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(54) **Apparatus for opening and closing a flapper valve**

(57) A typical flapper valve (10) includes a substantially tubular housing (26), a valve seat (18) defining a flow passage (18c) therethrough, and a flapper valve closure member (32) pivotally connected to the housing (26) adjacent the valve seat (18) for selectively moving between an open position and a closed position against the valve seat (18). The flapper valve includes a lever arm (36) on the closure member (32). The lever arm (36) extends from adjacent to the flapper valve pivotal connection away from the closure member (32). A piston (60) is mounted adjacent to a tubular wall of the housing (26), and a pivotal connection is provided for operatively connecting the piston (40) to the lever arm (36). Thus, moving the piston (60) in a first direction urges the closure member (32) to pivot about the pivotal connection toward the closed position. Moving the piston (60) in a second direction that is opposed to the first direction urges the closure member (32) to pivot about the pivotal connection toward the open position. A control line and fluid communication passages (68a,68b,68c) in the housing (26) are provided for selectively transmitting fluid pressure from a remote location to the piston (60) for moving the piston (60) in at least one direction, thereby urging the closure member (32) to pivot in at least one direction about the pivotal connection between the open position and the closed position

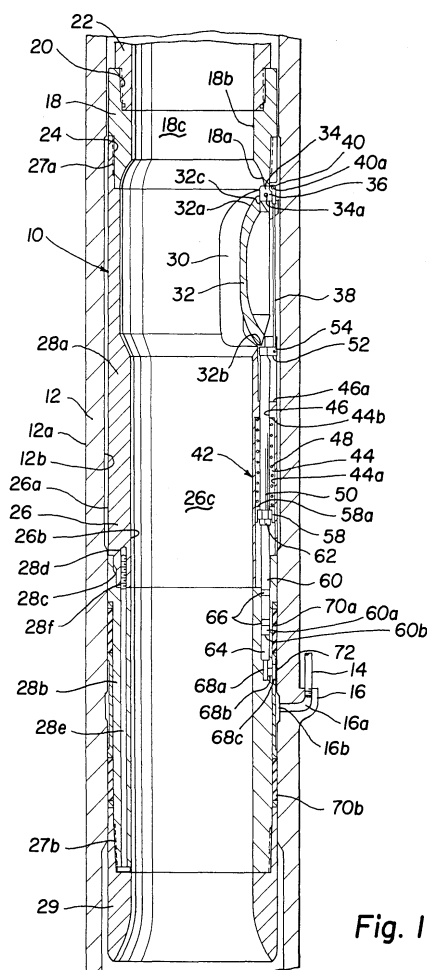


Fig. 1

Description

[0001] This invention relates to flapper valves, which are particularly useful in tubular flow conduits to permit flow therethrough in one direction and prevent flow in the opposite direction. Flapper valves are sometimes called check valves, back pressure valves, or safety valves.

[0002] It is common practice to complete oil and gas producing wells with safety systems including a subsurface safety valve controlled from the well surface to shut off fluid flow in the well tubing string. Generally, such a safety valve is controlled in response to fluid pressure conducted to the valve from a remote location at the well surface via a small diameter conduit (control line). The surface controller is typically equipped to cause the safety valve to shut in the well in response to emergency conditions such as blow out, overproduction, fire, broken flow lines, oil spills, etc.

[0003] Furthermore, from time to time it is necessary to conduct well servicing operations through a subsurface safety valve. A well servicing operation may require, for example, extending a wireline tool string through the subsurface safety valve. Examples of such well servicing operations are pressure and temperature testing. Additional well servicing procedures are required to retrieve damaged downhole equipment. These procedures require selective opening and closing of the safety valve.

[0004] The typical safety valve has the valve closure member biased to a closed position by a torsion spring. To selectively open the safety valve, an actuator tube is longitudinally lowered through the flow passage to deflect or jar the valve closure member to an open position and so that well fluids may move through the actuator tube. The actuator tube may also be part of a wireline tool string for performing well servicing procedures through the safety valve.

[0005] In the case of a typical surface controlled subsurface safety valve, the actuator tube is part of the safety valve assembly. The actuator tube is normally biased away from the valve closure member so that the valve closure member can be moved by the torsion spring to the closed position. Thus, the safety valve is biased to the closed position.

[0006] The typical means for biasing the actuator tube away from the valve member such that the safety valve is biased to the closed position includes a spring or a pressurized gas in a gas chamber acting on a piston in a first direction. Applying an opposing pressure through the hydraulic control line to the piston in the opposite direction drives the actuator tube longitudinally downward through the flow passage to deflect or jar the valve closure member to an open position. Generally, the means for biasing the safety valve to a closed position must overcome the hydrostatic head pressure in the hydraulic control line as well as provide a force for moving the actuator tube to close the safety valve. Because the

hydrostatic head pressure in the hydraulic control line increases with increasing depth, the deeper the safety valve is installed, the greater the hydrostatic head pressure in the hydraulic control line that must be overcome to bias the safety valve to the closed position.

[0007] For well completions at depth, a relatively small piston area is one way to minimize the effect of hydrostatic head pressure from the control line leading to the well surface. Pistons having a small cross-sectional area in comparison to the cross-sectional area of the complete safety valve assembly have been used in surface controlled subsurface safety valves (SCSSV). Examples of such pistons are shown in the following: U. S. Patent No. 2,780,290 entitled Surface Controlled Subsurface Tubing; U.S. Patent No. 2,798,561 entitled Blowout Preventer For Wells; U.S. Patent No. 4,049,052 entitled Subsurface Annulus Safety Valve; U.S. Patent No. 4,161,219 entitled Piston Actuated Well Safety Valve; and U.S. Patent No. 4,444,266 entitled Deep Set Piston Actuated Well Safety Valve.

[0008] In addition, U.S. Patent No. 4,252,197 entitled Piston Actuated Well Safety Valve discloses a well safety valve having a longitudinally tubular member telescopically movable in the safety valve housing and through the valve seat for controlling the movement of the valve closure member. At least one piston is telescopically movable and has its longitudinal axis within the wall of the housing and outside the tubular member. The first end of the piston is in fluid communication with a hydraulic control line extending to the well surface for moving the tubular member to deflect the valve closure member and open the valve. The second end of the piston extends into a closed gas chamber. The pressure of the gas in the gas chamber is used to bias the piston and the tubular member away from the valve closure member and close the safety valve. The piston has a small cross-sectional area (i.e., a width less than the thickness of the housing) for reducing the pressure effect in the gas chamber caused by movement of the second side of the piston, whereby the differential between the opening and closing forces is reduced.

[0009] U.S. Patent No. 4,945,993 entitled Surface Controlled Subsurface Safety Valve discloses a surface controlled subsurface safety valve including a valve closure member, an operator tube for opening the valve closure member, a small diameter offset piston to move the operator tube in response to control fluid pressure conducted from the well surface, and a spring biasing the operator tube to a position closing the valve.

[0010] Unfortunately, the use of an operator tube to open and close a flapper valve member can result in damage to the flapper valve member, particularly during a forceful slam opening or slam closing of the flapper valve. Thus, there has been a long-felt need for an improved flapper valve that does not have an actuator tube to open and close the flapper valve member.

[0011] Another problem shared by most flapper valves is insufficient bias or rotational closure force to

move the flapper valve closure member into (or "cut") a high mass flow rate stream for closure. The problem is especially challenging when large diameter flapper valves are used on well packers or subsurface safety valves that are in the vertical position in well conduits where the closing springs must initially overcome the weight of the flapper valve member itself.

[0012] The rotational force for closing the flapper valve closure member has usually been provided by torsion springs. Many forms of torsion springs have been used in an attempt to develop more flapper closing force. But the problem is aggravated by the fact that there is usually not enough space to house a large torsion spring designed to provide sufficient closing force in a well packer or subsurface safety valve.

[0013] U.S. Patent No. 5,159,981 entitled Flapper Valve discloses a flapper valve assembly wherein the flapper valve is biased toward the closed position by one or more coil springs or Belleville washer springs in the wall of the flapper valve housing applied through a tension member that is connected eccentrically to the flapper valve hinge. To open the flapper valve, an operator tube or rod having a diameter near the inside diameter of the annular seat for the flapper valve is lowered from above to push the flapper valve open. As long as the flapper valve is open, the tension member compresses the spring. On raising the actuator tube to above the flapper valve, the spring is permitted to expand, moving the tension member and rotating the flapper valve to the closed position. The advantage of this structure is that greater forces available from coil or Belleville springs is applied through a tension member that is connected eccentrically to the flapper valve hinge to provide a lever arm to convert the greater spring force into rotational force for urging the flapper valve toward the closing position.

[0014] While the structures disclosed in U.S. Patent No. 5,159,981 solved the torsion spring problem, there has still been a long-felt need for way to eliminate the actuator tube for opening the flapper valve.

[0015] In accordance with the invention, an improved flapper valve is provided. A typical flapper valve includes a substantially tubular housing, a valve seat defining a flow passage therethrough, and a flapper valve closure member pivotally connected to the housing adjacent the valve seat for selectively moving between an open position and a closed position against the valve seat.

[0016] According to the present invention, the improvement in a flapper valve includes a lever arm on the flapper valve closure member. The lever arm extends from adjacent to the flapper valve pivotal connection away from the flapper valve closure member. A piston is mounted adjacent to the tubular wall of the housing, and a pivotal connection is provided for operatively connecting the piston to the lever arm. Thus, moving the piston in a first direction urges the flapper valve closure member to pivot about the flapper valve pivotal connection toward the closed position. Moving the piston in a

second direction that is opposed to the first direction urges the flapper valve closure member to pivot about the flapper valve pivotal connection toward the open position. A control line and fluid communication passages in the housing are provided for selectively transmitting fluid pressure from a remote location to the piston for moving the piston in at least one direction, thereby urging the flapper valve closure member to pivot in at least one direction about the flapper valve pivotal connection between the open position and the closed position.

[0017] According to a further aspect of the invention, the piston is biased toward one direction, which results in the flapper valve closure member being normally biased toward either the open or closed position. It is to be understood, however, that in the typical flapper valve, the flapper valve closure member is biased toward the closed position for safety considerations. Thus, according to a further aspect of the invention, the improvement includes a means for biasing the piston to move the piston in a first direction, thereby urging the flapper valve closure member to be biased to pivot about the flapper valve pivotal connection toward the closed position; and also includes a control line and fluid communication passages in the housing for selectively transmitting fluid pressure to the piston to move the piston in a second direction that is opposed to the first direction and to overcome the means for biasing, thereby urging the flapper valve closure member to pivot about the flapper valve pivotal connection toward the open position. Biasing the piston can be accomplished, for example, by using a mechanical or fluid spring.

[0018] One advantage of the invention is that a relatively short stroke of the piston can actuate the flapper valve closure member between the open and closed positions. Thus, a flapper valve according the invention can be shorter than a conventional flapper valve.

[0019] Another advantage of the invention is that the flapper valve can be remotely actuated through the control line and fluid passages through the housing so that it is possible to open the flapper valve from the well head without using a downhole actuator tube to open the flapper valve closure member. Therefore, the flapper valve closure member will not be subject to damage caused by an actuator tube during a slam opening or closing of the flapper valve.

[0020] In a typical flapper valve application, such as for use as a safety valve, the flapper valve closure member is oriented such that the closure member is on the side of the valve from which fluid flow through the valve is desired to be controlled (i.e., the side of the flapper valve expected to be exposed to higher fluid pressure), and such that the valve seat is on the other side of the valve (i.e., the side of the flapper valve expected to be exposed to lower fluid pressure). Thus, when the flapper valve member is closed, the fluid pressure exerted on the flapper valve closure member from the high-pressure side of the flapper valve assists in maintaining the flapper valve closure member engaged against the

valve seat. In a typical downhole environment, the high fluid pressure desired to be controlled would normally be expected to come from below the flapper valve.

[0021] According to yet another aspect of the invention, the piston is preferably mounted in the tubular housing such that the flapper valve closure member is between the valve seat and the piston. Thus, the piston in the flapper valve is positioned on the high-pressure side of the flapper valve closure member relative to the valve seat. This positioning of the piston allows the piston to act on the lever arm extending from adjacent the flapper valve pivotal connection away from the flapper valve closure member without interfering with the sealing between the flapper valve closure member and the valve seat. This positioning of the piston also has the advantage of maximizing the internal diameter of the valve relative to the outer diameter of the valve; the piston can act on the lever arm extending into the housing wall without any protrusion into the diameter of the flow passage defined by the valve seat.

[0022] Reference is now made to the accompanying drawings, in which:

FIG. 1 is an elevational drawing in section of a preferred embodiment of a surface controlled subsurface flapper valve assembly according to the invention, wherein the flapper valve closure member is shown in the open position;

FIG. 2 is an elevational drawing in section of a preferred embodiment of a surface controlled subsurface flapper valve assembly according to the invention, wherein the flapper valve closure member is shown in the closed position;

FIG. 3 is a detailed elevational drawing from a side of the flapper valve assembly of FIG. 2 showing a detail of the hinge connection of the flapper valve closure member to the flapper valve housing;

FIG. 4 is an detailed elevational drawing in section of an embodiment of an actuator subassembly for the flapper valve closure member, which includes a remotely operable piston and hydraulic fluid chamber operatively connected to pivot the flapper valve closure member about its hinged connection to the housing; and

FIG. 5 is a cross-section of the piston taken along lines 5-5 of FIG. 4.

[0023] Reference numerals are employed to designate like parts throughout the various figures of the drawing. Unless the context requires otherwise, references used herein such as "upper," "lower," and "side" are relative to the orientation of the drawing referred to. Similarly, as used herein, "longitudinal" means with respect to the axis of the substantially tubular housing of the flapper valve disclosed herein.

[0024] Referring now to FIGS. 1 and 2 of the drawing, the reference numeral 10 generally designates a flapper valve assembly positioned inside a tubing string 12.

Tubing string 12 is substantially tubular, having a substantially cylindrical outer surface 12a and a substantially cylindrical inner surface 12b. As is well known to those skilled in the art, a tubing string typically extends from a well head assembly (not shown) above the ground surface toward a hydrocarbon producing formation (now shown).

[0025] The flapper valve assembly 10 can be installed during well completion to control fluid flow to the well surface through the tubing string 12 from a downhole location. When the flapper valve assembly 10 is in the open position as illustrated in FIG. 1, oil, gas, water, and other fluids can pass through the tubing string 12 from a hydrocarbon producing formation to the well head, and well treating fluids can be pumped down through the tubing string 12 toward the formation. Other well servicing operations can be carried out through tubing string 12 and the flapper valve assembly 10, such as bottom hole temperature and pressure surveys.

[0026] As is well known to those skilled in the art, a control line 14 is used for transmitting control fluid pressure from the well head assembly at the surface down to the flapper valve assembly 10. The control line 14 is routed along the tubing string 12 in the annulus between the inner surface of the casing (not shown) and the outer surface 12a of tubing string 12 to a conventional control line nipple 16. A nipple passage 16a provides fluid communication from the control line nipple 16 to the interior surface 12b of the tubing string 12 at nipple opening 16b.

[0027] As described in U.S. Patent No. 4,945,993, a conventional well head assembly typically includes a hydraulic manifold including pumps, a fluid reservoir, accumulators, control valves, and a hydraulic controller for the purpose of providing a control fluid pressure signals downhole. Hydraulic controller includes apparatus that functions in response to temperature, surface line leaks, blow out, and other emergency conditions under which the well should be shut in by closing the flapper valve assembly 10.

[0028] The flapper valve assembly 10 includes a seat member 18. The seat member 18 is substantially tubular and has a seat sealing surface 18a at the lower end thereof that is circumferential of the tubular seat member 18. The inner surface 18b of the tubular seat member defines a seat flow passage 18c, through which well fluids can move when the flapper valve assembly 10 is open as shown in FIG. 1.

[0029] According to the presently most preferred embodiment of the invention, the seat member 18 has a threaded box connector 20, which can be used to connect the seat member 18 to a well tool or other downhole tubing, represented by downwardly extending tubular end 22. It is to be understood by those skilled in the art, of course, that any appropriate connector structure can be used instead of threaded box connector 20, such as a pin connector. The seat member 18 also preferably has a threaded pin connector 24, which can be used to connect to the flapper valve housing 26. It is to be un-

derstood by those skilled in the art, of course, that any appropriate connector structure can be used instead of threaded pin connector 24, such as a box connector. Although not critical to the practice of the invention, providing an appropriate releasable connection between the seat member 18 and the flapper valve housing 26 is helpful in simplifying the manufacture and maintenance of the flapper valve assembly 10.

[0030] The flapper valve housing 26 is substantially tubular, thus defining a central axis for the housing 26. The housing 26 has an outer surface 26a and an inner surface 26b. The inner surface 26b defines a housing flow passage 26c, through which well fluids or tools can move when the flapper valve assembly 10 is open.

[0031] According to the presently most preferred embodiment of the invention, the housing 26 has a threaded box connector 27a, which can be used to connect the housing 26 to the pin connector 24 of seat member 18. It is to be understood by those skilled in the art, of course, that any appropriate connector structure can be used instead of threaded box connector 27a, such as a pin connector. The housing 26 also preferably has a threaded pin connector 27b at the lower end thereof, which can be used to connect to a deflector 29 or other downhole tool. It is to be understood by those skilled in the art, of course, that any appropriate connector structure can be used instead of threaded pin connector 27b, such as a box connector.

[0032] For manufacturing considerations, the flapper valve housing 26 is preferably formed of an upper section 28a and a lower section 28b connected together at interface 28c. A first alignment bore 28d is formed in the upper section 28a, and a similar second alignment bore 28e is formed in the lower section 28b. Thus, to facilitate assembly of the housing 26, an alignment pin 28f can be installed to help maintain the rotational alignment of the upper section 28a and the lower section 28b.

[0033] The flapper valve housing 26 has a side opening 30 formed therein into which the flapper valve closure member 32 is moved when the flapper valve assembly 10 is opened as shown in FIG. 1. The flapper valve closure member 32 is out of the seat flow passage 18c and also out of the housing flow passage 26c when it is moved into the side opening 30, thereby permitting maximum flow of well fluids through the flapper valve assembly 10.

[0034] The flapper valve closure member 32 has a flapper valve sealing surface 32a, which engages the seat sealing surface 18a of the seat member 18 when the flapper valve assembly 10 is closed as shown in FIG. 2. The flapper valve closure member 32 preferably is substantially dome shaped as shown in the drawings and has a substantially circular periphery 32b.

[0035] The flapper valve closure member 32 is pivotally connected to the housing 26, preferably by a flapper valve hinge 34 located on one small segment 32c of the circular periphery 32b. Thus, the flapper valve closure member 32 can be pivotally moved about the flapper

valve hinge 34 in a range of about 90 degrees between the open position shown in FIG. 1 and the closed position shown in FIG. 2. As best shown in FIG. 3, the flapper valve hinge 34 includes a hinge pin 34a mounted in a first flapper valve hinge hole in the housing 26 and in a second flapper valve hinge hole in the flapper valve closure member 32. These first and second flapper valve hinge holes are positioned to align such that the hinge pin 34a provides a pivotal connection between the flapper valve closure member 32 and the housing 26.

[0036] Referring to FIGS. 1 and 2, and as best shown in the detailed view of FIG. 4, a lever arm 36 is formed on the segment 34c of the flapper valve closure member 30. The lever arm 36 is a structural member extending outwardly away from the segment 34c of the circular periphery 34b of the flapper valve closure member 32 and is preferably integrally formed with the flapper valve closure member 32. Applying a force to the lever arm 36 is a means of providing a moment arm about the pivotal connection of the flapper valve closure member 32 to the housing 26.

[0037] According to the presently most preferred embodiment of the invention, a link member 38 is pivotally connected to the lever arm 36. The link member 38 is a rigid structural material for applying a force to the lever arm 36 on the flapper valve closure member 32. The link member 38 is preferably in the form of an elongated rod positioned in the side opening 30 of the housing 26 outside of the housing flow passage 28 and substantially parallel to the housing axis.

[0038] The link member 38 is preferably connected to the lever arm 36 by a lever arm hinge 40. The lever arm hinge 40 includes a hinge pin 40a mounted in a first lever arm hinge hole in the lever arm 36 and in a second lever arm hinge hole in the link member 38. These first and second lever arm hinge holes are aligned such that the hinge pin 40a provides a pivotal connection between the lever arm 36 of the flapper valve closure member 30 and the link member 38. In addition, the lever arm hinge pin 40a of lever arm hinge 40 is preferably positioned to be parallel to the flapper valve hinge pin 34a of the flapper valve hinge 34.

[0039] The lever arm hinge 40 is spaced apart from the flapper valve hinge 34. The effective length of the lever arm 36 is the distance between the flapper valve hinge 34 and the lever arm hinge 40. The greater the effective length of the lever arm 36, the greater the moment arm force that can be transferred to pivot the flapper valve closure member 32. However, space considerations in the typical flapper valve application limit the effective length of the lever arm 36, which must fit substantially within a wall portion of the housing 26. Thus, the effective length of the lever arm 36 usually must be less than the overall thickness of the housing 26 as defined by the overall distance between outer surface 26a and inner surface 26b. An advantage, however, of having a relatively short effective length of the lever arm 36 is that the link member 38 need be moved a commen-

surately short distance to actuate the flapper valve closure member 32. As shown in the drawing, the lever arm hinge 40 can be spaced a relatively small distance from the flapper valve hinge 34 compared to the overall diameter of the flapper valve assembly 10.

[0040] Thus, applying a force to urge the link member 38 to move in an upward direction (with respect to the typical orientation of the flapper valve assembly 10 shown in the drawing) is translated through the lever arm hinge 40 to the lever arm 36 to urge the flapper valve closure member 30 to pivot about flapper valve hinge 34 and toward the open position illustrated in FIG. 1. Applying a force to urge the link member 38 to move in a downward direction (with respect to the typical orientation of the flapper valve assembly 10 shown in the drawing) is translated through the lever arm hinge 40 to the lever arm 36 to urge the flapper valve closure member 30 to pivot about flapper valve hinge 34 and toward the closed position illustrated in FIG. 2.

[0041] As will hereinafter be described in more detail, the link member 38 can normally be biased toward one direction, which can result in the flapper valve closure member 32 being normally biased toward either the open or closed position. It is to be understood, however, that in the presently most preferred embodiment of the invention, and in the typical flapper valve, the flapper valve closure member 32 is biased toward the closed position for safety considerations.

[0042] An actuator subassembly 42 is provided for urging the link member 38 to move the flapper valve closure member 32 between the open and closed positions.

[0043] According to the presently most preferred embodiment of the invention, the actuator subassembly 42 includes a spring bore 44 formed in a wall segment of the upper section 28a of the flapper valve housing 26. The spring bore 44 is an elongated bore, preferably substantially cylindrical in shape and having its axial length oriented parallel to the housing axis. Spring bore 44 is preferably defined by a cylindrical inner surface 44a and an upper internal shoulder 44b. Internal shoulder 44b is preferably circumferential of the upper end of the spring bore 44. The spring bore 44 has a relatively small cross-section compared to the cross-section of the housing flow passage 26c. An upper guide bore 46 is formed in the housing 26 above the internal shoulder 44b. The upper guide bore 46 is an elongated bore, preferably substantially cylindrical in shape and having its axial length oriented parallel to the housing axis and aligned with the spring bore 44. Upper guide bore 46 is preferably defined by a cylindrical inner surface having a smaller internal diameter than the internal diameter of the spring bore 44. An external shoulder 46a is preferably formed at the upper end of the upper guide bore 46.

[0044] According to the presently most preferred embodiment illustrated in the drawings, a coil spring 48 is positioned in the spring bore 44, the upper end of which is positioned against the internal shoulder 44b of the

spring bore 44.

[0045] A spring rod 50 is positioned in the spring bore 44 and to extend through the upper guide bore 46. The spring rod 50 can be connected to the link member 38 by any convenient means. In the presently most preferred embodiment of the invention, the spring rod 50 is connected to the link member 38 by a linkage member 52 having a connecting pin 54.

[0046] The lower end of the spring rod 50 has a spring retainer 58 positioned thereon. Spring retainer 58 has an upper shoulder 58a such that the spring 48 can be captured on the spring rod 50 in the spring bore 44 between shoulder 44b and the shoulder 58a of the spring retainer 58.

[0047] A piston 60 is connected to the spring rod 50 through the spring retainer 58. Most preferably, the piston 60 is threaded into the spring rod 50 and secured in place with a threaded nut 62 as shown in FIG. 4.

[0048] Thus, in the presently most preferred embodiment of the invention, the spring 48 exerts a constant biasing force against the shoulder 58a of the retainer 58 on the spring rod 50. This constant biasing force urges the spring rod 50 downward (in the orientation shown in the drawings), which in turn is translated through the link member 38, hinge 40, and lever arm 36 to urge the flapper valve closure member 32 to pivot about hinge 34 toward the closed position shown in FIG. 2.

[0049] The piston 60 has an end portion 60a with a end surface 60b extending downward into a hydraulic fluid chamber 64 formed in the housing 26. Preferably, the end portion 60a of the piston 60 is cylindrical and the end surface 60b is circular. The end surface 60b defines a relatively small cross-sectional area for transferring hydraulic fluid pressure from the chamber 64 to the piston 60. The end surface 60b preferably has a diameter that is less than the overall thickness of the housing 26 defined by the distance between the outer surface 26a and the inner surface 26b of the housing 26. In other terms, the end surface 60b preferably has a cross-sectional diameter that is less than one tenth (0.1) of the cross-sectional diameter of the flow passage 18c through the flapper valve assembly 10.

[0050] Preferably, one or more piston seals 66 are positioned in the chamber 64 to provide a hydraulic pressure seal about the end portion 60a of the piston 60.

[0051] Fluid passages 68a, 68b, and 68c provide fluid communication for hydraulic fluid from the outside surface 26a of the housing 26 through to the chamber 64. As shown in FIGS. 1 and 2, housing 26 is circumferentially sealed against the inner surface 12b of the tubing string 12 with upper housing seal 70a and lower housing seal 70b. The upper housing seal 70a is positioned above nipple opening 16b, and the lower housing seal 70b is positioned below the nipple opening 16b. An annular space 72 is defined between the outer surface of housing 26 and the inner surface 12b of the tubing 12 adjacent the nipple opening 16b. Thus, hydraulic fluid communication can be established from the well head,

down through the control line 14, through the control line nipple 16, the annular space 72, fluid passages 68a-c, and to hydraulic fluid chamber 64.

[0052] According to the presently most preferred embodiment of the invention, increasing the pressure in the hydraulic fluid can be used to urge the piston 60 upward, thereby overcoming the biasing force on the spring rod 50 provided by the spring 48. Thus, applying control line pressure at the well head (in addition to any hydrostatic head pressure) in the control line 14 can be used to maintain the flapper valve closure member 32 in the open position against the biasing force provided by the spring 48. However, if the hydraulic pressure in the control line is reduced or the control line is severed, in some kind of an emergency situation, for example, the biasing force provided by spring 48 is translated to urge the flapper valve 10 back toward the closed position.

[0053] One advantage of the invention is that the spread between the hydraulic fluid pressure required to open and close the flapper valve assembly 10 is relatively small. Furthermore, a flapper valve according to the invention does not require a large compression spring to overcome the hydrostatic head pressure of the control line. These advantages are the result of the relatively small cross-sectional area of the end surface 60b of the piston 60 compared to the cross-sectional area of the flow passage 18c through the flapper valve assembly 10.

[0054] In addition, the piston 60 has an extremely short stroke. For example, in the presently most preferred embodiment of the invention, the stroke of the piston 60 is only 0.32 inch (8.1 mm), while the stroke to move the actuator tube of a conventional flapper valve with the same outer diameter is 6.7 inches (170 mm). Thus, the overall length of a flapper valve according to the invention can be 50% shorter than a conventional flapper valve.

[0055] Another advantage of the invention is that the flapper valve assembly 10 can be remotely actuated from the surface through the control line 14 so that it is possible to open the flapper valve assembly 10 from the well head without using a downhole actuator tube to open the flapper valve closure member 32. Therefore, the flapper valve closure member will not be subject to damage caused by an actuator tube during a slam opening or closing of the flapper valve assembly 10.

[0056] It will be appreciated that the invention described above may be modified.

Claims

1. Apparatus for use in a flapper valve (10) having a substantially tubular housing (26), a valve seat (18) defining a flow passage (18c) therethrough, and a flapper valve closure member (32) pivotally connected to the housing (26) adjacent the valve seat (18) for selectively moving between an open position

and a closed position against the valve seat (18), the apparatus comprising a lever arm (36) adapted to be provided on the flapper valve closure member (32), such that the lever arm (36) extends from adjacent to the flapper valve pivotal connection away from the flapper valve closure member (32); a piston (60) adapted to be mounted in the tubular housing (26); a pivotal connection for operatively connecting the piston (60) to the lever arm (36); and a control line and fluid communication passages (68a,68b,68c) adapted to be provided in the housing (26) for selectively transmitting fluid pressure from a remote location to the piston (60) for urging the piston (60) in at least one direction, thereby urging the flapper valve closure member (32) to pivot in at least one direction about the flapper valve pivotal connection between the open position and the closed position.

2. Apparatus for use in a flapper valve (10) having a substantially tubular housing (26), a valve seat (18) defining a flow passage (18c) therethrough, and a flapper valve closure member (32) pivotally connected to the housing (26) adjacent the valve seat (18) for selectively moving between an open position and a closed position against the valve seat (18), the apparatus comprising a lever arm (36) adapted to be provided on the flapper valve closure member (32), such that the lever arm (36) extends from adjacent to the flapper valve pivotal connection away from the flapper valve closure member (32); a piston (60) adapted to be mounted in the tubular housing (26); a pivotal connection for operatively connecting the piston (60) to the lever arm (36); a means for biasing the piston (60) to move the piston (60) in a first direction, thereby urging the flapper valve closure member (32) to be biased to pivot about the flapper valve pivotal connection toward the closed position; and a control line and fluid communication passages (68a,68b,68c) adapted to be provided in the housing (26) for selectively transmitting fluid pressure to the piston (60) to move the piston (60) in a second direction that is opposed to the first direction and to overcome the means for biasing, thereby urging the flapper valve closure member (32) to pivot about the flapper valve pivotal connection toward the open position.

3. Apparatus according to claim 2, wherein the means for biasing the piston (60) to move in a first direction comprises a coil spring (48).

4. Apparatus according to Claim 1, 2 or 3, wherein the piston (60) is adapted to be mounted in the tubular housing (26) such that the flapper valve closure member (32) is between the valve seat (18) and the piston (60).

5. Apparatus according to Claim 1, 2, 3 or 4, wherein the piston (60) is operatively connected to the lever arm (36) through a linkage member (52).
6. A flapper valve (10) comprising: a seat (18) having a substantially tubular seat wall (18b) defining a seat axis and a seat flow passage (18c) and having a circumferential seat sealing surface (18a); a housing (26) having a substantially tubular housing wall (26b) defining a housing axis and a housing flow passage (26c), the housing (26) being connected to the seat (18) and the housing axis being axially aligned with the seat axis, whereby the seat flow passage (18c) and the housing flow passage (26c) define a continuous flow passage through the flapper valve (10); a side opening (30) formed in the housing wall (26c); a valve closure member (32) for blocking the continuous flow passage, the valve closure member (32) having a valve sealing surface (32a) for engaging the seat sealing surface (18a); a valve pivot connection for mounting the valve closure member (32) to the housing (26) adjacent to the side opening (30) such that the valve closure member (32) is in the side opening (30) and a closed position where the valve closure member (32) is moved to block the continuous flow passage and engage the sealing surface (18a) of the seat (18); a lever arm (36) extending from adjacent to the valve pivot connection away from the valve closure member (32); a piston (60) mounted adjacent to the housing wall (26b) for reciprocal movement parallel to the axis of the housing (26); an arm pivot connection for operatively connecting the piston (60) to the lever arm (36) on the valve closure member (32); and means for selectively transmitting fluid pressure to the piston (60) for moving the piston (60) in at least one direction, thereby urging the flapper valve closure member (32) in at least one direction about the valve pivot connection between the open position and the closed position.
7. A flapper valve according to Claim 6, wherein the piston (60) is mounted in the tubular housing wall (26b) such that the valve sealing surface (32a) of the valve closure member (32) is between the seat sealing surface (18a) of the seat (18) and the piston (60).
8. A flapper valve (10) comprising: a cylindrical housing (26) having a wall, the wall having at least one longitudinal bore formed therein; a valve closure member (32); a valve closure member hinge (34) for pivotally connecting the valve closure member (32) to the housing (26); a seat member (18) connected to the housing (26), the seat member (18) having a flow passage (18c) therethrough, the valve

closure member (32) movable between an open position where two way flow may occur through the seat member (18) and a closed position where the valve closure member (32) sealingly engages the seat member (18) and closes the seat member flow passage (18c); a piston (60) positioned for longitudinal movement in the longitudinal bore, the piston (60) being eccentrically and pivotally connected to the valve closure member hinge (34) so that when the piston (60) is urged in a first longitudinal direction, the valve closure member (32) is urged toward the closed position, and so that when the piston (60) is urged in a second longitudinal direction, the valve closure member (32) is urged toward the open position; a spring (48) for urging the piston (60) in the first longitudinal direction; and a selectively operable control line providing hydraulic fluid pressure for urging the piston (60) in the second longitudinal direction.

9. A flapper valve (10) according to Claim 8, wherein the piston (60) is positioned in the cylindrical housing (26) such that the valve closure member (32) is between the seat member (18) and the piston (60).
10. A flapper valve (10) according to Claim 8 or 9, wherein the spring (48) comprises a coil spring.

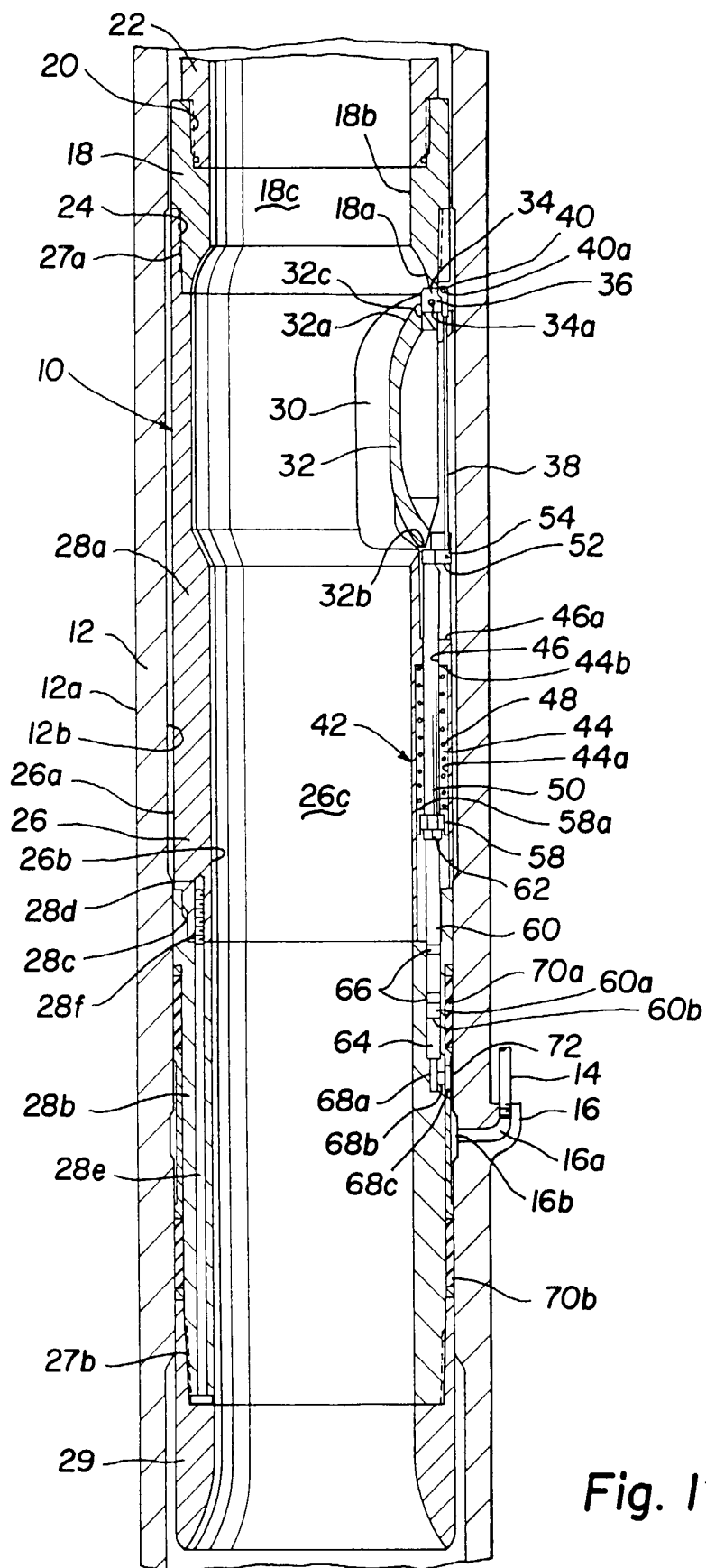


Fig. 1

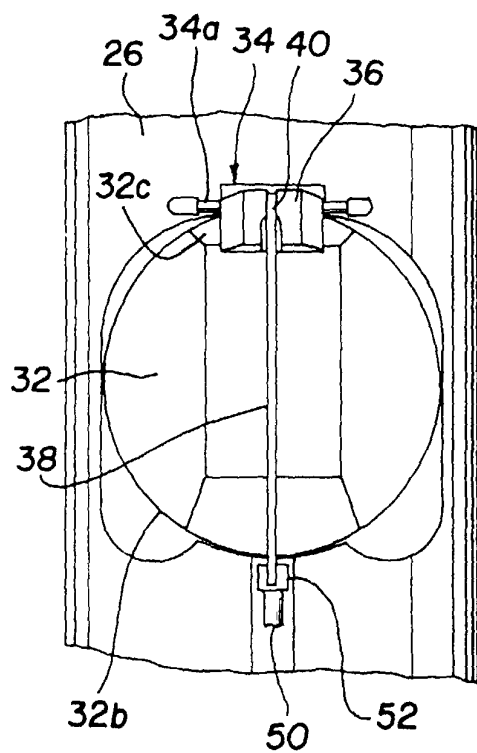


Fig. 3

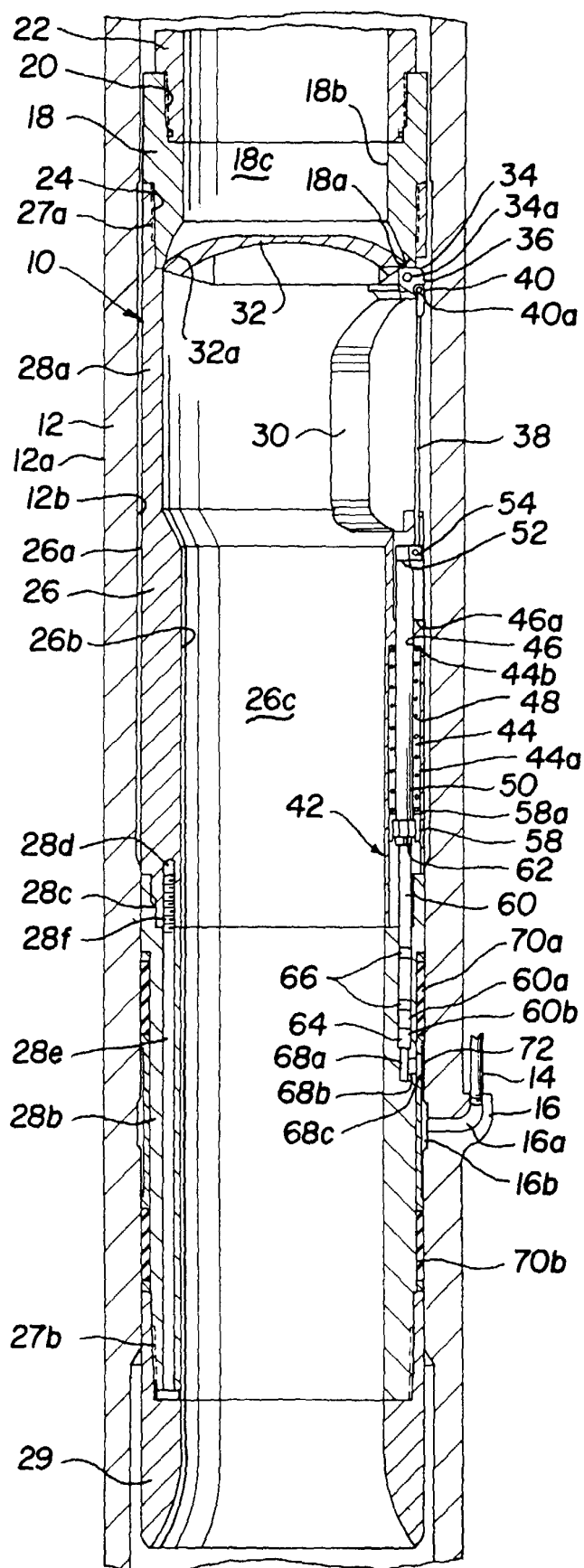


Fig. 2

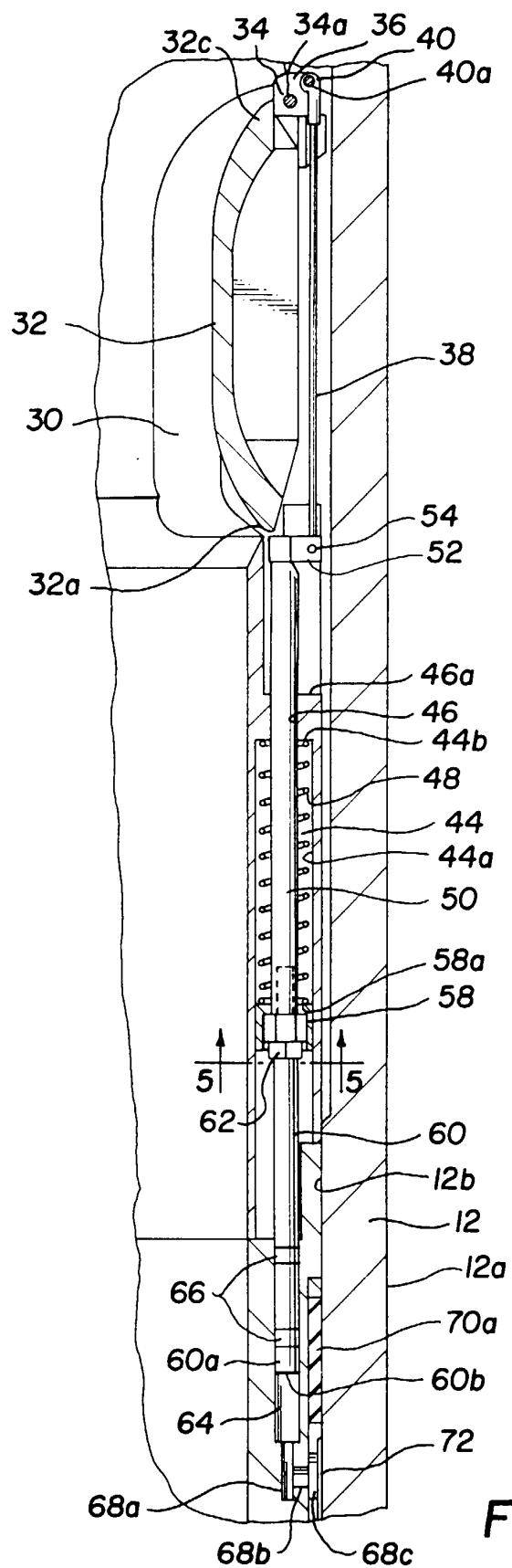


Fig. 4

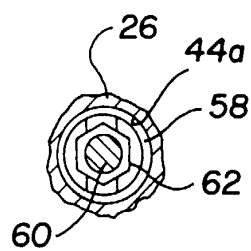


Fig. 5