June 26, 1962 H. PISTOLE ET AL 3,040,811

SUBSURFACE SAFETY VALVE

Filed April 23, 1959 2 Sheets-Sheet 1

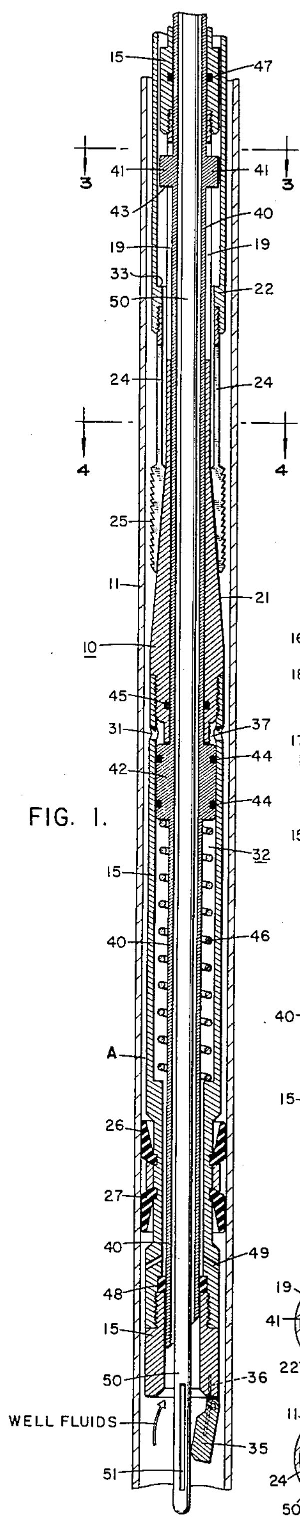


FIG. 1.

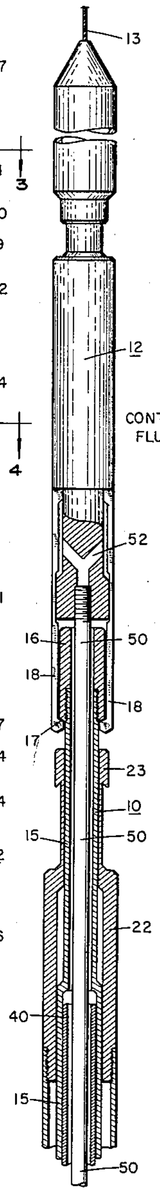
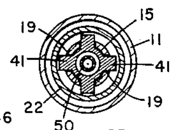


FIG. 2.

FIG. 3.



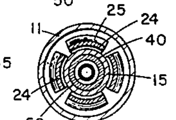


FIG. 4.

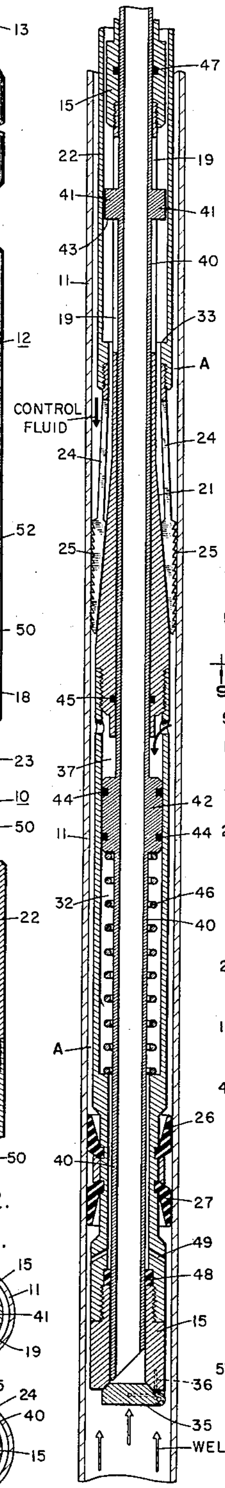
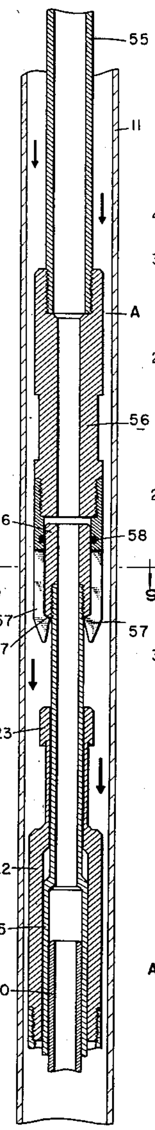


FIG. 7.

FIG. 8.



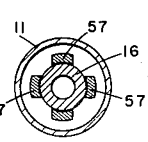


FIG. 9.

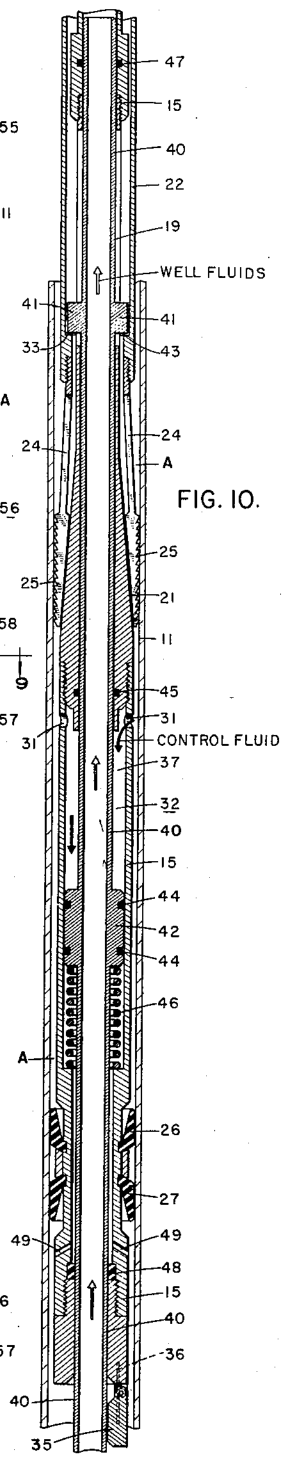


FIG. 10.

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SUBSURFACE SAFETY VALVE

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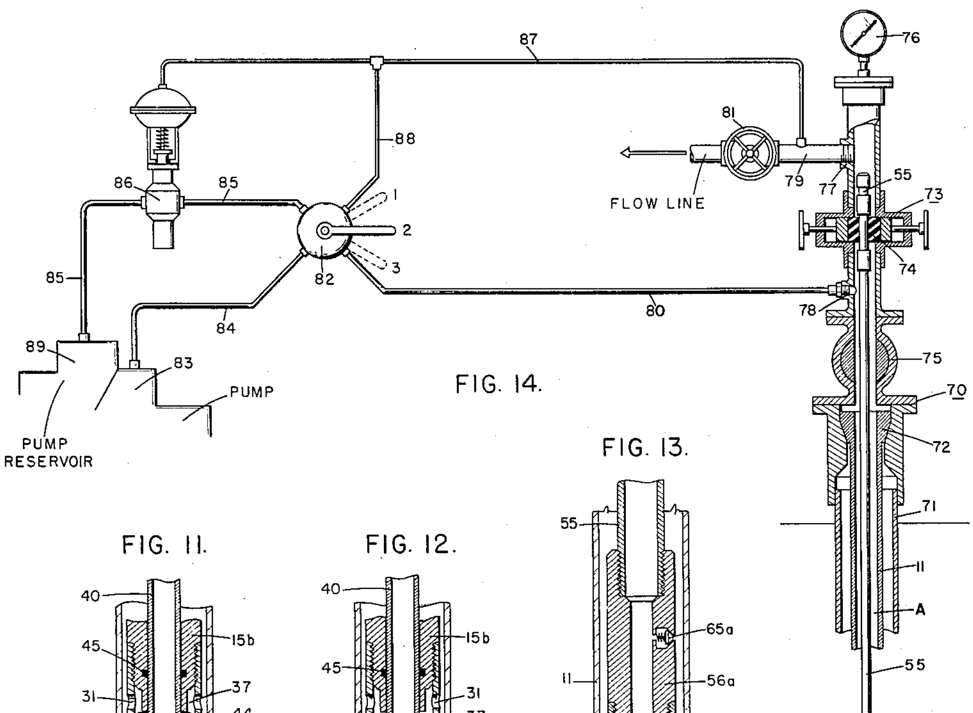


FIG. 14.

FIG. 13.

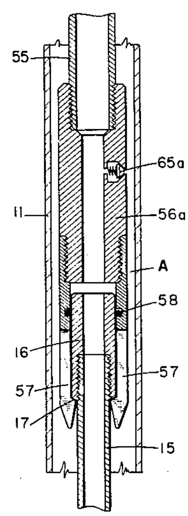


FIG. 11.

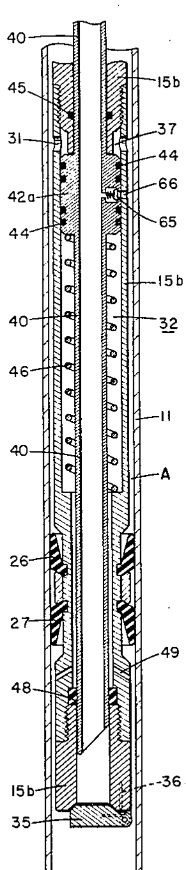


FIG. 12.

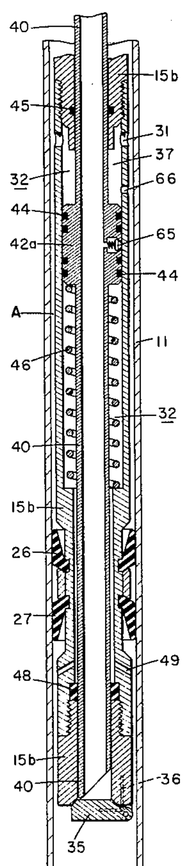


FIG. 5.

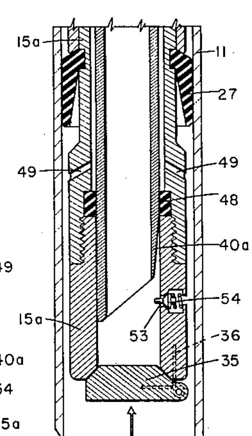
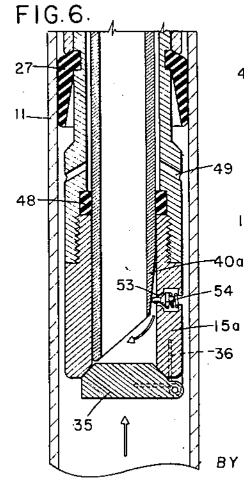


FIG. 6.



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SUBSURFACE SAFETY VALVE

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5 Claims. (Cl. 166—72)

This invention concerns a hydraulically operated subsurface safety valve or storm choke.

It is known to equip wells with subsurface safety valves to stop the flow of production fluids when for some reason the well's production cannot be controlled. Valves of this type have been especially useful in offshore wells to prevent blowouts when excessive flow from the well resulting from damage to the well head or other surface equipment caused by storms, floating objects, or other happenings necessitate halting of production.

Many of these valves are flow velocity operated; that is, they are designed to close off the production flow conduit when the velocity of the fluids flowing through the valve reaches a predetermined value. These velocity type valves are disadvantageous in that they cannot be periodically tested without flowing the well at a high rate for a short period of time to cause closure of the valve.

Other type safety valves employ an external fluid pressure originating at the surface to maintain the valve open and depend upon release of this fluid pressure to cause the valve to automatically close.

The safety valve of the invention, which is an improvement in this latter type valve, comprises briefly, a tubular conduit for carrying production fluids to the surface arranged in a well pipe; a subsurface closure means for permitting and preventing fluid flow through the conduit; pressure responsive means for actuating the closure means; means for fluidly communicating the annulus between the conduit and the well pipe and the pressure responsive means; packer means for closing off the annulus; means at the surface for supplying fluid pressure to the annulus whereby fluid pressure applied to the annulus actuates the closure means to open position and release of annulus fluid pressure actuates the closure means to closed position. In a preferred embodiment, a pressure equalizing opening positioned below the packer means is provided to fluidly communicate the annulus and the flow path through the tubular conduit. The invention includes a control system at the surface for bleeding the fluid pressure in the annulus when surface conditions, as, for example, excessive heat, excessive wind velocity, excessive wave height or force, impact, etc., require closing off the flow of production fluids. A valved port may be provided above the packer means to maintain a pressure differential between the annulus and the tubular conduit and to fluidly communicate the annulus and the flow path through the tubular conduit for equalizing pressure and for permitting fluid circulation therebetween. The flow path provided by the tubular conduit is preferably of substantially constant cross-sectional area throughout its length. This feature is important since it prevents the accumulation of sand carried by the production fluids. Since the production fluids from many wells contain free sand, accumulation of this sand along any part of the flow path presents a problem. Sand accumulation is a disadvantageous feature in many of the velocity type safety valve installations.

Another important aspect of the present invention is the use of the annulus between the production fluid flow

passage or conduit and the tubing or well pipe as the path for the external fluid pressure used to actuate the safety valve. This construction eliminates the need for an additional tubing string or pipe to conduct the valve actuating fluid pressure from the surface to the valve which is the manner of operation in all known valves of this type.

An object of the present invention is to provide a subsurface safety valve that is easily installed and operated; that overcomes the problem of sand accumulation; that eliminates the need for a separate valve actuating fluid pressure pipe string; that is reliable; and that has other improvements and advantages over known safety valves which will be apparent from a more detailed description of the invention which follows.

Referring briefly to the drawings:

FIG. 1 is a vertical, partly sectional view of the lower portion of the valve assembly of the invention;

FIG. 2 is a view similar to that of FIG. 1 showing the upper portion of the valve assembly connected to a running tool;

FIG. 3 is a view taken on lines 3—3 of FIG. 1;

FIG. 4 is a view taken on lines 4—4 of FIG. 1;

FIGS. 5 and 6 are vertical, partly sectional views of the lower portion of the valve assembly and illustrate a preferred embodiment employing an equalizing valve;

FIG. 7 is a vertical, partly sectional view of the lower portion of the valve assembly showing the slips initially set in the tubing string and the piston member and attached mandrel in a lower position;

FIG. 8 is a view similar to that of FIG. 7 showing the upper portion of the valve assembly of FIG. 7 and also showing the running tool replaced by a conduit extending to the earth's surface;

FIG. 9 is a view taken on lines 9—9 of FIG. 8;

FIG. 10 is a view similar to that of FIG. 7 showing the piston member and attached mandrel in a still lower position and the valve element open;

FIGS. 11 and 12 are views similar to that of FIG. 7 illustrating two positions of a modified valve assembly;

FIG. 13 is a vertical, partly sectional view of a portion of the valve assembly illustrating a still further modification; and

FIG. 14 is a partly schematic view illustrating surface apparatus connected to well head equipment.

The valve assembly of the invention generally designated 10 is shown in the figures arranged in a tubing string 11. A running tool 12 suspended on a wire line 13 and which may be suitably a modification of the type shown and described on page 4015 of the Composite Catalog of Oil Field and Pipe Line Equipment, 21st ed., is connected to the upper end of valve assembly 10. Valve assembly 10 includes a housing 15 provided with a bore therethrough. A collar 16 having a downwardly and inwardly tapering annular lower shoulder 17 is connected to the upper end of housing 15. Spring biased arms 18 connected to the lower end of running tool 12 releasably engage shoulder 17. Housing 15 also includes a plurality of radially spaced slots 19 (see FIG. 3) and an inwardly, upwardly tapering exterior surface 21. A sleeve 22 provided with a fishing head 23 adapted to engage with a fishing tool and carrying a plurality of radially spaced slip arms 24 (see FIG. 4) provided with serrated surfaces 25 adjacent their lower ends is slidably arranged on housing 15. Slip arms 24 engage inclined surface 21 in a manner such that downward movement of sleeve 22 relative to housing 15 causes slip arms 24 to move outwardly and embed serrations 25 in the wall of tubing string 11. Opposed cup packers 26 and 27 are arranged on housing 15 and function to seal off the annulus A between housing 15 and tubing string 11. Above opposed cup packers 26, 27, housing 15 is provided with a port 31 fluidly communicating the interior and exterior thereof. Also adjacent port 31, housing 15 is provided with a recessed section 32.

A flapper valve 35 biased to the closed position by means of a spring 36 is connected to the lower end of housing 15 and is adapted to permit and prevent flow of well fluids upwardly through the bore of the housing. A tubular member or mandrel 40 is movably arranged in the bore of housing 15. Lugs 41 arranged on mandrel 40 extend through and are movable along slots 19 of housing 15 (see FIG. 3). Bottom surfaces 43 of lugs 41 are adapted to engage an annular shoulder 33 formed on sleeve 22. Adjacent the recessed section 32 of housing 15, mandrel 40 is provided with a piston member 42 which forms an expansible pressure chamber 37 between port 31 and piston member 42. Spaced sealing members 44 are provided on piston member 42 to seal off the space between the interior of housing 15 and piston member 42 and sealing member 45 is provided on housing 15 above recessed section 32 to seal off the space between mandrel 40 and the interior of housing 15. A spring 46 arranged in recess 32 below piston member 42 biases piston member 42 and connected mandrel 40 upwardly. Additional sealing members 47 and 48 are provided for sealing off the space between the mandrel and the housing. Also, an opening 49 fluidly communicating the interior and exterior of housing 15 is provided for the release of fluid trapped below piston member 42. A hollow stinger 50 provided with a lower opening 51 and an open upper end is screw-threadedly connected to running tool 12. The open upper end of stinger 50 connects to ports 52 provided in running tool 12.

In the preferred embodiment of the invention, shown in FIGS. 5 and 6, a spring biased equalizing valve 54 is mounted in the lower end of a modified housing 15*a* below packers 26, 27. A mandrel 40*a* modified by having a portion of the lower end tapered inwardly and downwardly is adapted to engage and open valve 54 against the bias of the spring to fluidly communicate the interior of mandrel 40*a* and the exterior of housing 15*a* upon downward movement thereof.

In the illustration of FIGS. 7 and 8, running tool 12 and stinger 50 connected thereto have been disconnected from collar 16 and removed from tubing string 11. A production pipe 55 which is substantially of the same diameter as that of the bore of mandrel 40 and which has connected to the lower end thereof an adapter latching sub 56 provided with latching arms 57 (see FIG. 9) adapted to releasably engage surface 17 of collar 16 has replaced running tool 12. Sub 56 is provided with a sealing member 58 adapted to seal off the space between collar 16 and sub 56. Slip arms 24 are engaged with tubing string 11 and the lower end of mandrel 40 is positioned adjacent closed flapper valve 35.

FIG. 10 shows the piston member 42 and attached mandrel 40 in still another position. Valve 35 is open in this position of mandrel 40.

The elements of FIGS. 11 and 12 are the same as those described with regard to FIGS. 1 and 2 except the piston member and housing have been modified. Thus, in FIGS. 11 and 12, a piston member 42*a* is provided with a spring biased combination fluid circulation and equalizing valve 65 which is adapted to maintain a differential pressure between annulus A and production pipe 55. Housing 15*b* is provided with an additional opening 66, which is adapted to fluidly communicate the interior and exterior thereof. FIG. 11 shows the fully retracted position of piston member 42*a* in which position valve 65 and port 66 are aligned. The flow passage through the aligned valve 65 and port 66 is sealed off by means of sealing members 44. FIG. 12 shows mandrel 40 in an intermediate position with the lower end of mandrel 40 adjacent valve 35 and valve 65 sealed off from port 66 by means of sealing members 44.

FIG. 13 differs from the apparatus of FIGS. 1 and 2 in that a fluid circulation or equalizing check valve 65*a* is arranged in an adapter sub 56*a*. This valve functions the same as valve 65; that is, it can be used to equalize pressure and to circulate fluids between production pipe string 55 and annulus A.

The control system shown in FIG. 14 includes a well head, generally designated 70, mounted on a casing 71 and provided with a suitable hanger assembly 72 for supporting tubing string 11. Any desired packer arrangement for closing off the annulus surrounding pipe string 55 may be provided. For example, as shown, a blowout preventer 73 provided with a suitable packoff 74 is arranged on well head 70. Master valve 75, a pressure gauge 76, and flanges 77 and 78 to which are connected a flow conduit 79 and a pressurizing conduit 80, respectively, are provided on well head 70. Conduit 79, which fluidly communicates with the open upper end of pipe string 55, as shown, is provided with a valve 81. Conduit 80 connects at one end to annulus A below packoff 74 and at the other end to a 3-way control valve, generally designated 82. A hydraulic pump 83 connects to valve 82 by means of conduit 84 and a reservoir 89 of pump 83 connects to valve 82 by way of a conduit 85. A fluid pressure actuated spring biased diaphragm type valve 86, adapted to open upon release of fluid pressure on the diaphragm, is connected in conduit 85. A conduit 87 connects the diaphragm of valve 86 to flow conduit 79. A conduit 88 interconnects valve 82 and conduit 87. The three positions of valve 82 are designated 1, 2, and 3. When in position 1, conduits 80, 87, 88, and 84 are interconnected and hydraulic pressure from pump 83 fluidly communicates with both annulus A and pipe string 55. In position 2, conduits 80 and 84 are interconnected and hydraulic pump 83 fluidly communicates with annulus A. In position 3, conduits 80 and 85 are interconnected thereby fluidly communicating reservoir 89 and annulus A.

In operation, the valve assembly 10 connected to the running tool 12 provided with stinger 50 is lowered in tubing string 11 by means of wire line 13 to a desired depth. Stinger 50 holds flapper valve 35 in the open position against the bias of spring 36 during the running-in operation. Well fluids may circulate through the hollow stinger via opening 51 and the open upper end of stinger 50 and through connected passages 52 in the running tool 12. Slip arms 24 are in retracted position, as shown in FIGS. 1 and 2. At the desired depth, the wire line 13 is "jerked" upwardly which causes upward movement of housing 15. Since sleeve 22 and slip arms 24 are slidable on housing 15, serrations 25 are forced into engagement with tubing string 11 as slip arms 24 travel downwardly relative to tapered surface 21. After slip arms 24 have engaged tubing string 11, arms 18 of running tool 12 are disengaged from collar 16 by pulling up on cable 13. Stinger 50 connected to running tool 12 also moves upwardly within housing 15 and permits spring 36 to close flapper valve 35. Running tool 12 and connected stinger 50 then are removed from tubing string 11. When flapper valve 35 closes, pressure of the well fluids exerts an upward force on housing 15 which causes serrations 25 of slip arms 24 to more firmly engage the wall of tubing string 11, as seen in FIG. 7. Then pipe string 55 and connected sub 56 are run-in tubing string 11 until latch arms 57 engage shoulder 17 of collar 16. Seal 58 seals off fluid communication between annulus A and the interior of housing 15 and pipe string 55.

When utilizing the preferred embodiment illustrated in FIGS. 5 and 6, the surface connections, shown in FIG. 14, are made-up and valve 82 is placed in position 2 which connects hydraulic pump 83 to annulus A only and pressure in annulus A is increased to above well pressure to cause movement of piston member 42 downwardly against the bias of spring 46. As seen in FIG. 6, initial movement of mandrel 40*a* downwardly to the intermediate position which places the lower end of mandrel 40*a* adjacent flapper valve 35 causes the tapered surface of mandrel 40*a* to engage valve 54 to open valve 54 against the bias of the spring. Opening of valve 54 fluidly communicates and thereby equalizes fluid pressures between the the interior of housing 15*a* below sealing member 48 and the interior of mandrel 40*a* and the exterior of housing 15*a*. Once the well pressure has equalized through valve 54, additional fluid pressure applied to annulus A causes piston member 42 to move further downwardly against the bias of spring 46. In this movement the lower end of mandrel 40*a* engages flapper valve 35 and moves this valve to the open position shown in FIG. 10 against the bias of spring 35. Also, as seen in this figure, lugs 41 move downwardly until the bottom surfaces 43 thereof engage annulus shoulder 33 formed on sleeve 22 to lock slips 24 in the outward or tubing engaged position.

If the preferred equalizing valve embodiment, as illustrated in FIGS. 5 and 6, is not employed then valve 82 is initially placed in position 1 which connects pump 83 to annulus A via conduit 80 and to pipe string 55 via conduits 88, 87, and 79. Hydraulic pressure then is applied to annulus A and to pipe string 55 simultaneously until the hydraulic pressure equals well pressure. At this time, valve 82 is moved to position 2 which connects hydraulic pump 83 to annulus A only and pressure within pipe string 55 is maintained while hydraulic pressure in annulus A is increased to above well pressure to cause movement of piston member 42 downwardly against the bias of spring 46. Initial movement of piston member 42 carries the lower end of mandrel 40 to adjacent flapper valve 35, as seen in FIG. 7. Additional movement of piston member 42 downwardly forces mandrel 40 to engage flapper valve 35 and move the valve to the open position against the bias of spring 36, as seen in FIG. 10. Within FIGS. 7 and 10, the dark arrows designate the direction of flow of the pressurizing fluids and the light arrows designate the flow direction of production fluids.

The embodiment of the invention shown in FIGS. 11 and 12 permits circulation of fluids such as hot oil or solvent as well as equalization of pressure. To operate, valve 82 is placed in position 2 and fluid is pumped into annulus A and through aligned port 66 and check valve 65 (see FIG. 11) into mandrel 40. Pumping is continued until fluid pressure within mandrel 40 equals well pressure. Then, because the predetermined pressure differential maintained by check valve 65 is sufficient to overcome the biases of springs 46 and 36, piston member 42*a* and mandrel 40 move downwardly (see FIG. 12) until valve 35 is opened. Upon downward movement of piston member 42*a* sealing members 44 close off fluid communication between check valve 65 and port 66.

With the apparatus in the position shown in FIG. 11 fluids can be circulated through conduit 80, down annulus A, through aligned port 66 and check valve 65, up mandrel 40 and pipe string 55 and through open valve 81.

The operation of the embodiment of the invention shown in FIG. 13 is the same as that described for the embodiment shown in FIGS. 11 and 12. The essential difference between the two embodiments resides in the position of the check valve. In FIG. 13 check valve 65*a* is mounted in a stationary sub 56*a* and there is no feature of sealing off this check valve as there is in the embodiment of FIGS. 11 and 12.

In the described embodiments, when valve 35 is in the open position, as seen in FIG. 10, valve 82 is moved to position 3 which connects conduit 80 and conduit 85. In this position, fluids are produced through mandrel 40 (or 40*a*) and pipe string 55 and conduit 79. A decrease in fluid pressure in conduit 87 caused by a decrease in fluid pressure to a predetermined value through conduit 79 causes diaphragm valve 86 to open. When this occurs, the annulus pressure bleeds through conduit 80, conduit 85, and open valve 86 into reservoir 89. Upon release of annulus pressure, piston member 42 moves upwardly under the bias of spring 46 and well pressure acting below the piston member 42 causes mandrel 40 to be retracted

into housing 15 and valve 35 closes under the bias of spring 36 and well pressure. Although, as described, valve 86 is designated a valve which opens only in response to a decrease in fluid pressure, it may be of the type which opens in response to increased pressure as well as decreased pressure. Additionally, while the arrangement is described with regard to preventing blowouts or other pressure changes, any other type of control system is to be considered as within the scope of the invention; for example, the surface apparatus may provide for bleeding hydraulic fluid pressure from the annulus when excessive heat, or excessive wind velocity, or excessive wave height, or excessive wave force, or impact from surface objects require closing off of production fluids.

It is to be emphasized that in the open position, valve 35 provides a full opening. Because the bores of mandrel 40 (or 40*a*), sub 56 (or 56*a*) and pipe string 55 are substantially the same diameter as the diameter of the valve 35 opening, sand cannot settle on the valve or within the valve because this straight through type design does not have an increased flow area to cause sand accumulation.

When it is desired to remove the safety valve from tubing string 11, arms 57 of sub 56 are disengaged from collar 16 by pulling up on pipe string 55 and removing this detachable apparatus from the borehole. Then, a fishing tool is lowered in tubing string 11 and engaged with fishing head 23. Slip arms 24 are disengaged from tubing string 11 and the valve assembly 10 is removed through tubing string 11 to the surface.

A production casing would be mounted in well head 60; however for purposes of simplicity only casing 71 is shown. Also, although not shown, tubing string 11 is provided with a tubing-casing packer above the production zone in order to direct production fluid flow upwardly through the tubing string to the safety valve.

Having fully described the objects, nature, and apparatus of the invention, we claim:

1. Apparatus for controlling fluid flow through a tubing arranged in a borehole comprising a housing positioned in said tubing and having a bore therethrough and provided with a port fluidly communicating the interior and exterior thereof; first valve means arranged on the lower end of said housing and movable between an open position adapted to permit, and a closed position adapted to prevent upwardly directed fluid flow therethrough; first biasing means arranged on said first valve means adapted to urge said first valve means to the closed position; packer means arranged on said housing below said port in the annulus between said housing and said tubing and engaging said tubing wall to prevent fluid flow therepast; longitudinally movable means arranged within said housing adapted to move downwardly to engage and move said first valve means to its open position, said movable means also being provided with a piston member below said port adapted to move said movable means downwardly upon application of fluid pressure to said piston member; second biasing means arranged in said housing and engaging said piston member adapted to urge said movable means upwardly out of engagement with said first valve means; normally closed second valve means arranged on said housing below said packer means adapted to open upon engagement with said movable means to fluidly communicate and equalize fluid pressure between the interior and exterior of said housing; a production pipe string connected to the upper end of said housing and extending to the earth's surface adapted to provide an isolated flow path for said well fluids; and fluid pressure supply means connected to said tubing and fluidly communicating with said annulus adapted to supply fluid pressure to said piston member via said annulus and said port to move said piston member and connected movable means downwardly against the bias of said second biasing means to engage and move said first valve means against the bias of said first biasing means from its closed to its opened position, the release of fluid pressure in said annulus permitting

said piston member and connected movable means to move upwardly under the bias of said second biasing means to permit said first valve means to close under the bias of said first biasing means.

2. Apparatus as recited in claim 1 including means connected to said fluid pressure supply means adapted to release fluid pressure in said annulus in response to variation in pressure of produced well fluids.

3. Apparatus as recited in claim 2 including an additional port arranged on said housing above said packer means and a one-way, spring-biased valve arranged on said piston member cooperating when aligned to permit fluid flow from said annulus to the interior of said tubular member.

4. Apparatus as recited in claim 2 including a one-way, spring-biased valve arranged on said production pipe string for permitting fluid flow from said annulus to the interior of said pipe string.

5. Apparatus as recited in claim 2 wherein the opening of said first valve means and the bores of said movable means and said production pipe string are substantially equal in cross-sectional areas.

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