United States Patent [19]

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[54] **SUBSURFACE SAFETY VALVE**

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[21] Appl. No.: **98,777**

[52] **U.S. Cl.** **137/67**, 137/498, 251/62

[51] **Int. Cl.** **F16k 17/20**, F16k 17/36

[58] **Field of Search**.....137/67, 460, 469, 470, 472, 137/498, 484.4

[56] **References Cited**

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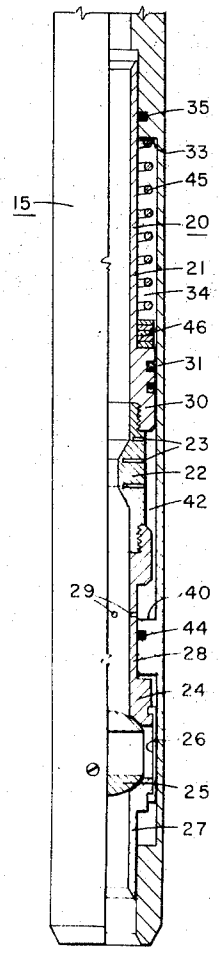
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[57] **ABSTRACT**

A subsurface safety valve capable of being installed in and retrieved from a well tubing string is held open by a spring and is closed by well pressure. Erosion from well fluids and/or a predetermined flow rate of well fluids through the valve will cause the valve to close.

22 Claims, 11 Drawing Figures



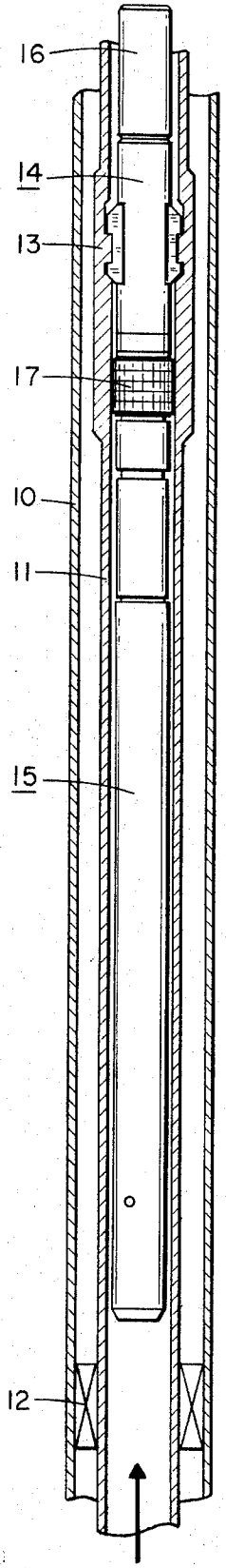


FIG. 1.

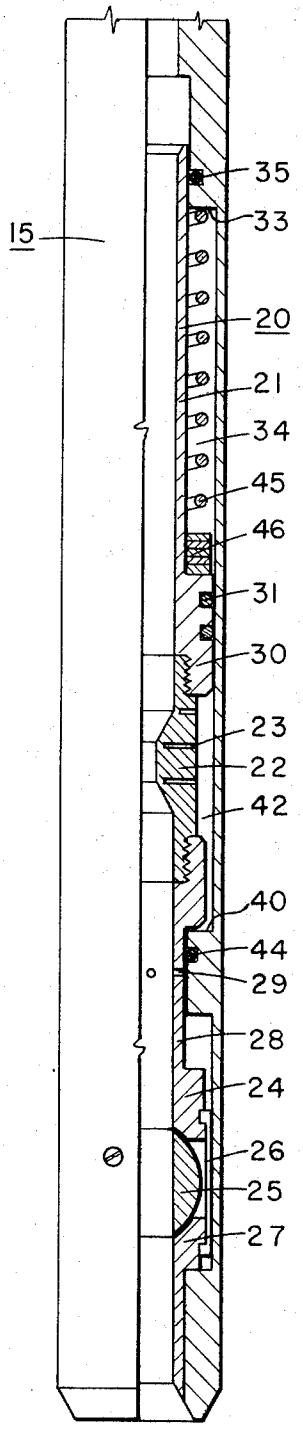


FIG. 2.

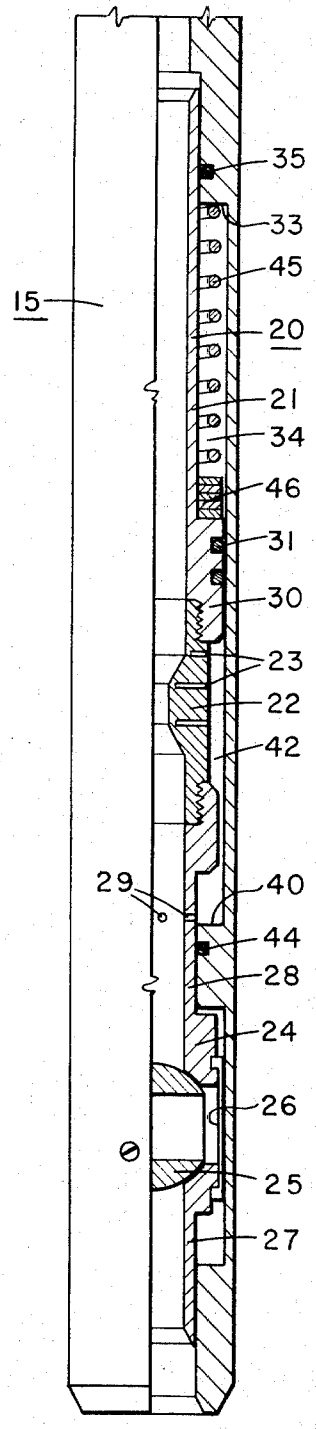


FIG. 3.

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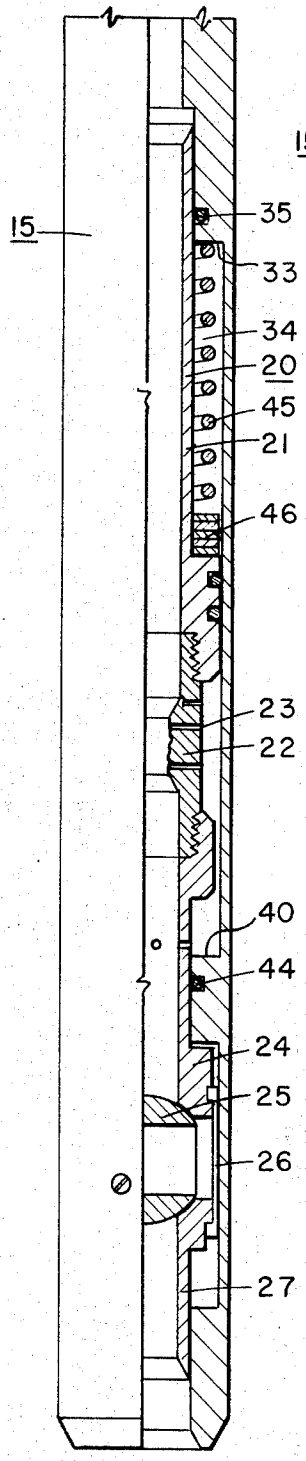


FIG. 4.

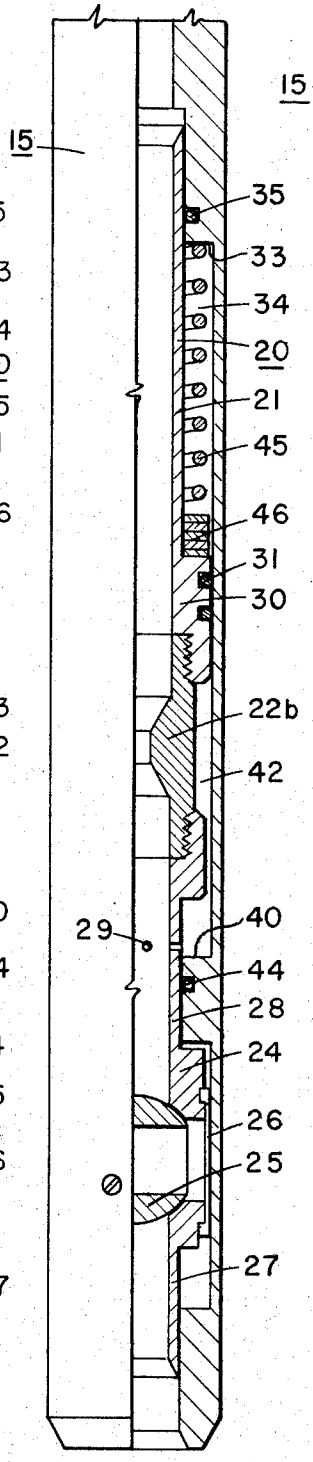


FIG. 5.

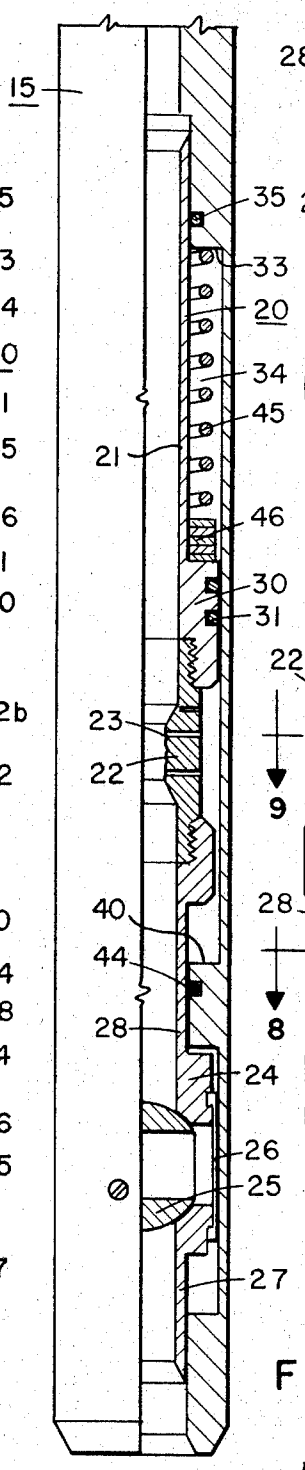


FIG. 6

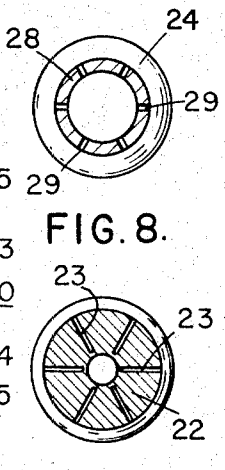


FIG. 8.

FIG. 9.

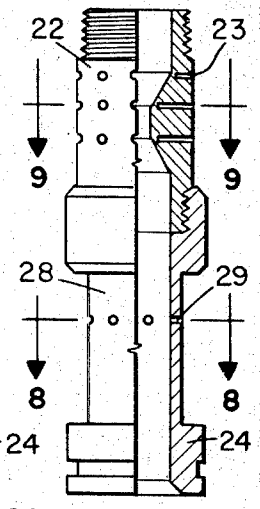


FIG. 7.

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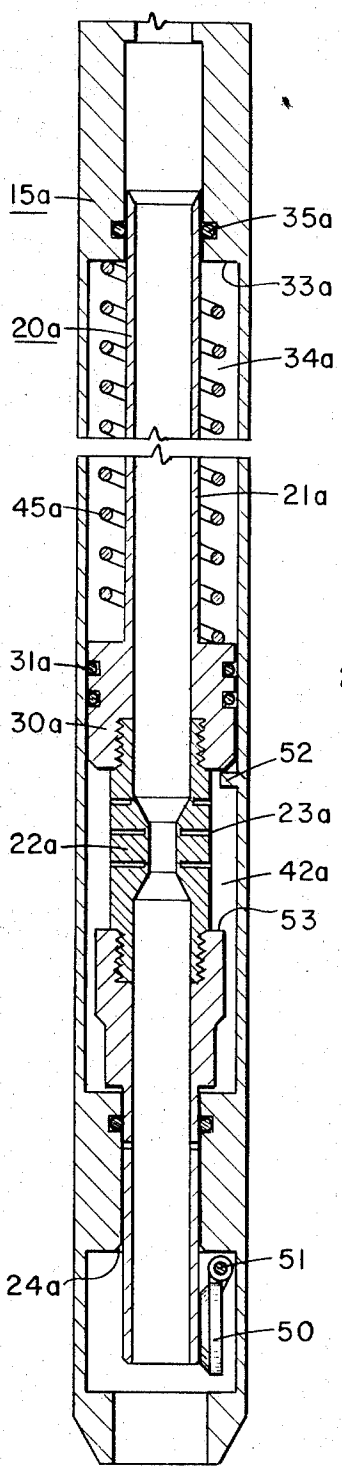


FIG. 10.

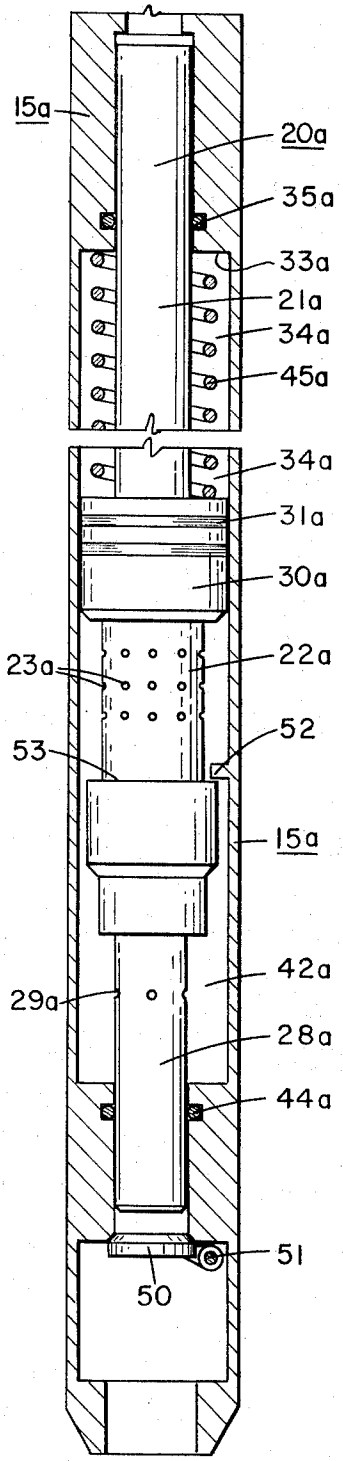


FIG. 11.

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SUBSURFACE SAFETY VALVE

BACKGROUND OF THE INVENTION

This invention relates to a subsurface safety valve for controlling the flow of well fluids. Current flow actuated valves become more insensitive to increased flow rates as erosion of the valve progresses. The valve of the invention is sensitive to the erosive effect of well fluids. It is designed to close when erosion caused by well fluids flowing through the valve occurs. The valve of the invention is also designed to close with very small pressure drops across it. The valve has "stored energy" in the form of atmospheric pressure gas to fully close the valve when erosion occurs or the closing flow rate is reached.

SUMMARY OF THE INVENTION

A subsurface safety valve designed to operate in well pipe strings comprising a valve housing; a valve assembly arranged in said valve housing and including a valve member capable of controlling flow of fluids through said valve assembly and a flow sub providing a restricted flow passageway through said valve assembly, said valve assembly cooperating with said valve housing to form two chambers therebetween; sealing means sealing off the ends of said chambers; biasing means arranged in one of said chambers for moving said valve assembly to position said valve member to permit flow of fluids through said valve assembly; and means for fluidly communicating the interior of said valve assembly and said other chamber to permit well fluids to move said valve assembly to position said valve member to prevent flow of well fluids through said valve assembly.

In one embodiment of the invention the means for fluidly communicating the interior of the valve assembly and the other chamber comprise holes formed in said flow sub which are initially closed but which open when the interior of the flow sub is eroded a preselected amount.

In another embodiment of the invention, the means for fluidly communicating the interior of the valve assembly and the other chamber comprise holes in the valve assembly which are initially closed but which open upon increased pressure differential across the valve assembly a predetermined amount and consequent movement of the valve assembly an amount sufficient to fluidly communicate the other chamber and the interior of the valve assembly.

In still another embodiment of the invention the means for fluidly communicating the interior of the valve assembly and the other chamber may include in one safety valve the features of both of the other two embodiments of the invention; that is, holes may be provided in the erodable flow sub to expose them and the valve assembly may be movable in response to a predetermined increased pressure differential across it to open other holes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a subsurface safety valve in accordance with the invention arranged in a well tubing string suspended in a well casing;

FIG. 2 is a partly sectional view illustrating an embodiment of the invention in which pressure differential and erosion valve actuatable components are arranged in a ball valve type flow control member shown in nonactuated or open position;

FIG. 3 is a view similar to that of FIG. 2 showing the components of the valve when the ball valve member is in actuated or closed position resulting from a predetermined increased pressure differential across the valve assembly;

FIG. 4 is a view similar to that of FIG. 2 showing the components of the valve when the ball valve member is in closed position resulting from erosion of the flow sub;

FIG. 5 is a view similar to that of FIG. 3 showing only the components of the valve directed to valve actuation upon a predetermined increased pressure differential across the flow sub;

FIG. 6 is a view similar to that of FIG. 2 showing only the components of the valve directed to valve actuation upon erosion of the flow sub;

FIG. 7 is a view of the flow sub and portion of the upper valve seat of the apparatus illustrated in FIGS. 2 and 3;

FIG. 8 is a sectional view taken along lines 8—8 of FIG. 7;

FIG. 9 is a sectional view taken along lines 9—9 of FIG. 7; and

FIGS. 10 and 11 are partly sectional views illustrating the embodiment of the invention shown in FIG. 2 with a flapper type flow control member in both open and closed positions, respectively.

DETAILED DESCRIPTION OF THE INVENTION

There is shown in FIG. 1 a well casing 10 in which a tubing string 11 is suspended. A packer 12 closes off the annulus between the casing and tubing string. The direction of flow of the well fluids is indicated by the arrow. Tubing string 11 is provided with a landing nipple 13 in which is latched a mandrel assembly 14 to which are attached a valve housing 15 at its lower end and a running sleeve 16 at its upper end. Mandrel assembly 15 carries packing 17 for sealing off the space between tubing string 11 and mandrel assembly 14 above valve housing 15.

In FIGS. 2, 3 and 4 are shown details of a ball type subsurface valve in accordance with one embodiment of the invention. A ball valve assembly, generally designated 20, is arranged within valve housing 15 and includes a flow tube 21, a flow bean or sub 22 provided with a series of holes or ports 23 that do not initially penetrate the inner wall, an upper valve seat 24, a ball valve 25, a retainer sleeve 26, a lower valve seat 27 and an upper valve seat extension 28 which is provided with a series of small holes or ports 29. A cylindrical shoulder 30 forms a piston on the outer wall of flow tube 21 and is provided with two O-ring seals 31 which engage the inner wall of valve housing 15. Piston 30, the inner wall of valve housing 15 and the outer wall of flow tube 21 together with a shoulder 33 formed on the inner wall of valve housing 15 form a chamber 34 which is sealed off by seals 31 and an O-ring seal 35 located on the inner wall of valve housing 15 and engaging the outer wall of flow tube 21. The inner wall of valve housing 15 is provided with another shoulder 40 which forms a chamber 42 with piston 30, the outer wall of flow bean 22, the inner wall of valve housing 15,

O-seal 44 on the inner wall of valve housing 15 engaging the outer wall of the upper valve seat extension 28 and a portion of the outer wall of the upper valve seat extension 28. A spring 45 is arranged in chamber 34. Spring adjustment rings 46 are shown positioned on shoulder or piston 30 in chamber 34.

The diameters of O-ring seals 35 and 44 are the same and the diameters of O-ring seals 31 are greater than the diameter of either O-ring 35 or 44. The inner surfaces of flow bean 22 taper inwardly to form a restricted flow path through the valve assembly.

When the valve is assembled at the surface, air at atmospheric pressure is trapped in chambers 34 and 42 between O-ring seals 35 and 44. Since these rings are balanced i.e. the same size, lowering the valve assembly into the pressure of the wellbore does not cause any compressional forces on the atmospheric air trapped in chambers 34 and 42. In this position of the valve assembly ball valve 25 is held open by spring 45.

Valve housing 15 with valve assembly 20 contained therein is connected to mandrel assembly 14 at the surface. Running sleeve 16 is connected to mandrel assembly 14 and then valve housing 15, mandrel assembly 14 and running sleeve 16 are run into tubing string 11 to landing nipple 13 by wire line means (not shown). Details of the mandrel assembly 14 and landing nipple 13 and the manner in which the mandrel assembly is locked into the landing nipple have not been described. These components and the operation thereof are not part of the invention and constitute conventional apparatus available from various manufactures.

In the operation of the embodiment illustrated in FIGS. 2 to 4 the safety valve will close either upon a predetermined (small) pressure loss across the valve assembly or sufficient erosion of flow sub 22. As illustrated in FIGS. 2, when valve housing 15 is in place in tubing string 11 spring 45 holds ball valve 25 open as well as fluids pass upwardly through valve assembly 20. As illustrated in FIG. 4 well fluids carrying erodable materials, such as sand, erode flow bean or sub 22 and cause communication through exposed holes 23 between the flowing well tubing pressure and atmospheric pressure in chamber 42. Holes 23 may be drilled to within a small distance of the inner bean surface so that only a slight erosion will cause fluid communication through the wall of the flow bean and closure of the valve. Well pressure in chamber 42 is exerted on O-rings 31 which moves piston 30 and compresses the air in chamber 34 surrounding spring 45 forcing ball 25 to rotate to the closed position. Ball valve 25 is pinned eccentrically on housing 15 in such a manner that upward movement of valve assembly 20 rotates the ball to the closed position. The ball valve components are conventional apparatus such as shown in the *Composite Catalog of Oil Field Equipment and Services*, 27th Revision, 1966–67, Volume III on page 3838 published by World Oil. As illustrated in FIG. 3, when the well flow rate increases the pressure loss across valve assembly 20 increases and when the pressure differential is great enough to overcome the bias of spring 45, flow bean 22, flow tube 21 and upper valve seat extension 28 along with valve seat 24, ball valve 25 and retainer sleeve 26 move upward which moves holes 29 upward past O-ring 44. Well pressure is then in communication with chamber 42 and well pressure is exerted on the effective fluid pressure area of piston 30 which moves piston 30 and compresses the air in chamber 34 forcing ball 25 to rotate to the closed position.

The flow rate required to close the valve can be adjusted by changing the bean diameter and the number of spacer rings below the spring. The amount of erosion required to close the valve is adjusted for the amount of erosion which must occur to expose the holes in the flow bean. The valve apparatus described herein will fit existing wireline equipment and can be hung from any of the retrievable tubing or nipple locking mandrels. The safety valve must be retrieved from the well tubing and reset for reuse once it has been actuated to close.

FIG. 5 is the same as FIGS. 2, 3 and 4 except flow bean or sub 22 which contains holes 23 has been substituted by a flow bean or sub 22*b* which has no holes whatsoever. This figure illustrates an operation in which the safety valve will close only upon increased pressure differential across flow bean 22*a* and not upon erosion of the inner flow bean surface.

FIG. 6 is the same as FIGS. 2, 3 and 4 except a different upper valve seat extension 28 containing no holes has been substituted for the upper valve seat extension 28 which contains holes 29. In the operation shown in this figure the safety valve will close only upon erosion of the inner surface of flow bean 22 (unless a high preselected pressure differential across flow bean 22 causes valve assembly 20 to move upward sufficiently to close or permit the valve element to close).

FIGS. 10 and 11 illustrate use of the erodable flow bean and flow velocity closure components in a clapper or flapper type valve. Components of the valve which are equivalent to the components illustrated in FIGS. 2, 3 and 4 have been designated with the same numerals plus the letter *a*.

Referring to FIG. 10 when valve housing 15*a* is in place in tubing string 11a spring 45*a* holds clapper valve 50 open as well fluids pass upwardly through valve assembly 20*a*. Well fluids carrying erodable materials erode flow bean 22*a* and cause fluid communication through holes 23*a* between the flowing well tubing pressure and atmospheric pressure in chamber 42*a*. Well pressure is exerted on the effective fluid pressure area of piston 30*a* causing piston 30*a* to move upwardly and compress the air in chamber 34*a* surrounding spring 45*a* forcing flow bean 22*a* and sleeve 28*a* upwardly within valve housing 15*a* and permitting spring 51 to close clapper valve 50. The closed positions of the clapper type valve components are shown in FIG. 11. A stop 52 on the inner wall of valve housing 15*a* engages a shoulder 53 on sleeve 28*a* to limit upward movement of valve assembly 20*a*.

Closure of the valve upon increased pressure operates in the same manner as the operation described above for the ball type safety valve. When the pressure differential across flow bean 22*a* is great enough to overcome the bias of spring 45*a* sleeve 28*a* is moved upward until holes 29*a* communicate with chamber 42*a*. Well fluid pressure acts on piston 30*a* to move it upwardly carrying sleeve 28*a* with it to permit spring 51 to close clapper valve 50. The clapper valve components are conventional apparatus such as shown in the *Composite Catalog of Oil Field Equipment and Ser-*

vices, 27th Revision, 1966–67, Volume I, on page 1124 published by World Oil.

Having fully described the nature, elements, operation and advantages of my invention, I claim:

1. A subsurface valve for controlling flow of fluids through a well pipe comprising:
a valve housing;
tubular means arranged in said valve housing and forming a flow path through said valve housing and movable between first and second positions;
said tubular means including a sub forming a narrowed flow passageway in said flow path;
a valve member arranged in said valve housing movable in response to movement of said tubular means to an open position for permitting flow of fluids through said flow path and to a closed position for preventing flow of fluids through said flow path;
biasing means arranged in said valve housing for urging said tubular means to said first position thereof;
a fluid pressure chamber formed in said valve housing initially sealed off from fluid communication with said flow path;
piston means arranged in said fluid pressure chamber and connected to said tubular means and responsive to pressure differential in said fluid pressure chamber to move said tubular means; and
openable means on said tubular means initially closing off fluid communication between said flow path and said fluid pressure chamber and capable of opening to fluidly communicate said flow path and said fluid pressure chamber.

2. A subsurface valve as recited in claim 1 in which said valve housing is arranged in said well pipe and when said openable means has opened, well pipe fluid pressure acts on said piston means to urge said tubular means to said second position thereof against the bias of said biasing means.

3. A subsurface valve as recited in claim 2 wherein said openable means on said tubular means comprises holes formed in said sub extending from the outer wall of said sub towards but not initially penetrating the inner wall of said sub, said holes being opened to expose said fluid pressure chamber to well pipe fluid pressure when the inner wall of said sub has eroded a preselected amount.

4. A subsurface valve as recited in claim 2 in which said tubular means moves in response to an increased pressure differential across said sub and said openable means on said tubular means comprises holes formed in said tubular means initially closing off fluid communication between said flow path and said fluid pressure chamber when said tubular means is in said first position thereof and permitting fluid communication between said flow path and said fluid pressure chamber upon movement of said tubular means from said first position thereof towards said second position thereof in response to an increased pressure differential across said sub.

5. A subsurface valve as recited in claim 2 in which said tubular means moves in response to an increased pressure differential across said sub and wherein said openable means on said tubular means comprises (1) holes formed in said sub extending from the outer wall of said sub towards but not initially penetrating the inner wall of said sub, said holes being opened to expose said fluid pressure chamber to well pipe fluid pressure when the inner wall of said sub has eroded a preselected amount and (2) holes formed in said tubular means initially closing off fluid communication between said flow path and said fluid pressure chamber when said tubular means is in said first position thereof and permitting fluid communication between said flow path and said fluid pressure chamber upon movement of said tubular means from said first position thereof towards said second position thereof in response to an increased pressure differential across said sub.

6. A subsurface valve as recited in claim 2 including means surrounding said valve housing for closing off the space between said valve housing and said well pipe.

7. A subsurface valve as recited in claim 2 including a chamber confining said biasing means; said valve member closing when said tubular means moves from said first to said second position thereof and opening when said tubular means moves from said second to said first position thereof.

8. A subsurface valve as recited in claim 7 including seal means on said piston means engaging said valve housing for sealing off said chambers from each other; and sealing means at the ends of said chambers engaging said tubular means for sealing off the ends of said chambers from said well pipe fluid pressure.

9. A subsurface valve as recited in claim 8 in which said sealing means at the ends of said chambers are balanced.

10. A subsurface valve as recited in claim 9 in which said chambers contain gas at lesser pressure than said well pipe fluid pressure prior to exposure of said fluid pressure chamber to said well pipe fluid pressure.

11. A subsurface valve as recited in claim 10 in which said lesser gas pressure is atmospheric pressure.

12. A subsurface safety valve as recited in claim 1 in which said valve member comprises a rotatable ball valve.

13. A subsurface safety valve as recited in claim 1 in which said valve member comprises a spring-biased, clapper-type valve.

14. A subsurface valve for controlling flow of fluids through a well pipe comprising:
a valve housing;
tubular means arranged in said valve housing and forming a flow path through said valve housing and movable between first and second positions;
a valve member movable in response to movement of said tubular means to an open position for permitting flow of fluids through said flow path and to a closed position for preventing flow of fluids through said flow path;
biasing means arranged in said valve housing for urging said tubular means to said first position thereof;
a fluid pressure chamber arranged between said tubular means and said valve housing initially sealed off from fluid communication with said flow path;
piston means connected to said tubular means and arranged in said fluid pressure chamber and responsive to pressure differential in said fluid pressure chamber to move said tubular means; and

means arranged on said tubular means and extending into said flow path and capable of being eroded by well fluids passing through said flow path to fluidly communicate said fluid pressure chamber and said flow path.

15. A subsurface valve as recited in claim 14 in which said valve housing is arranged in said well pipe and when said means extending into said flow path has eroded to fluidly communicate said fluid pressure chamber and said flow path, well pipe fluid pressure acts on said piston means to urge said tubular means to said second position thereof against the bias of said biasing means.

16. A subsurface valve as recited in claim 15 including means surrounding said valve housing for closing off the space between said valve housing and said well pipe.

17. A subsurface valve as recited in claim 16 including a chamber confining said biasing means; said valve member closing when said tubular means moves from said first to said second position thereof and opening when said tubular means moves from said second to said first position thereof.

18. A subsurface valve as recited in claim 17 including seal means on said piston means engaging said valve housing for sealing off said chambers from each other; and sealing means at the ends of said chambers engaging said tubular means for sealing off the ends of said chambers from said well pipe fluid pressure.

19. A subsurface valve as recited in claim 18 in which said sealing means at the ends of said chambers are balanced.

20. A subsurface valve as recited in claim 19 in which said chambers contain gas to lesser pressure than said well pipe fluid pressure prior to exposure of said fluid pressure chamber to said well pipe fluid pressure.

21. A subsurface safety valve as recited in claim 14 in which said valve member comprises a rotatable ball valve.

22. A subsurface safety valve as recited in claim 14 in which said valve member comprises a spring-biased, clapper-type valve.

* * * * *