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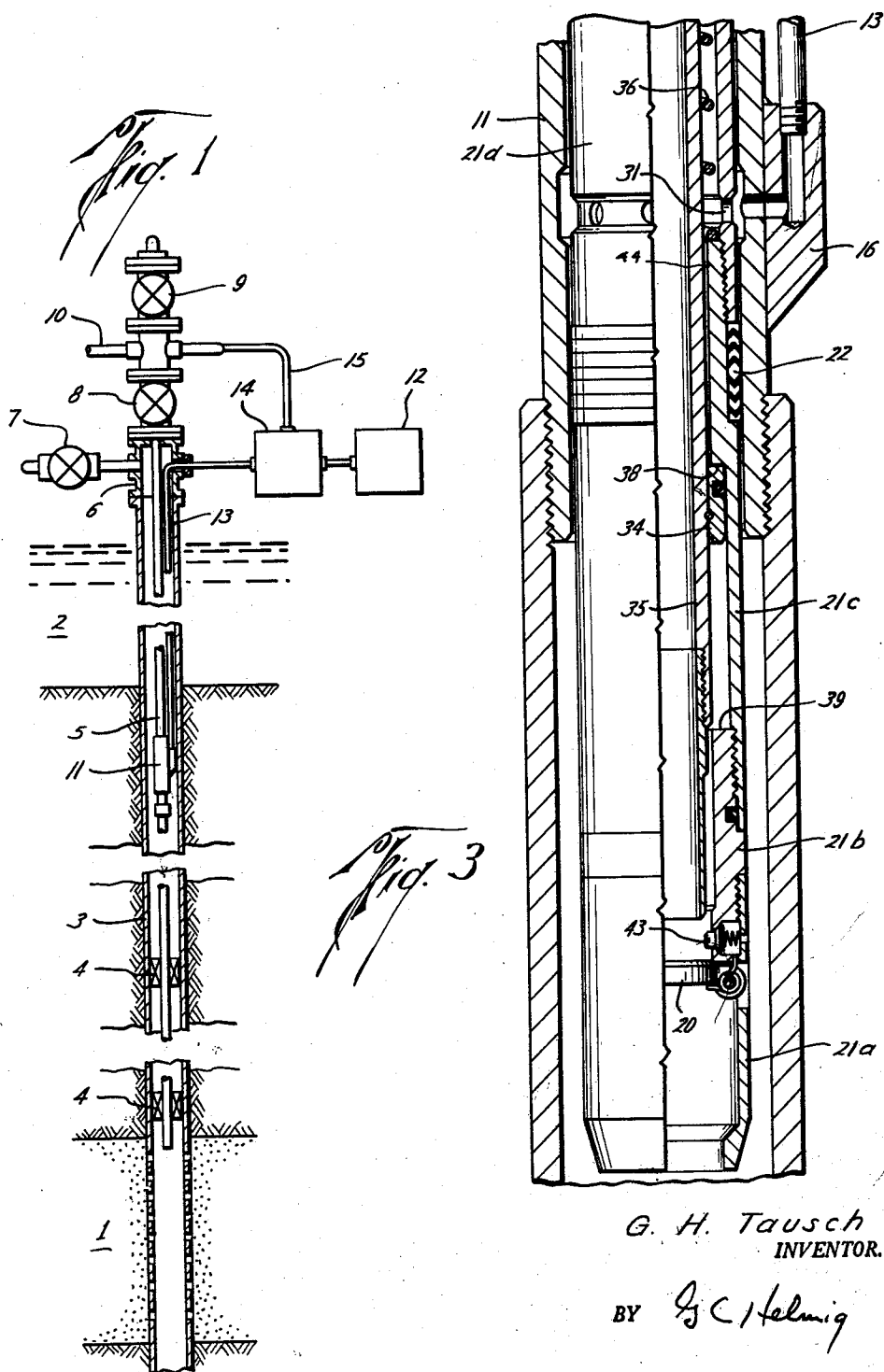
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SAFETY VALVE FOR WELLS

Filed April 15, 1960

2 Sheets-Sheet I



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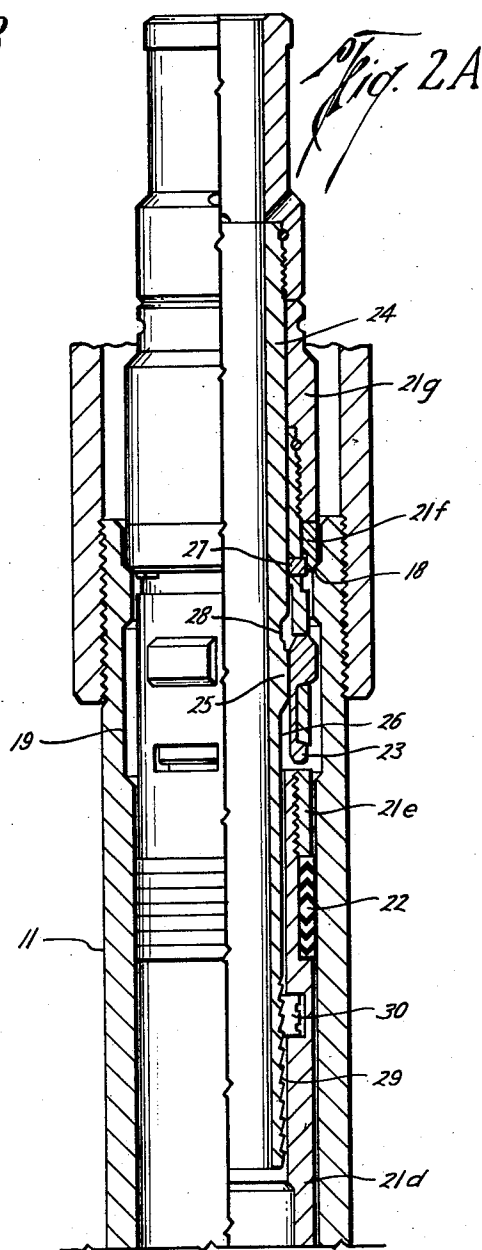
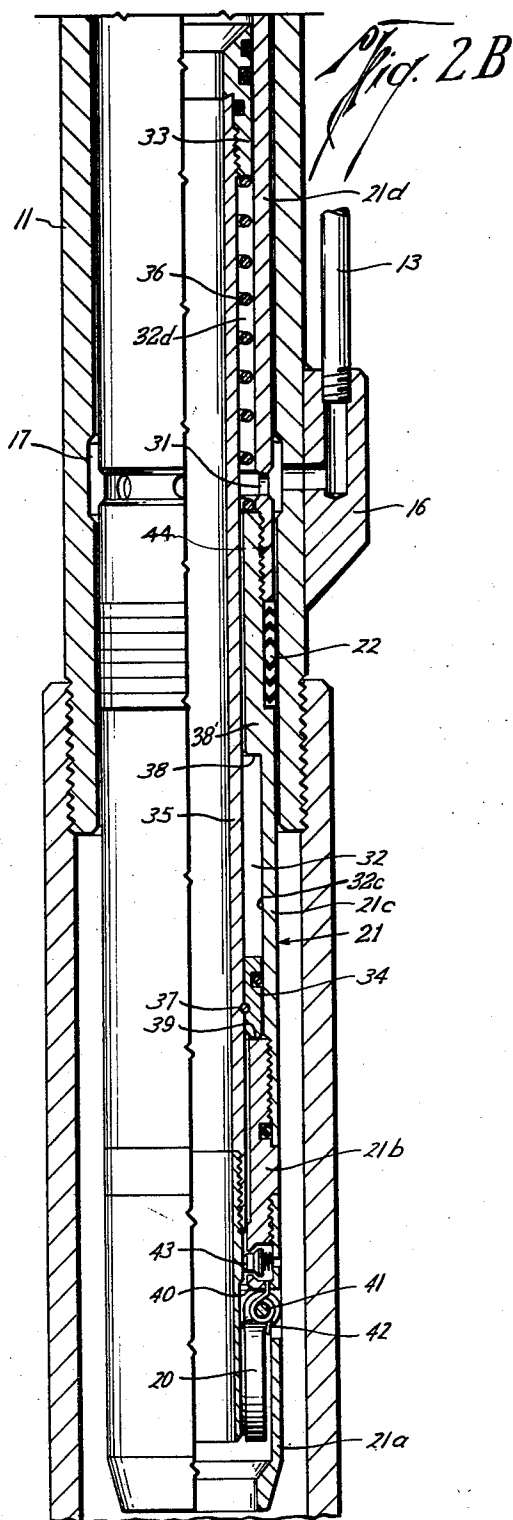
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2 Sheets-Sheet 2



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SAFETY VALVE FOR WELLS

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This invention relates to well safety valves and more particularly to surface controlled subsurface production conduit closures adapted especially for installation in offshore oil and/or gas wells. Normally, such valves are held open to permit flow through the tubing and may be closed by operating controls including controls located near to or remote from the well head and actuated either manually or automatically, as by timer mechanism. When the hold-open force is supplied through an energy transmitting conduit leading to the valve from adjacent the well head, force transmission can be cut off for valve closure in response to abnormal conditions, including changes in temperature or in flow pressure as well as breakage of well equipment as might result from hazards of storms and vessel collisions.

An object of the present invention is to provide an improved safety valve assembly for easy removal and replacement in a tubing string through the use of conventional wire line tools and which assembly is constituted by a few simple and generally standard parts for ready and low cost manufacture and involves a body having landing and latching-in mechanism at one end and a flap valve to seat against the other end and enclosing a valve position controlling slide tube spring biased to valve closing relation independently of fluid passage through the tube and normally held in valve opening position by pressure fluid supplied from above the well and to an expansion chamber between the body and slide tube, with the chamber movable wall being fixed to the valve position controlling slide tube for response thereof to the surface controlled fluid pressure in opposition to the aforementioned spring bias.

A further object of the invention is to provide a subsurface safety valve comprising a pair of concentric tubes the inner of which is open from end to end to afford a large through bore having substantially no choke or restrictive action on well fluid passage and is slidably mounted in the outer tube for lower end co-operation with a flap valve pivoted to swing upwardly into and downwardly away from passage closing engagement with a passage surrounding annular and downwardly facing seat on the outer tube.

Another object of the invention is to provide a pressure fluid receiving expansion chamber between the valve positioning inner tube and the valve mounting outer tube and closed at opposite ends by an upper relatively small area piston and a lower relatively large piston carried peripherally by the inner tube in sliding contact on axially spaced apart outer tube cylindrical portions of stepped or relatively small and large diameters whereby to provide opposing differential piston areas exposed to chamber pressure favorable to downward inner tube response against a coil spring conveniently housed within the chamber and arranged to exert its bias upwardly on the upper piston element.

Other objects and advantages will become apparent upon inspection of the preferred but not necessarily the only embodiment of the invention disclosed in the accompanying drawings wherein FIG. 1 shows on a small scale a cross section of a well in somewhat diagrammatic form; FIGS. 2A and 2B are enlarged vertical sectional views of a tubing string fragment and a safety valve positioned in the tubing with the parts in open position; and FIG. 3 is a view similar to FIG. 2B but with the valve

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closed against upward flow of well fluids through the tubing string.

By way of an explanatory example of an offshore well installation, FIG. 1 shows a well fluid producing zone 1 in the earth at some depth below the bed of a body of water 2 with a well bore lining or casing 3 extending from above the water surface to a casing side wall perforated area communicating with the production zone 1. Conventional packer units 4 are located within the casing 3 above the production zone and surround a production tubing string 5 for the flow of well fluid to the well head, which includes a tubing hanger 6 and various controls such as an annulus valve 7, a master valve 8, a swab valve 9 and an outflow line 10. At a subsurface location preferably just below the depth of the water 2 for solid earth protection, the tubing string 5 contains a landing nipple 11 to receive a retrievable safety valve by which tubing flow is to be controlled.

As here to be described, the safety valve is self closing upon absence or failure in delivery of a hold-open force supplied thereto through the well head. By such arrangement, adequate protective measures are provided against loss of and wild well production in the event of abnormal operating conditions or of damage to equipment rising above the valve and exposed to wave action and collision. The hold-open force conveniently is a source of pressure fluid such as air or a gas and is supplied from a rechargeable bottle and/or a pump 12 located on the well head work platform and joined by a pipe 13 extending downwardly through the casing annulus from the tubing hanger 6 to the safety valve landing nipple 11.

So long as the supply of pressure fluid is active on the valve, the tubing string will be open for production flow. Flow stoppage through the conduit 13 other than because of breakage, can be effected by inclusion in the supply line of one or more control valves 14 operable either or both manually and automatically in response to abnormal temperature and pressure conditions. For the transmission of well production pressures, the valve 14 is shown as having a pipe connection 15 with the well head end of the production tubing string 5 whereby should the pressure of outgoing well fluid reach outside given limits, the valve 14 will respond and cut off the supply of pressure to the line 13 and vent the same. Optionally, the control valving 14 may be made responsive to a clock or to receipt of a signal transmitted from a distant station. Furthermore, the supply source 12 may be connected to serve a group of wells through common or individual control valving.

FIG. 2B shows the lower end of the pressure supply conduit 13 connected through a ported boss 16 with a lateral port and an annular distribution groove 17 internally of the tubing string nipple 11, the boss 16 being welded on the outside of the nipple. At a predetermined distance above the internal distribution groove 17 and just below an upwardly facing landing shoulder 18 near the upper end of the nipple 11 is an internal latch keeper groove 19, as seen in FIG. 2A.

Use of a valve receiving nipple in the tubing string enables removable replacement therein of a valve unit and its withdrawal for inspection or repair. The valve unit includes a flap valve 20 pivotally mounted at the bottom of an outer tube or body 21 for swinging travel in a path across the flow passage toward and from an annular downwardly facing seat on the body, together with an inner tube slidably mounted in the body for travel between a downward position in which its lower end projects beyond the valve seat and beside the flap valve to hold the flap valve open and an upper position in which its lower end is elevated above the valve seat and out of interference to closing travel of the flap valve 20.

The tubular body 21 for convenience of assembly is made up of a number of separately machined tubular portions to be threaded together in end to end succession. They include a lower nose piece 21a, a coupling member 21b, a piston receiving cylinder 21c, a spring housing 21d, a latch holder 21e, a landing collar 21f and an upper terminal 21g. Between adjacent end portions of the outer tube sections 21c and 21d and between the adjacent portions of the outer tubing sections 21d and 21e there are formed external pockets for the location therein of upper and lower sets of V-sectioned rings 22 to engage with the inner nipple surface for sealing the same above and below the distribution channel 17.

Projected through side windows in the latch holder 21e are a set of dogs 23 which are laterally projectable and retractable and co-operate with the keeper notch 19 when projected thereinto for locking the valve assembly against displacement. Latch dog projection and retraction is controlled by a slidable plunger tube 24 having in the region of the dogs an enlarged peripheral zone or boss 25 and a reduced diameter peripheral portion 26. In the position of the parts as seen in FIG. 2A, the larger zone 25 is in backing alignment with the dogs 23 and holds the dogs projected outwardly. When the smaller portion 26 is aligned with the dogs, they may be retracted inwardly and out of latching relation with the keeper groove. The alternate positioning of the zones 25 and 26 is dependent on slide adjustment of the plunger 24. Initially, the plunger is elevated or projected upwardly in relation to the valve body and is latched thereto by the inward projection of one or more laterally movable dogs 27 into an external notch 28 in the plunger. The dogs 27 are held inwardly by the retainer ring 21f which has a stepped internal diameter and the smaller thereof downwardly overlaps the outside of the dogs when the ring 21f is in the lower of two relative axial positions on the body. This ring 21f during the lowering of the valve assembly comes into engagement with the nipple landing seat 18, whereupon further downward movement of the ring 21f is stopped while additional downward movement of the remainder of the valve assembly brings the dogs 27 into alignment with the larger of the internally stepped diameters of the ring 21f to accommodate their outward shift travel out of latch engagement with the notches 28. Downward movement of the plunger relative to the landed valve body shifts the dog expander portions 25 into alignment with and projects the latching dogs 23. Such relative plunger movement additionally causes the ratchet teeth 29 carried exteriorly on its lower end to slip down on the mating ratchet teeth of a set of expendable segments 30. These segments are pocketed within an internal groove in the body section 21d and have contractile springs to yieldably bias them inwardly and accommodate a ratcheting action. The plunger 24 is thus held in its lower position until such time as removal of the valve unit is desired, whereupon an upward jar imposed on the fishing neck of the plunger 24 will shear the teeth of the ratchet segments 30 and accommodate upward travel of the plunger and the passage of the latch expander 25 upwardly out of alignment with the latch dogs 23.

Below the upper hanger end of the outer tubular body and spaced axially from the position of the latching dogs a distance corresponding to the spacing between the dog keeper groove and the distribution channel 17 in the nipple, the wall of the body has one or more lateral ports 31 for alignment with the groove 17 and leading into an expansion chamber 32 formed between the inner and outer tubes and opposite end closures afforded by upper and lower ring enlargements or pistons 33 and 34 respectively fixed to the inner tube 35 and in slide bearing engagement with the interior surface of the outer tubular body. The outer cylindrical wall of the piston receiving chamber 32 is afforded by wall portions at axially spaced apart internal bores 32c and 32d of the body sections

21c and 21d, which are of stepped diameters with the internal diameter of the lower body portion 21c exceeding by a selected dimension the internal diameter of the upper body section 21d. Accordingly, opposing faces of the piston portions 33 and 34 present different areas to fluid pressures within the chamber 32, with the upwardly facing area of the lower piston 34 being greater than the downwardly facing area of the piston 33. Such difference in area in response to fluid pressure forces supplied to the chamber 32 will bias the inner tube 35 downwardly in the outer body. Acting upwardly in opposition to internal chamber pressure is a compression coil spring 36 housed within the expansible chamber and inside the body section 21d. At its lower end the coil spring is bottomed on an internal shoulder of the body afforded by the upper end of the internal pin coupling member of the body section 21c for threadedly receiving the lower end of the body section 21d. At its upper end the coil spring seats against the upper slide piston 33 for transmitting the elastic spring force for upwardly biasing the slide sleeve 35.

For convenience of assembly, the upper slide piston 33 is sleeved on and screw threaded to the upper end of the slide tube 35 and the lower piston 34 is sleeved on the tube and is held thereto by one or more fastening pins 37. The screw threaded fastening and the pin fastening 37 provide motion transmitting connections between the tube 35 and the longitudinally spaced apart piston heads 33 and 34 and join both heads for co-operative action as a unitary piston member which is slidably fitted to the cylinder afforded by the internal bores 32c and 32d in the tubular body 21. By more effectively sealing the slide bearing surfaces, both pistons are shown as carrying O-ring seals in their peripheries. Axial slide travel of the inner tube and piston assembly is within the limits established by internal shoulders axially spaced apart and including the downwardly facing shoulder 38 on the body section 21c and the upwardly facing end seat 39 on the body coupling member 21b and which limit stops are for co-operation with the top and bottom of the slide piston member 34.

In the presence of pressure fluid within the chamber 32 of a value sufficient to overcome the bias of the coil spring 36, the inner slide tube will be depressed to its lower limit of travel, as seen in FIG. 2b. Tube length is such that the lower end of the tube depends below the piston 34 and for a distance to project below the annular valve seat 40 formed at the bottom of the body member 21b and in surrounding relation with the flow passage. This annular seat is for co-operation with the flap valve 20 hinged on a pivot pin 41 in the flap valve housing or bottom nose piece 21a. Preferably, a coil spring 42 surrounds the pivot shaft 41 and has one end anchored to the body and its opposite end bearing on the flap valve for urging the valve toward closed position.

Closing travel of the flap valve is in a swinging path about its pivot mounting and across the flow passage for the well production fluid until engagement with the annular seat 40 is established. Such movement of course cannot occur when the inner valve control tube 35 is depressed, since its lower end extends beside the dependent flap valve 20 and holds the same open. In the absence of a pressure force in the chamber 32 sufficient to overcome the spring 36, the dominant spring force lifts the inner tube until the piston 34 comes into limit stop abutment with the shoulder 38. As such time the lower end of the slide tube, as seen in FIG. 3, is raised above the valve seat 40 and out of the path of the flap valve, which, in response to upward fluid flow in the tubing string, will be swung into valve closing position on the seat and thereafter will be held closed by fluid pressure therebelow. Thus when either lowered or raised, this lower end portion of the control tube 35 forming part of the slide piston assembly, is a valve posi-

tion controlling element and controls the position of the flap valve 20.

For reopening the flap valve, it will be desirable to equalize the pressures above and below the same and for that purpose an alternately shiftable equalizing valve 43 of a spring seated poppet type is housed for lateral seating and unseating travel within a pocket in the bottom of the body member 21b so that its inner end extends into the path of the lower end of the inner slide tube 35 and will be below the lower end thereof when the slide tube is in elevated position, as seen in FIG. 3. In this relation the equalizing valve is closed and co-operates with the flap valve in shutting off flow through the assembly. The equalizing valve is pushed away from its seat and laterally outwardly upon engagement of its inner tip with the peripheral surface of the inner tube portion whenever the latter is depressed from the position shown in FIG. 3. Such unseating affords a by-pass around the closed flap valve for balancing pressures in the production string above and below the subsurface unit. It follows that a reopening of a closed flap valve can be effected by the restoration of fluid pressure within the chamber 32 for shifting the inner piston tube downwardly and which movement first unseats the equalizing valve 43 and then, as pressures approach balance on opposite sides of the flap valve, further depression of the slide tube brings its bottom against and causes the flap valve to swing downwardly and sidewardly about its laterally located pivot until the position of the parts is restored to that shown in FIG. 2B.

It will be noted that the lower portion of the expansible chamber 32, in which the piston head 34 is slidable below the stop shoulder 38, is spaced below the pressure fluid entry port 31 in the side wall of the outer tubular body and that the upwardly extending connector pin of the body portion 21c is offset inwardly and constitutes an internal projection or annular rib 38' of a predetermined width to present its inner surface in slight clearance relation with the adjacent outer surface of the central slide tube 35 and thereby provide a constricted flow passage 44. By reason of this restricted clearance, free fluid flow between the spaced apart pressure fluid supply port 31 and the expansible chamber space 32 below the upper limit stop 38 and above the piston head 34 is of a given metered capacity. As a result, the fluid flow rate under differential pressures at opposite ends of the restricted clearance passage 44 is choked, whereby a sudden and wide change in pressures at the side port 31 cannot occur at the piston head 34 but instead there will be a gradual equalization of pressures as the metered flow takes place. There will be eliminated shock and strain and sudden starting and stopping of the relatively movable parts as well as pounding on seating surfaces. Responsive movement in both directions will be damped although it is to be expected that fluid pressure will usually be applied gradually in the valve opening direction and is more likely to be abruptly relieved in valve closing direction. By controlling the degree of passage clearance, the damping action will be had whether the pressure fluid is a gas acting directly on the piston or acting through a pressure transmitting body of silicon liquid or other suitable liquid introduced into the piston chamber to a level sufficient for displacement through the passage concurrently with piston travel. Instead of the use of pressure gas for controlling valve action, there is contemplated for some installations the employment of a column of hydraulic fluid.

Such modifications may be made in the details of the structure disclosed as come within the scope of the appended claims.

What is claimed is:

1. In a subsurface safety valve for stopping flow in a well production conduit and to be held open by pressure fluid supplied through piping extended from adjacent the well head, an annular valve seat to be fixedly mounted in

a production conduit, a movable closure valve therefor, means mounting the valve for movement in a path between an open position and a closed position on said annular valve seat, a valve position controlling element shiftable into and out of the path of said valve and thereby controlling its movement, relatively movable piston and cylinder members one of which is joined and movable with said valve position controlling element and the other of which is fixed relative to the annular valve seat, said cylinder member having axially successive internal cylindrical wall portions, each of different diameter relative to others and providing a pair of spaced apart piston receiving chambers, one of larger diameter than the other, and an annular wall portion separating said chambers and being of smaller diameter than the chambers for co-operation with the piston member in affording a choked passage communicating the chambers, said piston member having spaced apart piston heads in sliding seal fit with the respective chambers and presenting opposing faces of relative differential areas internally of the respective chambers, spring means co-operating with said members and biasing their relative movement in a direction to shift the valve position controlling element out of the path of said valve and means for introducing pressure fluid into the smaller of the piston receiving chambers for communication with the larger chamber through said choked passage and for action on the opposing piston faces in effecting projection of the valve position controlling element into the path of the valve in opposition to the bias of the spring means.

2. A well production conduit closure assembly for installation in the conduit below the well head and to be held open by pressure fluid delivered through a pipe leading thereto from adjacent the well head, said closure assembly including a tubular body having a downwardly facing annular valve seat and having above said seat a pair of axially spaced apart internal bore portions the lower of which is of larger diameter than the upper bore portion, an internal annular rib on the body separating the lower larger diameter bore portion from the upper smaller diameter bore portion except for a choked communicating passage between the two bore portions, a flap valve pivotally mounted on the body to swing to and from said seat, a central slide tube projected above and below said internal rib and slidably housed within the body for travel between a lower position in which its lower end projects below said annular valve seat and into the path of the flap valve to thereby hold the same open and an upper position in which said lower end is raised above the valve seat and out of interference to flap valve swing, a pair of upper and lower peripheral enlargements carried by the central tube in sliding bearing engagement with the upper and lower internal bore portions of the body to present opposed surfaces of differential areas exposed within said bore portions, a compression coil spring housed within the upper bore portion and seated downwardly on said internal annular rib and upwardly on the upper peripheral slide tube enlargement for exerting yieldable upward biasing force on the slide tube and a pressure fluid flow passage leading from the top of the well to the smaller diameter portion for conducting pressure fluid into said smaller diameter portion to exert fluid pressure on the opposed differential fluid pressure actuable areas of the enlargements and to act against the upward biasing force of said compression spring.

3. In combination, a well production conduit, including a subsurface nipple having a side wall port, pressure fluid delivery piping extending beside the conduit from adjacent its upper end to said nipple and communicating with said side wall port, a retrievable tool tubular body for peripheral fitment to the nipple interior and having lateral port means for alignment with said wall port, a downwardly facing annular valve seat on the body, an upwardly spring biased flap valve pivoted on the body for swinging travel to and from said annular seat in controll-

ing production fluid flow in the conduit, a pressure equalizing valve pocketed within the body immediately above said annular seat for lateral inward projection to and from closing position in which a portion thereof extends inwardly beyond the tubular wall of the body, an upwardly spring biased valve controlling tube having slide bearing in the body for travel between a lower position in which the lower tube end projects below said annular seat and engages both valves to hold them open and an upper position in which said lower end rises above and out of engagement with both valves, said tube being arranged for slide travel and disengagement with said valves sequentially and return engagement first with the equalizing valve to open the same in advance of hold-open engagement with the flap valve and a piston carried by the tube externally thereof in slide bearing on said tubular body interior and with the upwardly facing surface of the piston exposed and within a pressure fluid expansible chamber presented between said tubular body and the tube and below said lateral port means.

4. In a subsurface valve for controlling flow in a well production conduit, an outer tubular body member having a downwardly facing valve seat and a flap valve pivotally mounted below said seat for swinging travel to and from seat closing relation, an inner tubular member slidably fitted within the body member for travel between upper and lower positions and provided with a dependent portion which in one of said positions extends below said valve seat and obstructs flap valve travel and in the other position is elevated above the seat, an annular piston carried exteriorly of the inner tubular member in bearing engagement with the outer tubular member for spacing the members apart and affording a variable chamber above the piston, an upper spacer ring carried by one of the tubular members in slide bearing engagement with the other member and closing the upper end of the chamber, means to introduce pressure fluid in the upper closed end of the chamber for downward action on the piston and an internal annular projection on said outer tubular body member extended into said piston chamber and located below said means, said annular projection providing a downwardly facing stop abutment for the piston to limit its upward travel and having restricted clearance relation with the inner tubular member for forming therewith a pressure fluid flow metering passage across said annular projection.

5. In a subsurface valve for controlling flow in a well production conduit, an outer tubular body member having a downwardly facing valve seat and a flap valve pivotally mounted below said seat for swinging travel to and from seat closing relation, an inner tubular member slidably fitted within the body member for travel between upper

and lower positions and provided with a dependent portion which in one of said positions extends below said valve seat and obstructs flap valve travel and in the other position is elevated above the seat, an annular piston located on the inner tubular member in bearing engagement with the outer tubular member for spacing the members apart and affording a variable chamber above the piston, an upper spacer ring carried by one of the tubular members in slide bearing engagement with the other member and closing the upper end of the chamber, means to introduce pressure fluid in the upper portion of the chamber below the upper end thereof for downward action on the piston and an annular projection extended into the chamber and located on the outer tubular member below said means in restricted clearance relation with the inner tubular member to choke and retard the rate of pressure fluid flow between said means and said piston.

6. In a subsurface safety valve for controlling flow in a well production conduit, an outer tubular body member to be mounted in the production conduit, a tubular piston member slidably fitted within said outer tubular body member for travel between upper and lower positions and provided with a central bore for production fluid flow therethrough, valve means controlling said bore and including a bore closure shiftably mounted on the body member for movement between opened and closed positions, closure position controlling means connected with the piston member for movement therewith, said position controlling means having hold-open relation with the closure in the lower position of the piston member and being movable from such hold-open relation upon movement of the piston member into its upper position, spring means acting on the piston member to bias the same to its upper position, said tubular members having therebetween an annular expansible chamber and said piston member having an annular enlargement fixed thereto and slidable in the chamber to present an upwardly facing area exposed to pressure fluid within the chamber and means to deliver pressure fluid to the chamber above said upwardly facing area for thereby controlling piston member position in opposition to the spring means and including a choked pressure fluid passage located in the expansible chamber intermediate portions thereof for restricting the rate of piston travel upon fluid pressure change.

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