

- [54] **PETROLEUM WELL SAFETY VALVE**
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Related U.S. Application Data

- [63] Continuation-in-part of Ser. No. 123,805, March 12, 1971, abandoned.
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[51] Int. Cl.E21b 43/00
[58] Field of Search166/224; 137/456, 466, 517, 137/520, 521, 527, 527.2, 527.4; 251/348

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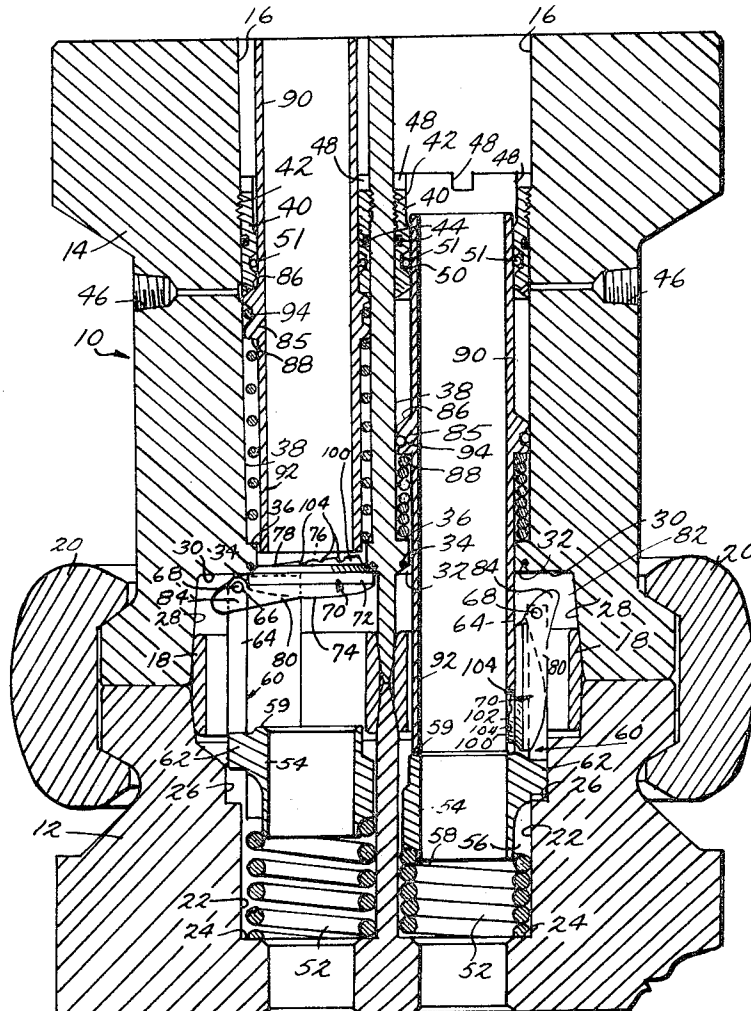
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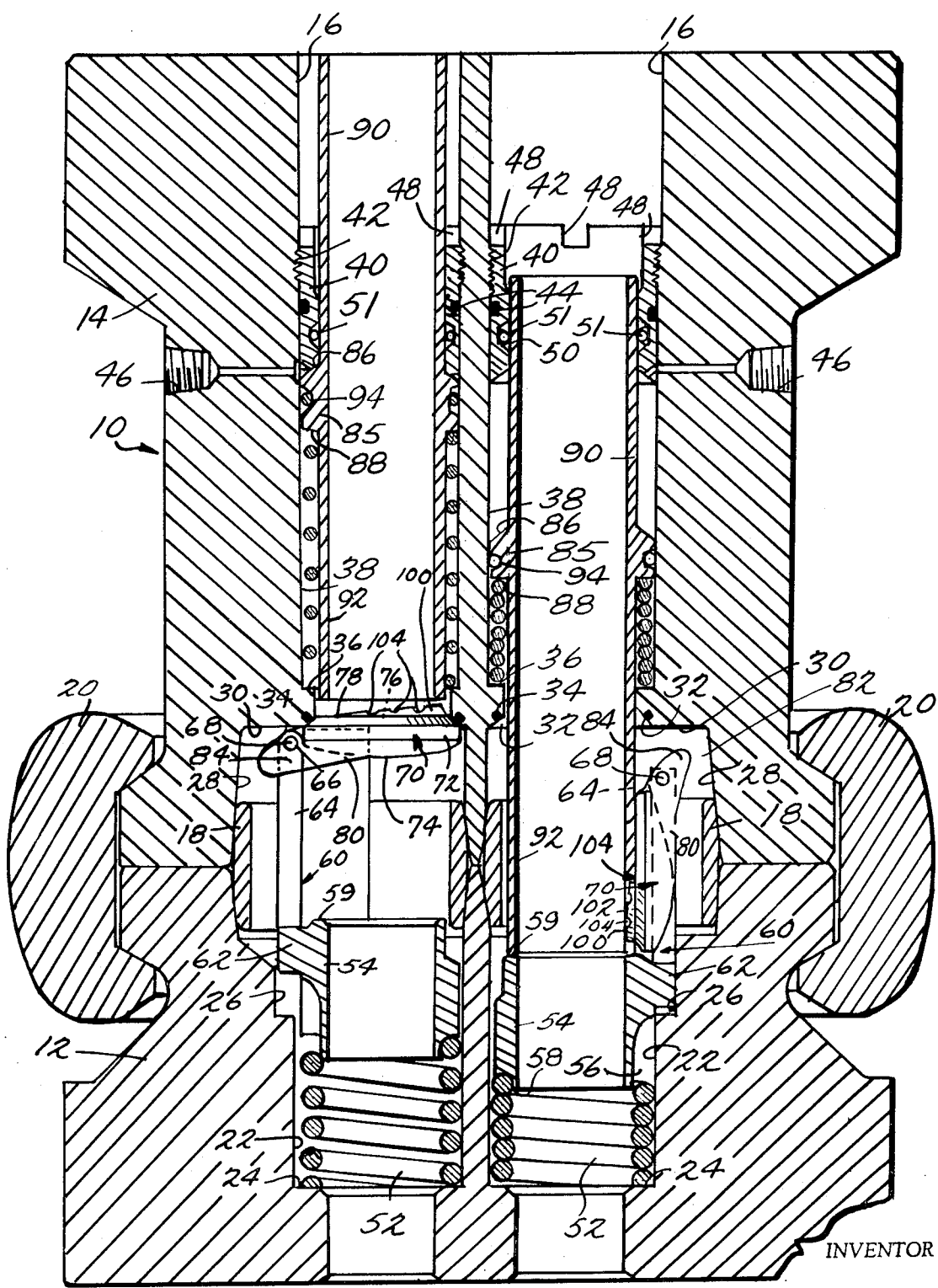
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[57] **ABSTRACT**

By preference, the safety valve is mounted in a tubing bonnet throughbore. A tubular piston mounted above the valve flapper has a communication to an exterior supply of fluid pressure tending to force the piston down so it opens the flapper; subterranean pressure is active against the opposite side of the piston. The lower end of the piston seats against an annular shoulder on the member which carries the flapper to isolate the valve seat and flapper sealing surface from wear while the valve is in an open condition. The rear of the flapper is angled to cause first incidence of flapper opening force at the part of the flapper furthest from the trunnions. A sacrificial wear feature is also incorporated into the rear of the flapper. Even though closed, the flapper type safety device allows for pumping fluids downward into the well.

21 Claims, 1 Drawing Figure





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PETROLEUM WELL SAFETY VALVE

REFERENCE TO RELATED CASE

This is a Continuation-in-Part of my copending United States patent application Ser. No. 123,805 filed Mar. 12, 1971, and now abandoned, whose entire disclosure is intended to be incorporated herein by this reference thereto.

BACKGROUND OF THE INVENTION

Recent highly publicized offshore petroleum well fires and other mishaps have brought to increasing scrutiny the measures taken to minimize the potentials for disasters of various well-connected mishaps such as fires, subterranean pressure surges, platform disturbances due to storms, shifting submarine foundations and the like. Some wells which were completed when the potential hazards were not as fully understood could be better equipped than they are to prevent surprises from turning to disasters. However, the disassembly of wells to make safety-related modifications is not without risk-taking. Some disassembly procedures needed for installation of conventional safety equipment call for dewelding, cutting of pipes, and other procedures which can make not-normally-timid workers edgy until their task has been completed, owing to their respect for the dangers.

Of course, safety valves, basically, are not a new development. The following United States patents depict flapper valves in the context of petroleum wells:

Patentee	Patent Number	Issue Date
R.L. Fletcher	1,255,147	Feb. 5, 1918
J.C. Fortune	1,814,549	July 14, 1931
B.H. Scott	1,818,508	Aug. 11, 1931
M.L. Hacker	2,162,578	June 13, 1939
C.E. Burt et al.	2,189,703	Feb. 6, 1940
L.O. Goodwin	2,354,310	July 25, 1944
T.M. Ragan	2,624,412	Jan. 6, 1953
J.R. Baker	2,630,865	March 10, 1953
J.R. Baker et al.	2,841,171	July 1, 1958
H.H. Fisher, Jr.	2,921,601	Jan. 19, 1960
M.B. Conrad	2,944,793	July 12, 1960
J.R. Baker	2,984,303	May 16, 1961
C.C. Brown	2,994,381	Aug. 1, 1961
J.D. Keithahn	3,016,914	Jan. 16, 1962
R.H. Magill et al.	3,016,955	Jan. 16, 1962
J.S. Page	3,035,641	May 22, 1962
P.S. Sizer	3,071,151	Jan. 1, 1963
G.H. Tausch	3,078,923	Feb. 26, 1963
J.R. Brown et al.	3,092,135	June 4, 1963
G.H. Tausch	3,265,134	Aug. 9, 1966

Note, e.g., from Tausch U.S. Pat. No. 3,078,923, that differential fluid pressure has been employed to keep such flapper valves open. A pressure equalizer is provided in Tausch at 43. Shear pins are sometimes used to keep various parts "cocked" until their actuation is desired, e.g., see the pin 53 in Brown U.S. Pat. No. 2,994,381 for one context where a shear pin is employed.

The present inventor and his coworkers have been active in the design of flapper-type check valves as evidenced by the U.S. Pat. of Latham and Holbert, Jr., No. 3,509,908, issued May 5, 1970, and the copending U.S. patent application of Boitnott, Ser. No. 869,160 filed Oct. 24, 1969.

SUMMARY OF THE INVENTION

Preferably installed in a socket in the well head, the flapper-type check valve incorporates a differential pressure-operated piston as an opening and closing sleeve. The valve may be economically installed in existing wells, e.g., offshore dual wells on multiple well platforms to provide internal blowout and anti-fire protection for wells which presently have no other positive closure than, e.g., a storm choke.

The prime purpose of the tubing bonnet safety valve is to provide a means by which the flow of potentially dangerous fluids and gasses may be positively stopped or shut off in the event of an emergency.

An example: Oil and gas wells, particularly those located on offshore platforms being relatively isolated, may be operated for extended periods without attendance. Should damage occur to the christmas tree, flow lines or manifold such as might result from a storm, collision by barge or ship or fire, the tubing bonnet safety valve has been designed to automatically close, confining well pressures within the tubing string(s). By doing so, a frequently, tremendous fuel source or potential fire hazard is eliminated.

In addition, the tubing bonnet safety valve is dependent upon only one metal-to-metal seal (at the flapper). The metal-to-metal closure is extremely resistant to damage from excessive temperatures which would destroy resilient or fiber seal materials.

Pressure is supplied to the valve's piston through a control port in the tubing head bonnet via a control line.

To actuate the safety valve to the open position, hydraulic fluid, under pressure, is forced down control line through the control port, into a cylinder cavity and brought to bear on the piston.

As the pressure against the piston is increased in an amount slightly greater than present in the well tubing bore, the piston will be forced downward.

As the piston rod stinger engages the valve's flapper during the opening operation, pressure trapped in the annulus is allowed to be displaced by virtue of equalizing port means on the back of the flapper.

As the piston causes the piston rod to move downwardly through the bore, the flapper is forced back into a recess allowing the piston rod end to cover the flapper and seal surface and to meet the end of a tubular flapper carrier sleeve and urge it downwardly, compressing a spring. The latter, upon release of downward pressure, assists in closing the flapper.

To close the safety valve, the unbalanced pressure is reduced. Pressure in the annulus will move piston and rod back to its uppermost position.

As the upward movement of the piston draws the piston rod end past the flapper and the flapper seat, the flapper will rotate about its pivot point and come to rest on the seal surface.

Upon reaching its uppermost position, tapered seals are forcedly seated against a seal surface forming a secondary metal-on-metal pressure barrier.

Control of the piston through the control port can be effected by pump pressure, a thermal actuated device, an electronic device, or well pressure, and such control may be adjacent to the christmas tree or at some remote place. Multiple well platforms, as are found in offshore producing areas, can have a monitoring ar-

rangement whereby, if a problem occurs at one well, all wells can be immediately shut in.

The safety valve device is full opening; tubing can be plugged below it; it is completely enclosed; and its opening and closing capabilities can be checked at any time. The internal parts can be made out of stainless steel and can be hard faced, if required.

The principles of the invention will be further hereinafter discussed with reference to the drawings wherein a preferred embodiment is shown. The specifics illustrated in the drawings are intended to exemplify, rather than limit, aspects of the invention as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, the FIGURE is a fragmentary longitudinal perspective view of a dual well well head equipped with two safety valves in accordance with the present invention. One valve is shown in an open, operating condition, the other is shown closed.

DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENT

In the drawing there is shown a tubing head bonnet 10 comprising a lower portion 12 and an upper portion 14. The latter may consist of an integral downward extension of the housing of the lower master valve of the christmas tree in which the bonnet 10 is incorporated. The tubing bonnet forms part of a well head, e.g. being mounted between the tubing head and the christmas tree master valve. An example of the location of tubing head bonnet in a well head is shown on page 2245 of the 1970-71 edition of the *Composite Catalog of Oil-field Equipment and Services*, Gulf Publishing Company, Houston, Texas. Other tubing head bonnets for use on single or multiple zone oil or gas wells are shown on pages 2238, 2239, 2248 and 2249 of the same catalog.

A real advantage of the safety valve design depicted in the figure is that it can be installed in existing wells with a very minimum of disturbance and disassembly. What is involved is: plugging the tubing, removing the main control valve and old tubing bonnet, mounting the control valve on a bonnet equipped with safety valve means as shown in the FIGURE, reinstalling this assembly on the remaining lower part of the well head, removing the tubing plugs and pressurizing the control lines to open the well to production.

Due to the relative ease with which such installations can be made, the safety valve structure of the FIGURE is preferred. The well depicted is a dual-completed well, partly in order to illustrate the valve in an open and a closed relationship in close juxtaposition; the tubing head bonnets of singly, triply or other multiply completed wells can be similarly provided with safety valves in accordance with the present invention. Although "tubing bonnet" is a well-known term in the oil and gas well equipment field, there is far from uniformity among well equipment manufacturers in structuring and naming the various parts of a well head, especially one for offshore use. For that reason, it should be appreciated that the apparatus of the invention may be installed in a functionally comparable part of a well head, even if that part is not called a tubing head, and yet not depart from the underlying principles of the present invention.

The bonnet 10 has two side-by-side throughbores 16 which are enlarged adjacent and below the valve seat in each. The enlargements are eccentrically located in the throughbores, being displaced laterally away from one another in order to leave adequate wall thickness between the bores at the level of their greatest enlargement and to provide recesses for the flappers to be received in when the valves are open.

It is for manufacturing, assembling and servicing convenience that the bonnet 10 is divided into separate portions 12 and 14. As depicted, sealing means, e.g., double tapered sealing cones 18, are received in the bores 16 at the juncture of the bonnet portions (see page 2251 of the *Composite Catalog of Oil Field Equipment and Services*, 1970/71 Edition, Gulf Publishing Company, Houston, Texas, U.S.A. Such seals are shown in well head use on pages 2242, 2245 and 2246 of said *Catalog*). Alternative sealing means could be used. The two sealed portions 12, 14 are clamped together with a clamp 20 of arcuate segments. Suitable clamps are shown and/or described on pages 2219, 2224, 2240, 2242, 2243, 2245, 2246, 2255-2257, 2260 and 2266 of the aforesaid *Catalog*. Of course, alternative connecting means such as bolted flanges, e.g., as illustrated on page 2225 of the aforesaid *Catalog* could be used instead.

Intermediate its ends, the bonnet throughbores have the following features of special interest, starting near the lower end of each: an enlargement 22 beginning at an upwardly facing shoulder 24 for receipt of a lower spring and a flapper carrier; a notch 26 at the outer side for accommodation of a yoke part of the flapper carrier; an eccentrically enlarged chamber 28 topped by a downwardly facing annular shoulder 30 which has a frustoconical annular recess at its juncture with the throughbore 16 to provide a valve seat 32. As depicted, there is an annular groove in the valve seat 32 which receives a sealing ring 34, e.g., of Teflon, a polymerized tetrafluorocarbon resin.

The throughbore 16 enlarges again a short distance above the valve seat to provide an annular, upwardly facing shoulder 36 for receipt of an upper spring and to provide a cylindrical surface 38 for sealing with a vertically slidable piston. The piston chamber is delimited at its upper extent by an annular plug 40 threadably received in the bore at 42 and sealed with respect to the bore by sealing ring means 44. The upper part of the piston chamber is intersected by a fluid pressure supply conduit 46 which extends to the exterior of the well head. The notches 48 in the upper end of the annular plug 40 are engaged by a suitable wrenching tool to threadably install or remove the plug. The radially inner surface of the tubular plug 40 has a radially inwardly opening circumferential groove 50 which receives a resilient O-ring 51 designed to seal with the exterior of an upper end region of the piston.

The equipment shown installed in each throughbore 16 will now be described, starting again at the bottom.

The lower spring 52 is a coil spring whose purpose is to bias the flapper and piston upwardly toward a valve-closed position, as depicted at the left side of the FIGURE. When the piston is down as far as it will go, the spring 52 is nearly completely compressed, as depicted at the right side of the FIGURE.

The spring 52 supports a flapper carrier 54. This member is shown being generally tubular, with a cir-

cumferential recess 56 at its lower outer corner to accommodate the upper end of the spring 52. The lower inner corner region 58 of the carrier which lines the upper portion of the spring 52 could be extended down further if desired to line more of the spring. The tubular carrier 54 is exteriorly sized to permit easy vertical sliding in the portion of the bore 16 in which it is located. Its upper end is flat to define an upwardly facing shoulder 59.

At one side, the carrier 54 is provided with a vertically extending U-shaped 60 whose base is integral with the tubular part of the carrier 54 at 62. At their upper ends, the two yoke arms 64 are provided with horizontally directed openings 66 at the same level and having a common longitudinal axis parallel to the plane of the U-shaped yoke.

The openings 66 receive a trunnion or axle 68 for the valve flapper 70. The latter comprises a generally circular disk 72 having an upstream face 74 and a downstream face 76. The outer periphery of the downstream face is provided with a circumferentially extending annular sealing region 78 shown being frustoconically curved. The upstream face of the valve disk is shown provided with boss means 80 toward and extending past an outside edge portion of the valve disk. The boss means 80 may be constituted by two parallel ribs (see the aforementioned parent application). The trunnion 68 is mounted in the boss means thus mounting the valve flapper on the yoke 60 for rotation about the longitudinal axis of the trunnion. It should now be noticed that the yoke is about as thick as the valve disk and is of sufficient length that it can receive the opening and closing valve disk. That is, the yoke defines between its arms, a recess 82 into which the valve flapper is received in the valve fully open condition (right half of the attached FIGURE).

Part of the boss means 80 comprises a cam lobe 84 extending on the opposite side of the trunnion from the flapper. The cam lobe 84 is shaped to bear against the downwardly facing shoulder of the top of the valve housing. When the valve is closed as shown at the left in the FIGURE, the cam lobe 84 is of insufficient radius to affect seating of the valve. The cam lobe increases in radius in the same sense as movement of the valve from a closed toward an open condition. That forces the valve flapper and the flapper carrier to move downwardly as the flapper is opened.

Note that the extremes of movement of the flapper and flapper carrier as a unit are seating of the trunnion surface 78 against the correspondingly tapered seat of the housing, and the condition depicted at the right in the FIGURE where not only is the flapper fully open and recessed, its cam lobe is down so it is no longer in engagement with the downwardly facing shoulder. In the embodiment depicted, full compression of the upper coil spring by the depressed piston by virtue of action of the piston on the shoulder 59 of the carrier 54 limits further downward movement of the flapper and the flapper carrier as a unit.

The tubular piston 85 comprises a tubular body exteriorly enlarged in an intermediate portion to provide an upwardly presented annular surface 86 placed to be forced downwardly by pressurized fluid admitted through the supply conduit 46, and, below that, a downwardly presented annular surface 88 placed to be

forced upwardly by subterranean pressures. The piston extends above its exteriorly enlarged portion as a tail 90 and below its exteriorly enlarged portion as a stinger 92.

Between the surfaces 86 and 88, the exterior of the piston is sealed with respect to the bore 16 by an O-ring seal 94 received in a circumferential groove in the piston.

The upper end portion of the piston tail is sealed with respect to the tubular plug 40 by the O-ring 51 to define the upper extent of the chamber for receiving pressurized fluid from the conduit 46.

The annulus between the piston stinger and the tubing head throughbore, below the surface 88, is unsealed so that when the valve is open, subterranean fluid pressures are transmissible through the turns of the lower coil spring, around the flapper carrier, the outer portion of the valve chamber, past the valve seat, around the upper coil spring and thus to the surface 88.

Radially inwardly from the sealing surface on the flapper, there is provided a ramp-like boss 100 which diminished in thickness toward the trunnion bearing edge of the flapper and which increases in thickness toward the opposite edge of the flapper from the trunnion mounting.

The rear face 102 of the boss is notched at 104 for sacrificial wear purposes as described in the next section.

OPERATION OF THE SAFETY VALVE OF THE PREFERRED EMBODIMENT

Hydraulic pressure entering port 46 forces piston 85 downwardly causing piston stinger 92 to contact angled surface 102 on the back of flapper. Angled surface 102 concentrates the piston load on the opposite side of the flapper from pivot pin 68 thus creating a lever effect, aiding in initial opening; continuing downward piston movement, the flapper will rotate about pin 68 until piston stinger 92 fully contacts angled surface 102 flatwise. Small by-pass or equalizing grooves 104 are sized so as to pass less fluid volume than can pass past the separation between the flapper and the valve seat. This feature concentrates high velocity erosion on sleeve 92 and grooves 104, not on matching critical seats between the flapper and the valve seat.

Further downward movement by the sleeve 92 will rotate the flapper 90°. Simultaneously, cam lobe 84 rotating about trunnion 68 will force the flapper carrier 54 downward, partially compressing the lower coil spring.

Finally, the sleeve 92 will move past the flapper and come to rest on shoulder 59 in turn, compressing the lower coil spring to a solid or nearly solid length. The mechanism so far described, has now completely isolated all seat surfaces from erosive and contaminating elements; in addition offering a smooth unrestricted bore for the passage oil or gas production or down hole tools.

So long as hydraulic pressure is maintained against the piston, the flapper valve will remain in an open, full-bore position. The pressure level required to maintain this position is equal to, or slightly greater than, the sum of well-pressure plus the load required to compress the coil springs.

When desired, the tubing bonnet safety valve may be caused to close by the release of the hydraulic control pressure maintained against piston. The release of pressure may be accomplished either manually or automatically (see FIG. 4 of the aforementioned U.S. patent application).

After the hydraulic pressure is released, energy stored in the lower coil spring will move the piston upward until the flapper cam strikes the downwardly facing shoulder in the valve chamber. Well pressure in bore 16, bearing against the under side of the piston, will continue the upward movement of the piston. After the piston stinger 92 passes up through the seat area of the bore 16, continued spring force against the flapper carrier will "cam" the flapper 90°, returning it to its sealing position on the valve seat.

ADVANTAGEOUS FEATURES OF THE PREFERRED EMBODIMENT

A. Full bore - no restrictions.

B. Permits full circulation down tubing bore in closed position, i.e., flapper will open upon application of pump pressure against top of flapper.

C. Equalizing, or by-pass ports, on flapper protect critical seal surfaces from becoming "fluid cut" when opening valve against high pressure trapped beneath flapper.

D. All critical parts are completely covered and protected by the piston sleeve in the open position.

E. All parts subject to wear are easily accessible for routine maintenance and will not normally require killing well, pulling tubing string(s) or wire line services when such maintenance is to be performed.

After some reflection, one skilled in the art will notice that the tubing bonnet is the equivalent of a wall portion, e.g. a neck of a pressure vessel, and that the safety valve as shown constitutes a means for access to the interior of a pressure vessel.

It should now be apparent that the petroleum well safety valve as described hereinabove possesses each of the attributes set forth in the specification under the heading "Summary of the Invention" hereinbefore. Because the petroleum well safety valve of the invention can be modified to some extent without departing from the principles of the invention as they have been outlined and explained in this specification, the present invention should be understood as encompassing all such modifications as are within the spirit and scope of the following claims.

What is claimed is:

1. A valve for a vessel containing pressurized fluid comprising:

a valve flapper constructed and arranged to sealingly close an opening into the vessel when oriented crosswise of the opening in engagement with an annular valve seat disposed on the vessel peripherally of the opening and to allow fluid passage through the opening when aligned with the opening;

trunnion means on the flapper laterally offset from a diameter of the flapper toward adjacency with the outer edge thereof;

means mounting the flapper trunnion with respect to the vessel so the flapper is rotatable about the trunnion between an open condition and a closed condition;

spring means biasing the flapper toward the closed condition thereof; and

a piston extensible into engagement with said flapper for overcoming the biasing action of said spring means to maintain said flapper in the open condition thereof;

the side of the flapper facing exteriorly of the vessel when the flapper is closed having means defining an inclined plane thereon which diminishes in thickness proceeding toward the trunnion and which increases in thickness proceeding away from the trunnion, the inclined plane being located for initial engagement by said piston during extension thereof, whereby initial force for moving the flapper toward an open condition is applied to the flapper distally of the trunnion; the piston being tubular and being constructed for sufficient travel upon extension to have a portion thereof pass the flapper to maintain the flapper out of the way of direct flow through the throughbore of the piston into and from the vessel; tubular abutment means on the opposite side of the flapper, when the flapper is in a closed condition, from the piston; said tubular abutment means being configured and located for coaxial abutment by the end of said portion of the piston which passes the flapper as the flapper is forced to an open condition in order to constitute a smooth tubular passageway into the vessel when the flapper is in an open condition; said flapper including a circumferentially extending annular sealing surface along the outer perimeter thereof for sealing with the vessel seat peripherally of the opening into the vessel, said sealing surface surrounding the inclined plane, means defining at least one notch in the inclined plane, the notch defining means having a cross-sectional area available for fluid passage which aggregates to less than the cross-sectional area of the gap between the flapper sealing surface and the vessel seat until the inclined plane is engaged flatwise by the said end of the tubular piston in order to remove the brunt of erosive force upon the valve opening from the region of the sealing surface.

2. The valve of claim 1 wherein the tubular abutment means is interposed between said spring means and the piston.

3. The valve of claim 2 wherein the spring means comprises a coiled compression spring.

4. The safety valve of claim 1 further including eccentric recess means in said carrier means below said valve seat, adjacent said axle means, for receiving the flapper when the flapper is in an open condition.

5. The safety valve of claim 4 wherein the carrier means comprises a tubular body with two upwardly directed, angularly spaced arms at one side thereof, the upper ends of said arms journaling the axle horizontally between them; the upper end of said tubular body being disposed for coaxial abutment by the lower end of the stinger of the piston as the flapper is brought to an open condition.

6. A valve for a vessel containing pressurized fluid comprising:

a valve flapper constructed and arranged to sealingly close an opening into the vessel when oriented crosswise of the opening in engagement with an

annular valve seat disposed on the vessel peripherally of the opening and to allow fluid passage through the opening when aligned with the opening;

trunnion means on the flapper laterally offset from a diameter of the flapper toward adjacency with the outer edge thereof;

means mounting the flapper trunnion with respect to the vessel so the flapper is rotatable about the trunnion between an open condition and a closed condition;

spring means biasing the flapper toward the closed condition thereof; and

a piston extensible into engagement with said flapper for overcoming the biasing action of said spring means to maintain said flapper in the open condition thereof;

the side of the flapper facing exteriorly of the vessel when the flapper is closed having means defining an inclined plane thereon which diminishes in thickness proceeding toward the trunnion and which increases in thickness proceeding away from the trunnion, the inclined plane being located for initial engagement by said piston during extension thereof, whereby initial force for moving the flapper toward an open condition is applied to the flapper distally of the trunnion; the piston being tubular and being constructed for sufficient travel upon extension to have a portion thereof pass the flapper to maintain the flapper out of the way of direct flow through the throughbore of the piston into and from the vessel; tubular abutment means on the opposite side of the flapper, when the flapper is in a closed condition, from the piston; said tubular abutment means being configured and located for coaxial abutment by the end of said portion of the piston which passes the flapper as the flapper is forced to an open condition in order to constitute a smooth tubular passageway into the vessel when the flapper is in an open condition; said tubular abutment means including U-shaped yoke means at one side thereof having two arms which mount said flapper trunnion between them for rotation of the flapper about the longitudinal axis of the trunnion.

7. The valve of claim 1 wherein the said two arms are sufficiently long and thick as to define between them a recess of sufficient size as to receive the flapper when the flapper has been rotated to said open condition.

8. A valve for a vessel containing pressurized fluid comprising:

a valve flapper constructed and arranged to sealingly close an opening into the vessel when oriented crosswise of the opening in engagement with an annular valve seat disposed on the vessel peripherally of the opening and to allow fluid passage through the opening when aligned with the opening;

trunnion means on the flapper laterally offset from a diameter of the flapper toward adjacency with the outer edge thereof;

means mounting the flapper trunnion with respect to the vessel so the flapper is rotatable about the trunnion between an open condition and a closed condition;

spring means biasing the flapper toward the closed condition thereof; and

a piston extensible into engagement with said flapper for overcoming the biasing action of said spring means to maintain said flapper in the open condition thereof;

the side of the flapper facing exteriorly of the vessel when the flapper is closed having means defining an inclined plane thereon which diminishes in thickness proceeding toward the trunnion and which increases in thickness proceeding away from the trunnion, the inclined plane being located for initial engagement by said piston during extension thereof, whereby initial force for moving the flapper toward an open condition is applied to the flapper distally of the trunnion; the piston being tubular and being constructed for sufficient travel upon extension to have a portion thereof pass the flapper to maintain the flapper out of the way of direct flow through the throughbore of the piston into and from the vessel; tubular abutment means on the opposite side of the flapper, when the flapper is in a closed condition, from the piston; said tubular abutment means being configured and located for coaxial abutment by the end of said portion of the piston which passes the flapper as the flapper is forced to an open condition in order to constitute a smooth tubular passageway into the vessel when the flapper is in an open condition; the tubular abutment means being interposed between said spring means and the piston; the flapper including means defining a cam lobe protruding from the flapper beyond the trunnion for pushing the flapper and tubular abutment means toward said spring means due to interfering contact between the cam lobe and the vessel during opening movement of the flapper.

9. A safety valve for incorporation in the flow path of petroleum issuing from a petroleum well through a tubing string comprising:

a tubular housing forming a part of a petroleum well completion;

means defining a circumferentially extending, annular seat in the throughbore of the housing, facing downwardly;

a flapper;

axle means on said flapper laterally offset from a diameter of the flapper;

carrier means mounted for limited vertical movement in said throughbore below said seat and said carrier means mounting the axle means with respect to the housing so the flapper is movable between an open condition wherein the flapper is disposed generally parallel to the petroleum flow path, below the annular seat and a closed condition wherein the flapper is seated against the annular seat, interrupting the petroleum flow path;

spring means mounted in the housing, said spring means mounting said carrier means and being disposed to bias urge the flapper toward the seat;

a tubular piston vertically slidably disposed in the throughbore of the housing so as to be disposed above the valve seat when the flapper is in a closed condition;

means defining an upwardly facing surface on said piston;

two circumferentially extending seal means disposed between and sealing with the housing and the piston, one above and one below said upwardly facing surface;

fluid conduit means communicating through the housing to the ambit of the upwardly facing surface so that pressurized fluid may be admitted to bear against said upwardly facing surface to drive said piston downwardly;

stop means in said housing and stop shoulder means on said piston abutable with one another to limit downward travel of the piston;

said piston including downwardly projecting stinger means engageable with the flapper as the piston is driven downwardly for forcing the flapper to an open condition;

downwardly facing surface means on the piston subject to pressure in the petroleum flow path for causing upward movement of the piston, withdrawing the stinger from forceable opening of the flapper so that the spring may close the flapper; and

cam means on said flapper engageable with the housing, internally, adjacent said seat to assist in pivoting the flapper to a closed condition as said spring means raises said carrier means.

10. The safety valve of claim 9 wherein said tubular housing is constituted by a well head part.

11. The safety valve of claim 10 wherein said tubular housing is constituted by a tubing bonnet.

12. The safety valve of claim 11 wherein the tubing bonnet is equipped for a multiple completion by having a plurality of side-by-side longitudinal throughbores, including said throughbore, provided at their upper ends with means for establishing a sealed relationship with respective bores of a christmas tree master valve and at their lower ends with means for establishing a sealed relationship with individual strings of tubing.

13. A petroleum well safety valve comprising:

- a tubing bonnet having a vertical throughbore;
- means defining a downwardly facing annular seat in an upper portion of said throughbore;
- said throughbore having a section of increased radius spaced above said downwardly facing annular seat to define a cylinder;
- a tubular piston slidably received in said cylinder; said piston having a downwardly facing annular lower end surface and an upwardly facing annular upper end surface;
- annular sealing ring means sealing between said piston and said cylinder vertically intermediate said piston upper and lower end surfaces;
- a tubular tail extending upwardly from the radially inner extent of the piston upper end surface;
- a tubular stinger extending downwardly from the radially inner extent of the piston lower end surface;
- annular sealing surface means sealing between said piston tubular tail and said cylinder at a level at least as far up as the upper end of said cylinder;
- fluid conduit means communicating through the tubing bonnet with the cylinder adjacent the upper end of said cylinder;
- said throughbore in said upper portion thereof being enlarged below said valve seat to provide a downwardly facing annular shoulder topping an upper portion of a valve chamber;

said throughbore in a lower portion thereof, adjacent and leading to the upper extent thereof, being enlarged to provide an upwardly facing annular shoulder at the bottom of a lower portion of said valve chamber;

a coil spring received in the lower portion of the throughbore and being seated on said upwardly facing annular shoulder;

a tubular flapper carrier received in the lower portion of the throughbore and being seated on said coil spring;

a valve flapper having axle means thereon laterally displaced from a diameter thereof toward the outer periphery thereof;

the tubular flapper carrier including upwardly extending arm means journaling the flapper axle means for rotation of the flapper about the longitudinal axis of the flapper;

means defining an annular sealing surface on said flapper configured and positioned to seal with said valve seat when the valve is closed;

means defining an upper end surface on the tubular flapper carrier of complementary shape with means defining a lower end surface on the piston stinger, said upper end surface being adapted to coaxially abut said lower end surface when the valve is open;

said piston being so configured and arranged that when the valve is closed, said piston stinger lower end surface lies above the valve seat and when pressurized fluid is introduced into the cylinder through said fluid conduit means forcing the piston downwardly, said stinger engages the flapper, forces the flapper to rotate downwardly about the flapper trunnion to an open condition, coaxially engages with its said lower end surface the upper end surface of the tubular flapper carrier, and forces the tubular flapper carrier downwardly, compressing said coil spring against said upwardly facing annular shoulder, thus lowering the open valve flapper away from the valve seat and disposing the valve flapper and valve seat outside a tubular conduit created by the coaxial abutment of the piston, including the tail and stinger thereof, and the tubular flapper carrier.

14. The petroleum well safety valve of claim 13 wherein the valve flapper further includes a cam lobe projecting radially outwardly beyond said sealing surface and being engageable with the downwardly facing annular shoulder of said valve chamber to assist in rotating the valve flapper about the trunnion to a closed condition as the flapper carrier is raised with assistance from the recovering compressed coil spring in closing said valve.

15. The petroleum well safety valve of claim 13 wherein said tubing bonnet is physically divided into two vertically coaxially aligned portions, being a lower portion and an upper portion, said throughbore upper portion extending in said tubing bonnet upper portion and said throughbore lower portion extending in said tubing bonnet lower portion; said tubing bonnet upper portion being mounted upon said tubing bonnet lower portion; annular sealing ring means received between the upper and lower portions of the tubing bonnet peripherally of the juncture of the throughbore upper and lower portions; and disconnectible securement

means on the exterior of the tubing bonnet upper and lower portions circumferentially of their juncture, securing the tubing bonnet upper portion to the tubing bonnet lower portion and maintaining the sealing ring means in sealing contact with the periphery of the throughbore upper and lower portions at their juncture.

16. The petroleum well safety valve of claim 15 further including an upper coil spring received within said cylinder and engaging between means defining an upwardly facing shoulder at the lower extent of said chamber and the downwardly facing lower end surface of said piston for becoming compressed, as the piston is driven downwardly to open the valve, and for assisting in raising the piston as the compressed upper coil spring recovers during closing of the valve.

17. The petroleum well safety valve of claim 13 further comprising means defining an inclined plane on said valve flapper, said inclined plane being radially circumscribed by said sealing surface on the valve flapper; said inclined plane increasing in thickness as it proceeds toward the valve trunnion and decreasing in thickness as it proceeds toward the valve trunnion; the upper surface of the inclined plane being positioned to be engaged by the lower end surface of the piston stinger upon initial contact of the lowering stinger with the flapper during opening of the valve; said initial contact being made only distally of the trunnion in order to utilize a lever effect to assist in initial opening of the valve.

18. The petroleum well safety valve of claim 17

further including notch means defined in the inclined plane to permit the upward passage of pressurized fluid from the petroleum well upon initial clearance of the valve flapper sealing surface from the valve seat; the notch means being so configured that the volumetric flow capacity thereof is less than the volumetric flow capacity of the clearance between the valve flapper sealing surface and the valve seat until after initial clearance of the valve flapper sealing surface from the valve seat, to predispose cutting action of the fluid to predominately affect the notch means and stinger rather than the valve flapper sealing surface and the valve seat.

19. The petroleum well safety valve of claim 18 wherein the valve flapper sealing surface and the valve seat are complementarily frustoconically curved.

20. The petroleum well safety valve of claim 13 wherein the arm means on the flapper carrier are constituted by a U-shaped yoke integral with the exterior of the flapper carrier at one side thereof; the U-shaped yoke having two vertically upwardly extending arms which extend above the upper end surface of the tubular flapper carrier and journal the trunnion horizontally between them near the upper extent of said two arms.

21. The petroleum well safety valve of claim 20 wherein said U-shaped yoke is sufficiently long and thick as to define between the two arms thereof a recess in which said flapper is received when the valve is open.

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