydraulic means, thereby enabling opening movement of said valve sleeve.

5. A well packer apparatus comprising: a body member having a flow passage and carrying packing means for packing-off a well bore; check valve means movable in said flow passage between an upper open position and a lower closed position, said check valve means having a downwardly facing transverse pressure surface subject to the pressure of fluids in said flow passage to cause upward movement to open position, and hydraulically operable means coupled to said check valve means and having an upwardly facing transverse pressure surface which can be selectively subjected to the pressure of fluids in said flow passage, said upwardly facing pressure surface having a larger area than the pressure surface of said check valve means, whereby a predominate fluid pressure in said flow passage will provide a net downward force on said check valve means to maintain it in closed position.

6. The apparatus of claim 5 further including flow conductor means extendible into said flow passage for selectively subjecting said upwardly facing pressure surface to the pressure of fluids in said flow passage.

7. The apparatus of claim 6 wherein said flow conductor means includes an elongated tubular member having an annular seal packing which is engageable with a seal surface on said body member to enable fluid pressure in said flow passage to act downwardly on said upwardly facing pressure surface, and with said hydraulically operable means to isolate said upwardly facing surface from the pressure of fluids in said flow passage.

8. A well packer apparatus comprising: a body member having a packing element thereon sealingly engageable with a well conduit wall, said body member having a flow passage closed

at one end and adapted to be communicated with the well bore via side ports through the wall of said body member; valve means for selectively opening and closing said flow passage, including a valve sleeve movable upwardly in said flow passage to enable fluids to flow through said side ports and downwardly in said flow passage to prevent fluid flow, said valve sleeve having a downwardly facing transverse pressure surface on which the pressure of fluids in said flow passage can act to move said valve sleeve upwardly, said valve sleeve having an upwardly facing transverse pressure surface on which the pressure of fluids in the well bore adjacent said side ports can act to bias said valve sleeve in closed position; and hydraulic means including a piston member coupled to said valve sleeve and having an upwardly facing transverse pressure surface of larger area than said downwardly facing surface, whereby a predominant fluid pressure in said flow passage can provide a net downward force on said valve sleeve to maintain said valve sleeve closed against said predominant fluid pressure.

9. The apparatus of claim 8 further including selectively operable means for isolating said upwardly facing surface on said piston member from fluid pressure in said flow passage, whereby a predominate fluid pressure in said flow passage can act upwardly on said downwardly facing surface to move said valve sleeve upwardly to open position.

10. The apparatus of claim 9 further including resilient means between said piston member and said valve sleeve tending to move said valve sleeve downwardly to closed position.

11. The apparatus of claim 9 wherein said selectively operable means includes an elongated tubular member adapted for connection to a pipe string extending upwardly to the earth's surface, said tubular member having an external annular seal packing engageable with said piston member to isolate said upwardly facing surface from the pressure of fluids in said flow passage.

12. A well packer apparatus comprising: a body member having a flow passage and annular packing around said body member adapted to pack-off against a well conduit wall; check valve means movable in said flow passage between an open position and a closed position with respect to said flow passage; a flow conductor sealingly received in said flow passage; and selectively releasable means on said flow conductor and said check valve means that is engaged by movement of said check valve means relative to said flow conductor and toward said open position for holding said check valve means

in said open position, said releasable means being releasable in response to movement of said flow conductor relative to said body member to enable closing movement of said check valve means.

13. The apparatus of claim 12 wherein said releasable means includes cooperating latch means on said flow conductor and said check valve means, said latch means including resilient fingers on the bottom of said flow conductor selectively engageable with detent means on said check valve means.

14. The apparatus of claim 12 further including cam means on said fingers engageable with a portion of said check valve means to cause release from said detent means.

15. A well packer apparatus comprising: a tubular body member having a packing element thereon sealingly engageable with a well conduit wall, said body member having a flow passage closed at one end and adapted to be communicated with the well bore via side ports through the wall of said body member; valve means for opening and closing said flow passage, including a valve sleeve movable downwardly in said flow passage to enable fluids to flow through said passage and upwardly in said flow passage to prevent fluid flow, said valve sleeve having an upwardly facing transverse pressure surface on which fluid pressure can act to move said valve sleeve downwardly, said valve sleeve having a downwardly facing transverse pressure surface on which fluid pressure in said flow passage can act to bias said valve sleeve in closed position; and hydraulic means including a piston member engageable with said valve sleeve and having a downwardly facing transverse pressure surface subject to fluid pressure tending to move said valve sleeve downwardly, the pressure surface of said piston member having a larger area than the pressure surface on said sleeve member to provide a net upward force on said valve sleeve to maintain it in closed position.

16. The well packer apparatus of claim 15 further including means for isolating said piston member from fluid pressure tending to move said valve sleeve downwardly, thereby enabling said fluid pressure to cause opening movement of said valve sleeve.

17. The well packer apparatus of claim 16 wherein said isolating means includes a flow conductor telescopically received on said body member, said flow conductor having sealing means thereon engageable with said body member below said side ports.

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