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Boyadjieff et al.

[11] **3,861,464**

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[54] **SAFETY VALVE FOR WELLS**

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[73] Assignee: **Varco International, Inc.,** Los Angeles, Calif.

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[52] **U.S. Cl.** ..... **166/224 A,** 166/72, 251/63.6

[51] **Int. Cl.** **E21b 43/12,** E21b 33/03

[58] **Field of Search** ..... 166/72, 73, 224, 274 A, 166/315; 251/62, 63.5, 63.6, 228, 213, 336

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[57] **ABSTRACT**

A safety valve to be lowered into a well and actuated from a location near the surface of the earth by a flexible line or the like extending downwardly into the well, and having a reversing mechanism acting to convert upward movement of the actuating line to downward movement of a valve opening part in the well, with the reversing mechanism including two pistons or other parts exposed to a common body of confined fluid in a relation causing downward displacement of one of the parts in response to upward movement of the other part.

18 Claims, 7 Drawing Figures

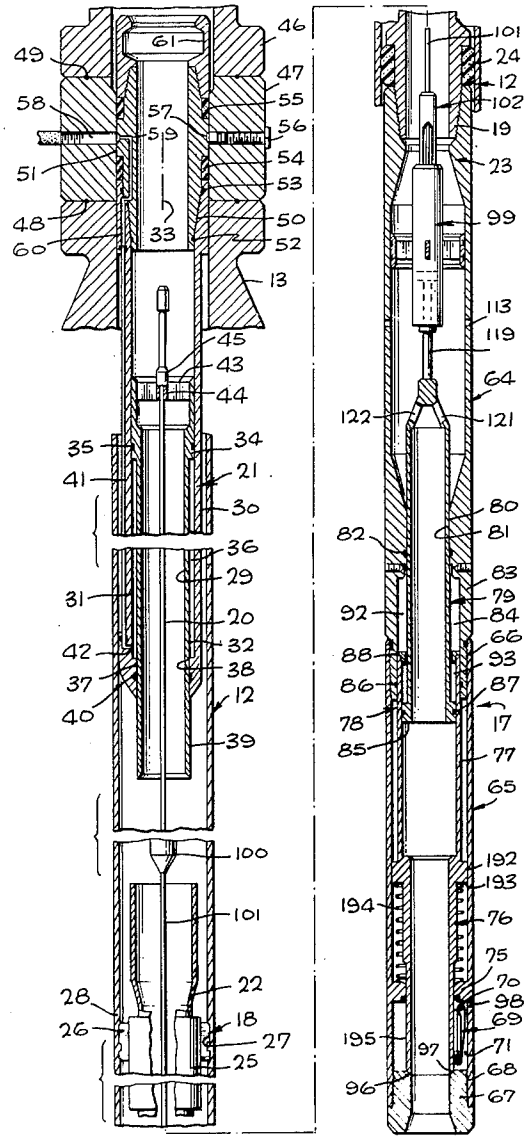


Fig. 2

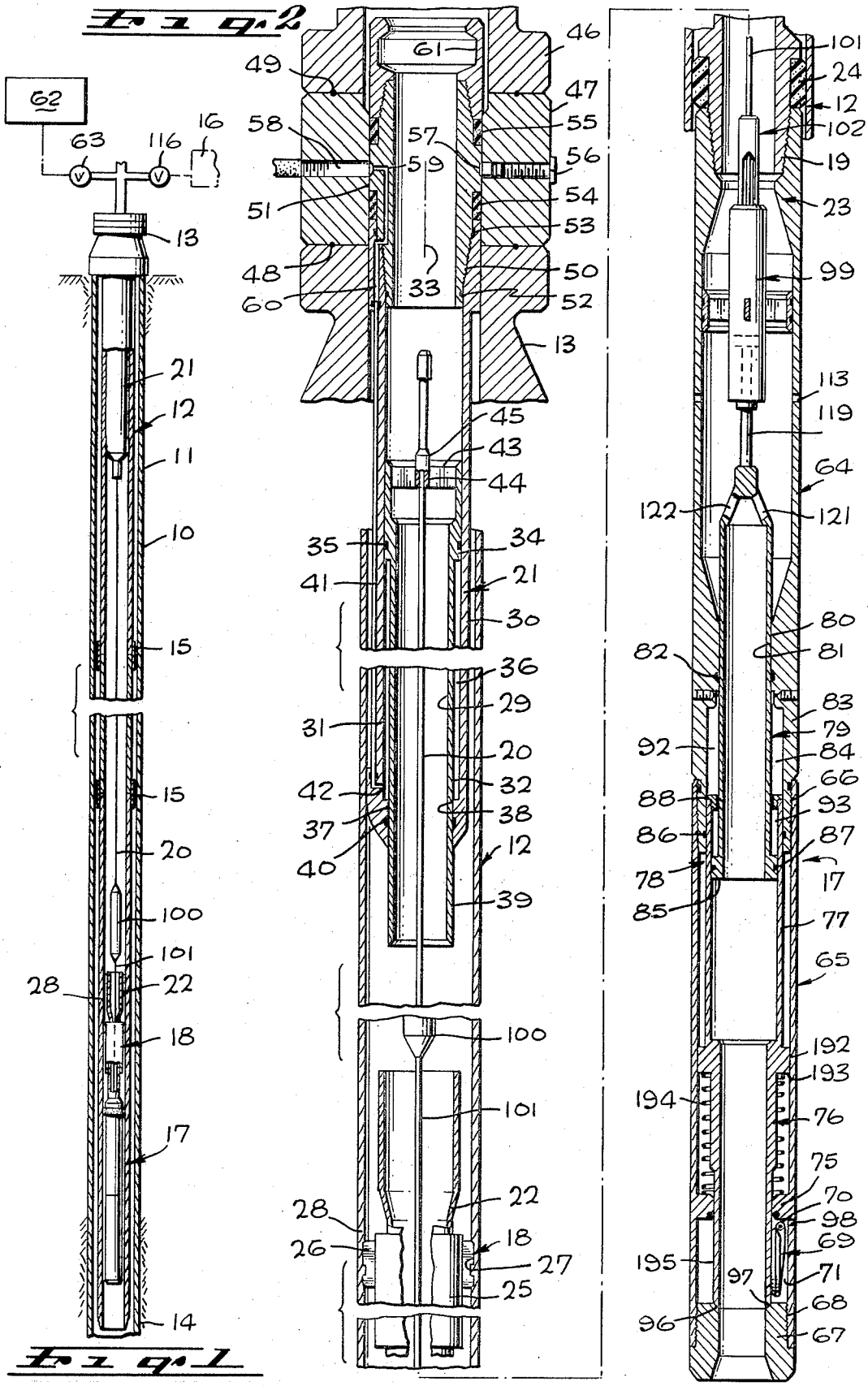

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Fig. 1

Fig. 3

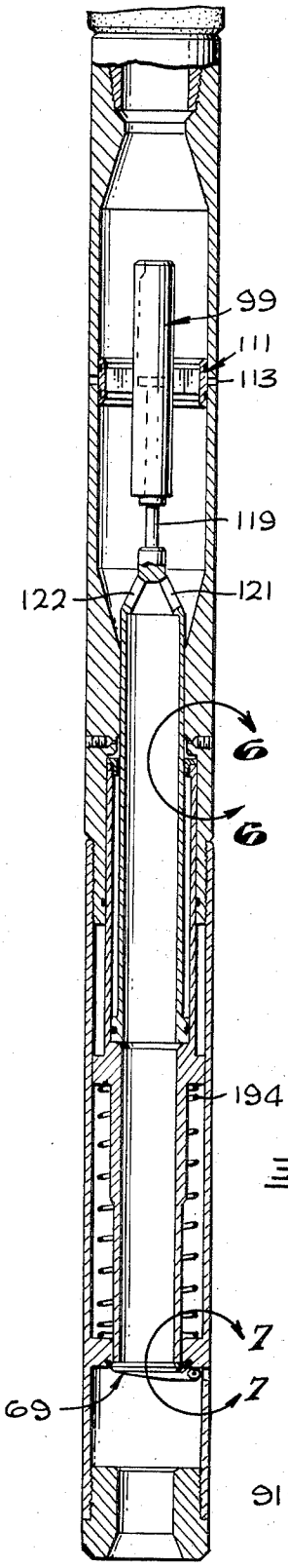


Fig. 4

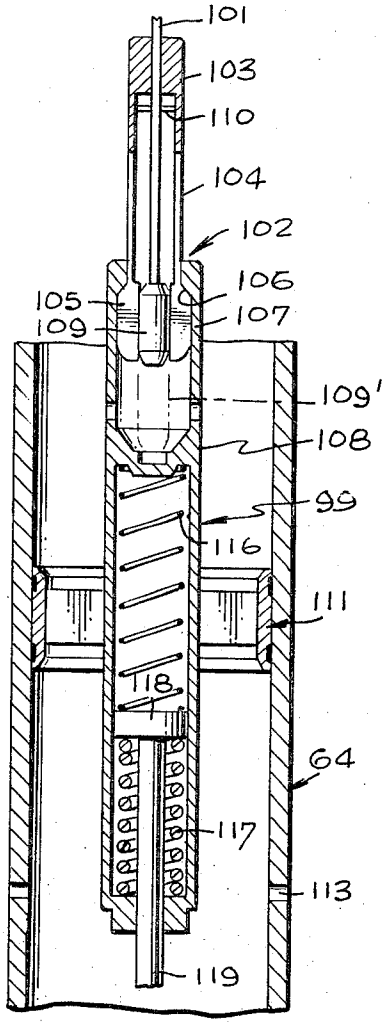


Fig. 5

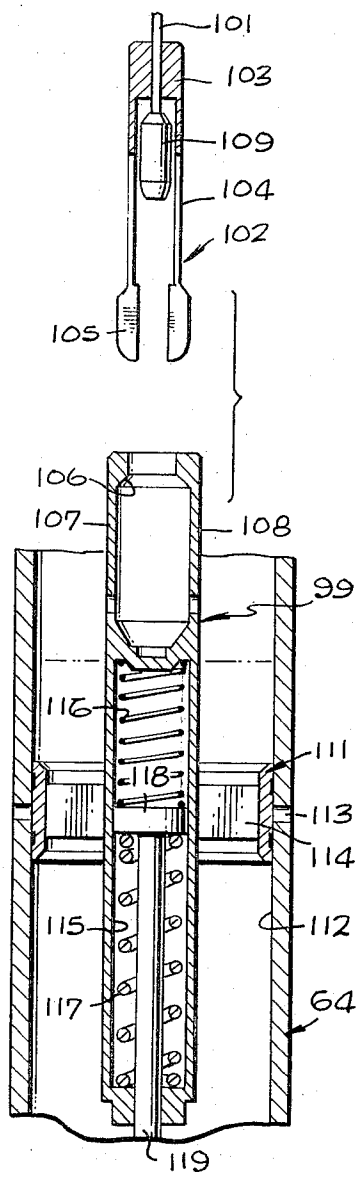


Fig. 6

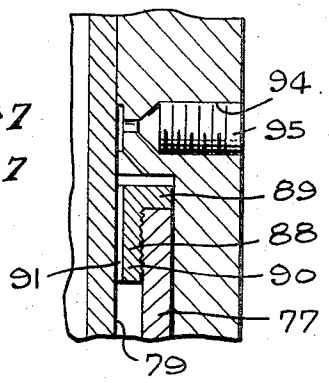
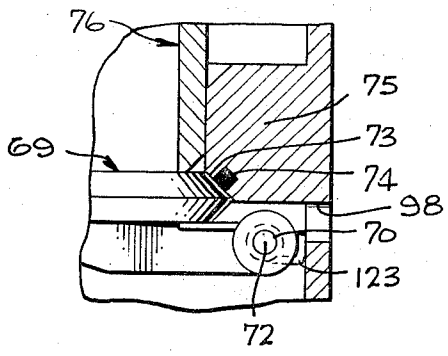


Fig. 7



SAFETY VALVE FOR WELLS

CROSS REFERENCE TO RELATED APPLICATION

Certain features of the apparatus disclosed in the present application have been shown and claimed in our prior copending application Ser. No 252,808 filed May 12, 1972 on "Remotely Operated Well Safety Valves," which was a continuation in part of application Ser. No. 203,142 filed Nov. 30, 1971 and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to improved well safety valves for closing off the flow of well fluid at a location deep within a well, and adapted for remotely controlled actuation and control from the surface of the earth.

Our above identified prior copending application Ser. No. 252,808 shows a remotely controlled safety valve which is actuated from a location near the surface of the earth by actuation of a flexible line extending downwardly within the well to the location of the valve. The line or cable is preferably maintained under tension when the valve is open, so that any release of that tensioned condition, either intentionally or accidentally, will automatically close the valve and shut off further escape of well fluid therefrom. Thus, the valve will close if adverse conditions develop which in some way break the cable, or break the supply of energy to an actuating unit at the surface of the earth which maintains the line in tension. This actuating unit may be a piston and cylinder mechanism located within an upper portion of the well and held in a line-tensioning condition by the force of a pressurized control fluid.

SUMMARY OF THE INVENTION

The present invention provides a safety valve unit which can be controlled remotely in a manner similar to the valves of my above discussed copending application, but in which the structure and functioning of the valve mechanism are different from, and for certain situations or installations preferable to, the valves of that prior application. One feature of particular importance to the present invention relates to the provision of a unique type of force reversing mechanism, which can be actuated by force applied to the mechanism in a first vertical direction through the flexible line or other actuator, and which will function to reverse the direction of that force to produce a valve operating force in the opposite vertical direction. Consequently, if a first of these forces is applied to the reversing mechanism by a flexible line of the above discussed type in an upward direction tensioning that line, the reversing mechanism can then apply to the valve or a valve operator a downward force for opening the valve, and holding it open until the tensioned condition of the flexible line is released. The force reversal is effected by a fluid type system, in which a confined body of fluid is exposed to and acts against two different movable parts, both of which may be considered as pistons, in a relation such that movement of one of the parts or pistons in a first direction acts through the fluid to cause movement of the other part in the opposite direction. Desirably, both of these pistons are tubular to provide within the interior of the pistons a relatively open vertical passageway through which the production fluid of the well can flow upwardly without substantial restriction to the surface of the earth. a portion of one of these parts may actuate the safety valve proper from a closed position of extension across the fluid passageway in the device to a laterally deflected open position. In that open position, a portion of the tubular piston element may extend vertically past the valve element, in a manner protecting or shielding it from contact with and deterioration by the upflowing stream of well fluid.

Another feature of the invention relates to a novel arrangement for actuating an equalizer valve, which functions to place the interior of the valve unit in communication with its exterior at a location above the main safety valve element proper just prior to opening of the main valve element, in order to eliminate or decrease the pressure differential across the main valve and thereby facilitate its opening movement. More particularly, this equalizer valve controls the flow of well fluid through an aperture or apertures in the wall of the valve unit body, at a location above the main safety valve element, and is actuable to open condition by initial upward movement of the actuating line. To assure opening of the equalizer valve before the mechanism attempts to open the main valve, a lost motion connection is provided which upon upward movement of the actuating line first opens the equalizer valve, and only after that valve has been opened commences actuation of the mechanism which opens the main valve element. A spring may yieldingly resist this lost motion, and a second and opposed spring may resist relative motion of the parts in an opposite vertical direction in a relation opening the equalizer valve during lowering of the tool into the well.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and objects of the invention will be better understood from the following detailed description of the typical embodiment illustrated in the accompanying drawings, in which:

FIG. 1 shows somewhat diagramatically a well containing safety valve equipment constructed in accordance with the invention;

FIG. 2 is an enlarged vertical fragmentary section through various portions of the apparatus of FIG. 1, showing the main safety valve element in its open condition;

FIG. 3 is a view showing the lower portion of the FIG. 2 apparatus, but with the safety valve in its closed condition;

FIG. 4 is an enlarged vertical section through the equalizer valve mechanism in its FIG. 2 condition;

FIG. 5 is a view similar to FIG. 4, but showing the equalizer valve closed, as in FIG. 3;

FIG. 6 is an enlarged fragmentary vertical section taken in the area of the circle 6—6 of FIG. 3 and;

FIG. 7 is an enlarged vertical fragmentary section showing a portion of the main valve, in the region of the cricle 7—7 of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows at 10 a well containing a casing 11 within which a string of production tubing 12 extends downwardly, in spaced relation to the casing. A conventional well head represented at 13 is connected to the upper end of the casing, and appropriately suspends the tubing string 12. Production fluid from the formation surrounding the well enters the lower end of the tubing string at the production zone 14, and ultimately

discharges from the upper end of tubing **12** into a storage tank **16** or appropriate distribution line past a suitable control valve **116.** The tubing **12** may be formed in conventional manner of a series of tubing sections connected together by threaded couplings **15.** In lieu of the typically illustrated type of well drilled directly into the surface of the earth, it is contemplated that the present well safety apparatus may also be utilized in the drilling of underwater wells, as from a barge or ship floating on the surface of a body of water, with the well casing and its contents extending downwardly through the water to the ocean floor or the like, and then into the earth at that location.

The safety valve unit proper is designated generally by the number **17** in FIG. **1,** and is set in fixed position within the lower portion of tubing string **12** by a landing and sealing unit represented at **18.** Unit **18** may be constructed integrally with valve unit **17,** or may be a separately formed attached conventional landing and sealing unit as illustrated, rigidly connected to the upper end of the valve unit **17** by a threaded connection **19** (FIG. **2**). The safety valve is actuated and controlled by an elongated flexible line **20,** preferably of the type commonly referred to as a 'wireline.' This line or cable extends upwardly to the surface of the earth for control by a powered operating mechanism designated generally at **21.** The line **20** may be any conventional or known type of flexible cable or the like, including elements of this type formed of either a single wire or strand, or a number of wires or strands interwoven or wound together.

The landing and sealing unit **18** is typically and somewhat diagramatically illustrated as of the same conventional 'key-type' shown and described in our above identified copending application. Specifically, this unit **18** may include a tubular body member **22** connected at its lower end to the upper end of body **23** of valve unit **17** by the previously mentioned threaded connection **19,** with an annular seal ring **24** of rubber or other elastomeric material clamped between shoulders on elements **22** and **23** as seen in FIG. **2** for annular engagement with the inner surface of tubing **12** to form a fluid tight seal therewith preventing upward flow of fluid about the outside of elements **22** and **23** at the location of seal **24.** Disposed about body **22,** the landing and sealing unit **18** includes a sleeve or mandrel **25** containing apertures through which a number of circularly spaced locking keys or dogs **26** project radially outwardly for interfitting reception within a mating locating groove or plurality of grooves **27** formed in a coacting locating or landing nipple **28** connected into tubing **12.** As is conventional in this type of device, keys **26** may be spring pressed radially outwardly relative to sleeve **25** for automatic reception within the groove or grooves **27** when they reach the location of the groove, with the keys then being locked in their outer holding positions in conventional manner by predetermined manipulation of body **22** from the surface of the earth. For example, the keys may be locked in their outer positions by a rapid vertical jarring movement of body **22** serving to shear a connection between the body and sleeve **25** and thereby move a locking or camming portion of the body into a position behind or radially inwardly of the keys. After being set by this type motion, the keys thereafter positively lock sleeve **25** and body **22** against both upward and downward movement relative to section **28** of the tubing, to thereby positively retain the valve unit **17** in its FIG. **1** position in the lower portion of the tubing string. Any other type of conventional landing equipment may of course be substituted for the particular key-type device typically illustrated in FIG. **2,** such as for example a type having slips designed to be forced outwardly against the tubing in frictional holding relation, or having lugs which are receivable between the ends of successive lengths of the tubing **12,** or any other known or usable type of apparatus controllable from the surface of the earth for holding the valve unit **17** in a fixed vertical setting.

The actuating unit **21** located near the surface of the earth preferably takes the form of an annular piston and cylinder mechanism, to which the upper end of the flexible line **20** is connectible, and through which a central vertical passage **29** is formed for passing production fluid upwardly through the interior of this actuating unit. The cylinder **30** of the piston and cylinder mechanism **21** is an essentially tubular element having a vertical cylindrical internal surface **31,** and contains a piston **32** which is movable upwardly and downwardly along the vertical axis **33** of the well. The piston **32** has an upper enlarged diameter portion **34** slidably received within and sealed by an O-ring **35** with respect to the inner cylindrical surface **31** of cylinder **30.** An annular hydraulic cylinder chamber **36** is thus formed between the cylinder and piston, acting to force the piston upwardly relative to the cylinder in response to the injection of pressure fluid into the chamber **36.** The lower end of chamber **36** is closed by provision of a reduced diameter portion **37** of the cylinder, having an internal surface **38** slidably engaging and receiving the lower reduced diameter portion **39** of the piston, and sealed with respect thereto by an annular O-ring **40.** Pressure fluid is introduced into the lower end of cylinder chamber **36** through a small fluid inlet line **41,** connecting into the cylinder chamber at **42.**

The upper end of piston **32** carriesa a spider **43,** which supports a tubular element **44** at a central location within the piston, so that the flexible line **20** may extend upwardly through this tubular portion **44** and be attached to an upper enlarged head element **45** shaped to serve as a fishing neck, for engagement with a fishing tool to pull the flexible line upwardly if and when desired. Upward movement of the piston acts to displace head element **44** and the connected flexible line upwardly, to open the valve unit **17** and maintain the flexible line under tension.

The piston and cylinder mechanism **21** is preferably suspended in the well from the well head **13,** from which the usual main flow control valve assembly or 'Christmas Tree' projects upwardly, the lower portion of this valve assembly being represented at **46** in FIG. **2.** To suspend the actuating piston and cylinder mechanism from the well head, there is desirably provded between elements **13** and **46** an adapter flange or ring **47,** suitably secured to the flanges of elements **13** and **46,** and appropriately sealed with respect thereto as by rings represented at **48** and **49.** The upper end of cylinder **30** may be connected threadedly at **50** to a short suspending tube **51,** sealed with respect to the cylinder at **52** and **53,** and annularly sealed with respect to flange **47** at two vertically spaced locations **54** and **55.** One or more locking dogs **56** may be threadedly connected into element **47** for projection into an annular external groove **57** formed in part **51,** to suspend that part and the connected piston and cylinder mechanism

in the illustrated position within the well. Actuating pressure fluid may be supplied to the piston and cylinder mechanism through an inlet passage **58** communicating through small passages **59** and **60** in elements **51** and **30** respectively with the previously mentioned line **41** extending downwardly to the lower end of cylinder chamber **36.** A fishing neck **61** may be connected onto the upper end of part **51,** for engagement with an appropriate fishing tool to enable removal of the unit **21** upwardly from the well when desired. The actuating pressure fluid is supplied to passage **58** from any appropriate source represented diagramatically at **62** in FIG. **1,** under the control of a manually or automatically operable three way valve or other valve represented at **63,** for selectively either applying pressure to or releasing pressure from the hydraulic cylinder chamber **36.**

The novelty of the present invention is particularly concerned with the structure of the safety valve unit **17** at the bottom of the well. Referring particularly to FIG. **2,** the previously mentioned outer body **23** of this valve unit may be a vertically elongated rigid tubular structure formed sectionally to include a first upper section **64** threadedly connected at **66** to a second section **65** in fluid tight annularly sealed relation, with an annular bottom section **67** being threadedly connected at **68** to the lower end of section **65.** The main safety valve element is a flapper type valve **69,** mounted pivotally at **70** for swinging movement between the closed horizontally extending position of FIGS. **3** and **5,** disposed transversely of vertical axis **33** of the well and tool, and the open position of FIG. **2,** in which the valve **69** extends essentially vertically within an annular pocket or recess **71** formed in section **65** of the body **23.** The pivotal axis **72** of valve **69** (see FIG. **7**) is disposed horizontally in the illustrated position of the tool, to lie in a plane extending transversely of vertical axis **33.** In its closed position of FIGS. **3** and **7,** the circular valve disc **69** has its annular peripheral surface **73** (FIG. **7**) in annular sealing engagement with a seal ring **74** carried by a radially inwardly projecting annular shoulder **75** formed within the interior of part **65,** to positively close off all upward flow of production fluid through the valve unit and past element **69.**

The valve element **69** is actuated to its open position by downward movement of a tubular part **76** whose upper portion **77** may function as part of a reversing mechanism **78** acting to displace part **76** downwardly in response to upward movement of flexible line **20** and a connected element **79** forming a second portion of the reversing mechanism. Part **79** functions as an annular piston element, having a tubular straight cylindrical portion **80** slidably received within and engaging an internal cylindrical surface **81** formed in part **64** of body **23,** and sealed with respect thereto by an O-ring **82.** Beneath the location of O-ring **82,** part **64** contains and enlarged diameter internal cylindrical surface **83,** defining the outer wall of an annular vertically extending cylinder chamber **84** within which a body of pressure fluid is contained in confined and hermetically sealed condition. At its lower end, the element **79** has an annular radially outwardly projecting piston head **85.**

Portion **77** or part **76** is shaped as a vertical tube functioning as a second annular piston having parallel internal and external cylindrical surfaces centered about axis **33.** The outer surface of portion **77** of part **76** slidably engages internal surface **83** of part **64,** and is sealed with respect thereto as by an O-ring **86.** The internal surface of portion **77** slidably contacts piston head **85** of the upper piston element **79,** being sealed with respect thereto by an elastomeric ring **87** at its upper end. Portion **77** of part **76** may threadedly carry an annular part **88,** which may have a portion **89** extending across the end of portion **77,** and an axially extending portion **90** projecting radially inwardly from and beyond the internal surface of portion **77** of part **76,** to define with the outer surface of piston element **79** an annular restricted passage **91,** which provides restricted communication between and has a radial width smaller than two upper and lower annular fluid compartments **92** and **93** forming portions of the previously discussed closed fluid chamber **84.** This chamber and its two compartments **92** and **93** are filled with fluid in any suitable manner, as by injection through one or more inlet passages **94** which, after injection of the fluid, may be closed and sealed by plugs **95** or otherwise. Desirably, the fluid within chamber **84** is a liquid, to render the actuation of the reversing mechanism as positive and controllable as possible.

At the lower end of the piston portion **77** of part **76,** this part has an annular portion **192** of increased radial thickness, defining a shoulder **193** against which a compression spring **194** bears upwardly to yieldingly urge part **76** upwardly toward the FIG. **3** closed valve condition thereof. Beneath the level of shoulder **93,** part **76** has a reduced diameter tubular portion **195,** which slidably contacts an internal cylindrical surface in shoulder portion **75** of body part **65,** and which has an annular beveled lower end surface **96** engageable annularly with an upwardly facing surface **97** formed on part **67** in the open position of valve **69,** to thereby close off access of the production fluid within the interior of part **67** and **76** to the open valve **69.** Thus, the valve is protected against erosion by or other damage from contact with the moving production fluid. An opening **98** in the side wall of part **65** beneath shoulder **75** allows fluid flow into and out of the annular valve receiving compartment **71,** to avoid any tendency for restriction of movement of the parts by entrapment of fluid in this compartment.

At its upper end, the upper piston part **79** of the reversing mechanism **78** is connected to flexible line **20** through an equalizing valve assembly **99** and a landing weight **100.** The landing weight **100** may be connected in an suitable manner to the lower end of flexible line **20,** and carry a downwardly projecting essentially rigid vertical rod **101** which is detachably connectible to the upper end of equalizer valve assembly **99** by a quick disconnect connection **102.** As seen best in FIGS. **4** and **5,** this connection **102** includes a part **103** disposed about the lower portion of rod **101** and forming a series of downwardly projecting circularly spaced spring fingers **104** whose lower enlargements **105** are receivable within a socket recess **106** formed in the upper chuck portion **107** of body **108** of the equalizer valve assembly **99.** The part **104,** rod **101** and weight **100** are not lowered into the well until after the valve unit **17** and landing unit **18** have been set therein. At that time, parts **100, 101,** and **103** are lowered into the well in a condition in which a lower camming enlargement **109** carried by rod **101** is located downwardly beneath the level of enlargements **105** on spring fingers **104,** as represented by the broken lines **109'** in FIG. **4.** With the parts in this condition, enlargements **105** of the spring fingers **104** can move downwardly into the socket re-

cess **106**, and then spring radially outwardly in that recess, and be retained in the FIG. **4** full line connecting position by upward movement of enlargement **107** relative to the fingers and to a position between and blocking inward movement of the fingers. Thereafter, the connection **102** secures the rod **101** to body **108**, with sufficient strength to withstand forces applied by the flexible line **20** in the FIG. **2** open position of valve **69**, and unless and until the cable **20** is forceably pulled upwardly with excessive force sufficient to shear a pin **110** which initially extends through and is carried by rod **101** in the position of FIG. **4**, but which upon exertion of an upper jarring force is sheared off to allow upward movement of rod **101** and its enlargement **109** from the FIG. **4** position to the FIG. **5** position in which fingers **105** are free to move radially inwardly for release from chuck **107**.

The equalizer valve assembly includes a tubular slide valve element **111** (FIGS. **4** and **5**), which slidably engages the inner cylindrical surface **112** of body part **64**, and which in the normal closed position of FIG. **5** to which it tends to return blocks fluid flow through one or more apertures **113** formed in the side wall of part **64**. When the valve is open, these apertures **113** place the interior of body part **64** in communication with its exterior, to apply the same pressure to the upper side of main valve element **64** as to its underside.

The body part **108** of equalizer valve assembly **101** is a vertically extending tubular part, which rigidly carries sleeve valve element **111**, as by provision of a series of circularly spaced radially extending web elements **114** connecting parts **108** and **111** but allowing upward flow of production fluid between elements **114**. Internally, part **108** has a chamber **115** beneath the upper chuck recess **106**, and within which two upper and lower compression springs **116** and **117** are received above and beneath an upper radial flange portion **118** carried at the upper end of a rigid rod **119** which projects upwardly from and is rigidly attached to the upper piston element **79** of the reversing mechanism **78**. A seen in FIGS. **2** and **3**, rod **119** may be connected to part **79** by providing the latter with an upper reduced diameter portion **120** attached to the main tubular portion of part **79** by a web structure **121** containing circularly spaced apertures **122** through which the production fluid can flow upwardly from the interior of part **79** to the space about rod **119**.

To now describe a cycle of use of the disclosed apparatus, the first step to be followed in placing the equipment in operation in a well is to lower valve unit **17** and landing and sealing unit **18** into the well and to a production zone location as represented in FIG. **1**. At this time, the flexible line **20** and all parts connected thereto above chuck **107** are not attached to the units **17** and **18** which are lowered into the well. An appropriate running tool lowers these units **17** and **18** and then actuates the unit **18** to lock itself and unit **17** in fixed position in the well. Thereafter, the flexible line **20** and connected parts are lowered into the well, and fingers **105** are actuated to form a connection with chuck **107** as seen in FIG. **4**. The actuating mechanism **21** is appropriately positioned in the upper portion of the well, and the upper end of flexible line **20** is passed through part **44** and connected to upper element **45** in an appropriate setting. Before application of pressure to the actuating unit **21**, the springs **116** and **117** retain element **108** and sleeve valve **111** in the FIG. **5** closed position of the equalizer valve, and spring **194** holds the part **76** in its FIG. **3** position in which the main valve **69** is also closed. When it is desired to open the safety valve to allow production of fluid from the well, control fluid under pressure is applied to actuating unit **21** through passages **58**, **59** and **60**, and line **41**, to force piston **32** upwardly to the FIG. **2** position, and thereby apply upward tensioning force to cable **20** moving that cable upwardly to its FIG. **2** position. The initial upward movement of the cable moves outer body **108** of the equalizer valve assembly upwardly relative to rod **109** and its head **118**, against the tendency of spring **117**, and to a position in which sleeve valve element **111** is in its broken line position of FIG. **5** relative to part **64**, to thereby open the equalizer or bleed passages **113**. The strength of spring **117** is not sufficient to cause upward movement of rod **19** and its connected parts during this initial upward movement of part **108**. However, when slide valve element **111** reaches its broken line position of FIG. **5**, the spring **117** is in its fully compressed condition and therefore transmits further upward movement of part **108** to rod **119**, to correspondingly move piston **79** upwardly relative to part **64**, to thereby force liquid from compartment **93** through the restriction **91** and into the upper compartment **92** of chamber **84**. The increased amount of liquid in upper compartment **92** forces the lower piston **77** downwardly in response to the upward movement of piston **79**, to thereby displace the lower portion **195** of part **76** downwardly to its FIG. **2** position opening main valve **69**. The narrow dimension of restriction **91** limits the rate at which this motion of the pistons can occur, to prevent damage to the pistons and/or valve and other related mechanism by too rapid motion. While the well is producing, the flexible line **20** is continuously maintained in this upwardly displaced tensioned condition of FIG. **2** by the actuating unit **21**, to hold valve element **69** in its opened condition.

If any adverse condition develops during production which breaks cable **20**, as by an earthquake or the like, the tensional force exerted by that cable is immediately released, and the main valve and equalizer valve are permitted to return to their normal closed positions, under the influence of springs **194** and **117**. A coacting spring **123** associated with element **169** may yieldingly urge that valve to its closed position pivotally about its axis **72**, to urge the valve closed upon upward movement of part **76**. The pressure fluid itself will of course normally assist this closure of valve **69**, and maintain it positively closed by virtue of the pressure differential at the opposite sides of the valve when the equalizer valve element **111** is closed.

The second spring **116** within the equalizer valve assembly **99** is provided for permitting opening of the equalizer valve **111** during lowering of the units **17** and **18** into the well. During such lowering, the running tool which installs these units in the well may displace part **108** downwardly relative to part **119** against the tendency of upper spring **116**, and downwardly beyond the FIG. **5** position of part **111**, to move part **111** out of blocking relation with respect to apertures **113** while the apparatus is being installed, and thereby allow fluid flow upwardly past seal element **24** and prevent the fluid in the well from resisting downward movement of the equipment.

While a certain specific embodiment of the present invention has been disclosed as typical, the invention is

of course not limited to this particular form, but rather is applicable broadly to all such variations as fall within the scope of the appended claims.

We claim:

1. In well safety apparatus, including a valve unit to be lowered into a well and located therein, and a member extending upwardly toward the surface of the earth for actuating said valve unit; the improvement comprising formation of said valve unit to include means containing and enclosing a confined body of fluid, said means including a first element connectible to said member for actuation upwardly thereby and exposed to and acting against said confined body of fluid in a manner displacing a portion of said fluid in response to said upward movement of said element, and a second element exposed to said confined body of fluid and actuable downwardly by the pressure of the fluid upon said upward movement of said first element, said valve unit including also valve means operable by said downward movement of said second element.

2. The improvement in well safety apparatus as recited in claim **1**, in which said two elements are pistons exposed to said body of fluid.

3. The improvement in well safety apparatus as recited in claim **1**, in which said two elements are two concentric annular pistons movable in opposite vertical directions.

4. The improvement in well safety apparatus as recited in claim **1**, in which said elements are two telescopically interfitting oppositely movable piston elements exposed to said confined fluid, one of said elements having a portion contacting said fluid which is thicker radially than an adjacent portion of said one element and which defines a restricted passage extending between and narrower than two compartments containing said confined fluid and between which said confined fluid must flow upon relative movement of the two elements.

5. The improvement in well safety apparatus as recited in claim **1**, in which said valve means include a valve element mounted to swing downwardly and radially outwardly from a closed position blocking off the flow of production fluid upwardly through the well to an open position permitting such flow, said second element having a portion positioned to engage said valve element and deflect it downwardly and outwardly to said open position upon downward movement of said second element.

6. The improvement in well safety apparatus as recited in claim **1**, in which said second element has a tubular lower portion through which production fluid flows upwardly in the open position of said valve means, said valve means including a valve member mounted pivotally for downward and outward swinging movement by downward movement of said tubular portion of said second element and from a closed position to an open position of reception radially outwardly of said tubular portion.

7. The improvement in well safety apparatus as recited in claim **1**, in which said valve unit includes a body through which production fluid flows upwardly when said valve means are open, and equalizer valve means operable upon upward movement of said first element to place the exterior of said body in communication with its interior at a location above said first mentioned valve means.

8. In well safety apparatus including a body to be lowered into a well and located therein; a main valve member carried by said body and actuable between an open position passing production fluid upwardly into the interior of the body and a closed position blocking off such fluid flow; an equalizer valve element movable between an open position for passing fluid through a bleed passage formed in a side wall of said body and placing the exterior of the body in communication with its interior at a location above said main valve member, and a closed position; an elongated member extending upwardly toward the surface of the earth and operable by upward movement to open both said main valve element and said equalizer valve element; means for exerting upward force on said elongated member from a location near the surface of the earth; and a lost motion connection between said two valve elements acting to open said equalizer valve element upon initial upward movement of said elongated member and to then open said main valve element upon further upward movement of the elongated member.

9. The improvement in well safety apparatus as recited in claim **8**, including spring means yieldingly resisting movement of said equalizer valve element independently of said main valve element.

10. In well safety apparatus, including a valve unit to be lowered into a well and located therein, and a member extending upwardly toward the surface of the earth for actuating said valve unit; the improvement comprising formation of said valve unit to include a first element connectible to said member for actuation upwardly thereby and exposed to and acting against a confined body of fluid in a manner displacing a portion of said fluid in response to said upward movement of said element, a second element exposed to said confined body of fluid and actuable downwardly by the pressure of the fluid upon said upward movement of said first element, and valve means operable by said downward movement of said second element, said valve unit including a tubular vertically extending body defining a side wall of a chamber containing said confined fluid, one of said elements being an annular piston having a tubular wall defining a second side wall of said chamber.

11. In well safety apparatus, including a valve unit to be lowered into a well and located therein, and a member extending upwardly toward the surface of the earch for actuating said valve unit; the improvement comprising formation of said valve unit to include a first element connectible to said member for actuation upwardly thereby and exposed to and acting against a confined body of fluid in a manner displacing a portion of said fluid in response to said upward movement of said element, a second element exposed to said confined body of fluid and actuable downwardly by the pressure of the fluid upon said upward movement of said first element, and valve means operable by said downward movement of said second element, said valve unit including a tubular body defining a radially outer wall of a cylinder chamber containing said confined fluid, one of said elements being tubular and defining a radially inner wall of said cylinder chamber and having a piston head acting against the confined fluid at an end of the chamber.

12. In well safety apparatus, including a valve unit to be lowered into a well and located therein, and a member extending upwardly toward the surface of the earth

for actuating said valve unit; the improvement comprising formation of said valve unit to include a first element connectible to said member for actuation upwardly thereby and exposed to and acting against a confined body of fluid in a manner displacing a portion of said fluid in response to said upward movement of said element, a second element exposed to said confined body of fluid and actuable downwardly by the pressure of the fluid upon said upward movement of said first element, and valve means operable by said downward movement of said second element, said valve unit including a vertically extending tubular body defining a radially outer wall of a cylinder chamber containing said confined fluid, one of said elements being a tubular part defining a radially inner wall of said chamber spaced radially from said outer wall and having a piston head acting against the confined liquid at an end of the chamber, the other of said elements being an annular piston element extending telescopically into said chamber and between said inner and outer walls thereof and slidably engaging said piston head in sealed relation.

13. In well safety apparatus, including a valve unit to be lowered into a well and located therein, and a member extending upwardly toward the surface of the earth for actuating said valve unit; the improvement comprising formation of said valve unit to include a first element connectible to said member for actuation upwardly thereby and exposed to and acting against a confined body of fluid in a manner displacing a portion of said fluid in response to said upward movement of said element, a second element exposed to said confined body of fluid and actuable downwardly by the pressure of the fluid upon said upward movement of said first element, and valve means operable by said downward movement of said second element, said valve unit including a vertically extending tubular body defining a radially outer wall of a cylinder chamber containing said confined fluid, one of said elements being a tubular part defining a radially inner wall of said chamber spaced radially from said outer wall and having a piston head acting against the confined liquid at an end of the chamber, the other of said elements being an annular piston element extending telescopically into said chamber and between said inner and outer walls thereof and slidably engaging said piston head in sealed relation, said second element having a portion within said chamber which is thicker than an adjacent portion of said element and defines with said radially inner wall of said chamber a restriction between two compartments in the chamber controlling the rate of displacement of said elements.

14. In well safety apparatus, including a valve unit to be lowered into a well and located therein, and a mmeber extending upwardly toward the surface of the earth for actuating said valve unit; the improvement comprising formation of said valve unit to include a first element connectible to said member for actuation upwardly thereby and exposed to and acting against a confined body of fluid in a manner displacing a portion of said fluid in response to said upward movement of said element, a second element exposed to said confined body of fluid and actuable downwardly by the pressure of the fluid upon said upward movement of said first element, valve means operable by said downward movement of said second element, said valve unit including a tubular vertically extending body having a first smaller internal diameter portion and having therebeneath a larger internal diameter portion defining an outer wall of a cylinder chamber containing said confined fluid, said first element being an annular first piston having a tubular portion slidably received in and sealed with respect to said smaller internal diameter portion and forming a radially inner wall of said chamber and having a lower annular radially outwardly projecting piston head, said second element being an annular second piston projecting upwardly telescopically about said piston head and in engagement therewith and telescopically within said chamber and in engagement with the interior of said larger diameter portion of said body in a relation causing downward movement of said second piston element relative to the body in response to upward movement of said first piston element relative to the body, said second element having a downwardly projecting tubular portion movable downwardly therewith, a valve seat carried by said body and facing downwardly and past which said lower tubular portion of said second element is movable upon downward movement of the second element, said valve means including a flapper valve element mounted to said body for swinging movement downwardly and outwardly by said lower tubular portion of said second element and from a closed position of engagement with said seat to a downwardly projecting open position of reception in the body at the outside of said lower tubular portion of said second element, and spring means yieldingly urging said second element upwardly relative to said body.

15. The improvement in well safety apparatus as reicted in claim **14,** in which said second element has a portion received within said chamber in contact with said confined fluid and projecting radially inwardly farther than an axially adjacent portion of said second element and into close proximity with said first element to define therewith a restricted passage narrower than two upper and lower compartments of said chamber, there being an upwardly facing annular seat surface carried by said body, and engageable annularly with the lower extremity of said lower tubular portion of said second element in the lowermost position. thereof to close off access of production fluid therepast to said valve element.

16. In well safety apparatus including a body to be lowered into a well and located therein; a main valve member carried by said body and actuable between an open position passing production fluid upwardly into the interior of the body and a closed position blocking off such fluid flow; an equalizer valve element movable vertically between two different open positions in which it passes fluid through a bleed passage formed in a side wall of said body and places the exterior of the body in communication with its interior at a location above said main valve member, and a vertically intermediate closed position; an elongated member extending upwardly toward the surface of the earth and operable by vertical movement to open both said main valve element and said equalizer valve element; and a lost motion connection between said two valve elements acting to open said equalizer valve element upon initial vertical movement of said elongated member and to then open said main valve element upon further vertical movement of the elongated member, said lost motion connection being constructed to enable movement of said equalizer valve element both upwardly and

downwardly from said closed position and to both of said open positions without opening movement of said main valve element.

17. In well safety apparatus including a body to be lowered into a well and located therein, a main valve member carried by said body and actuable between an open position passing production fluid upwardly into the interior of the body and a closed position blocking off such fluid flow, an equalizer valve element movable between an open position for passing fluid through a bleed passage formed in a side wall of said body for placing the exterior of the body in communication with its interior at a location above said main valve member, and a closed position, an elongated member extending upwardly toward the surface of the earth and actuable vertically to open said main valve element and said equalizer valve element, and a lost motion connection between said two valve elements acting to open said equalizer valve element upon initial vertical movement of said elongated member and to then open said main valve element upon further vertical movement of the elongated member, said lost motion connection including a part operatively connected to said main valve element for opening the latter in response to upward movement of said part, a coacting part actuable by said elongated member and operable by both upward and downward movement relative to the body to open said bleed passage, and two springs yieldingly resisting upward and downward movement respectively of said coacting part relative to said first mentioned part.

18. The improvement in well safety apparatus as recited in claim **17**, in which said first mentioned part is a hollow vertically elongated element connectible at its upper end to said elongated member and carrying externally said equalizer valve element for movement upwardly and downwardly therewith, said coacting part including a rod projecting upwardly into the interior of said first mentioned part and operatively connected to said main valve element and having an enlargement received vertically between said two springs.

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