United States Patent [19]

Hudson

[11] **3,796,257**

[45] **Mar. 12, 1974**

[54] **SUBSURFACE SAFETY VALVE**

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[73] Assignee: **Baker Oil Tools, Inc.,** Los Angeles, Calif.

[22] Filed: **Mar. 20, 1972**

[21] Appl. No.: **236,256**

[52] **U.S. Cl.** .... **166/.5,** 166/145, 166/224 S

[51] **Int. Cl.** **E21b 7/12,** E21b 33/035

[58] **Field of Search** .... 166/.5, .6, 72, 142, 145, 166/148, 188, 224; 251/31

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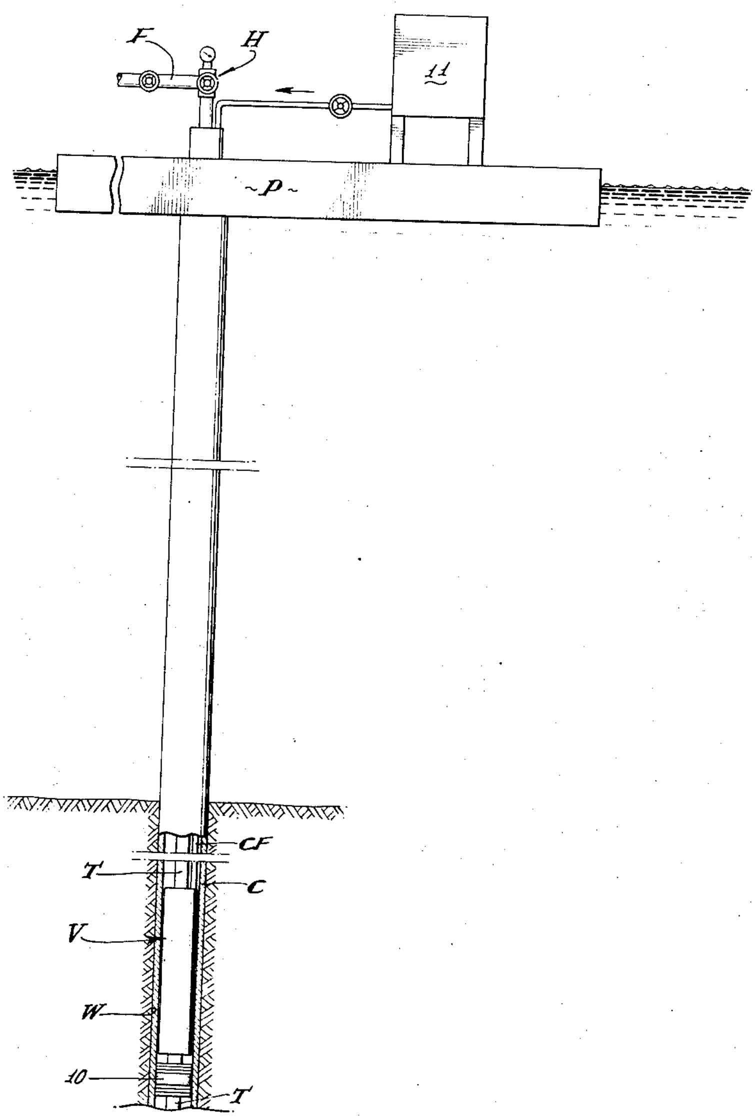
Primary Examiner—Werner H. Schroeder
Attorney, Agent, or Firm—Bernard Kriegel

[57] **ABSTRACT**

A subsurface safety valve for wells, including a ball valve closed by well fluid pressure and opened by control fluid pressure supplied from the surface. The subsurface valve includes a control fluid pressure responsive balancing valve for equalizing pressure across the closed ball valve to relieve the ball valve seating pressure. The ball valve is rotatable by support pins and is also slightly axially movable in its support. A sealing and operating sleeve below the ball valve is spring loaded upwardly. One of more additional springs are incorporated above the ball valve to assist in overcoming hydrostatic pressure in the control tubing. The subsurface valve assembly is incorporated in a production tubing string or is removably received in a seating nipple so as to be wireline retrieveable.

30 Claims, 26 Drawing Figures



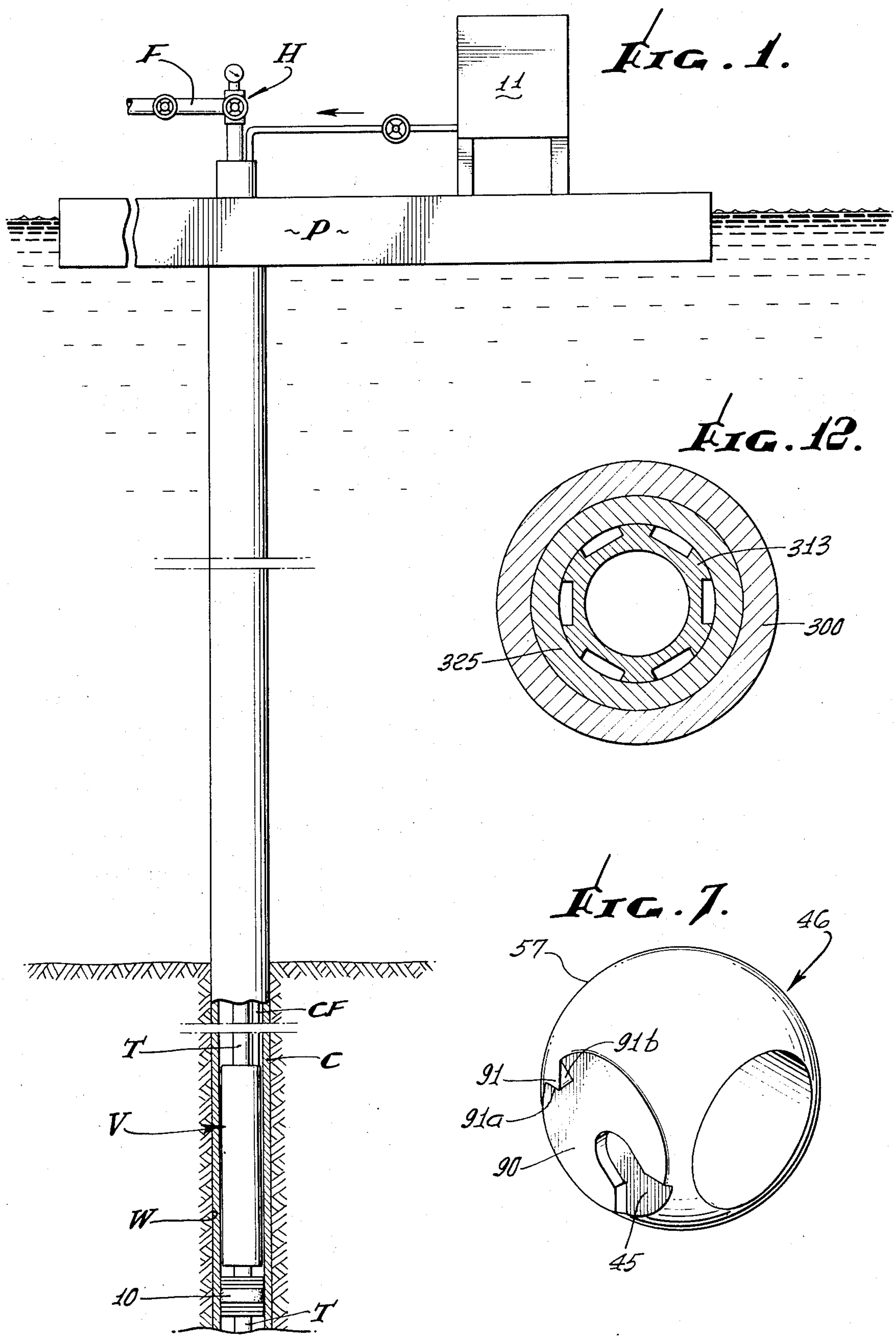


FIG. 1.

FIG. 12.

FIG. 7.

FIG. 2a.

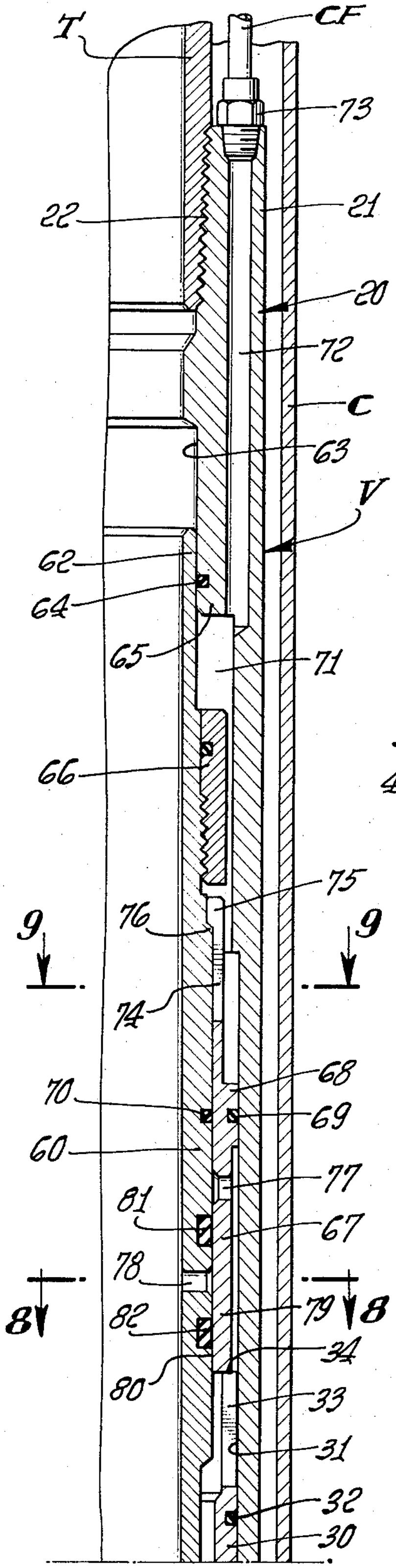


FIG. 2b.

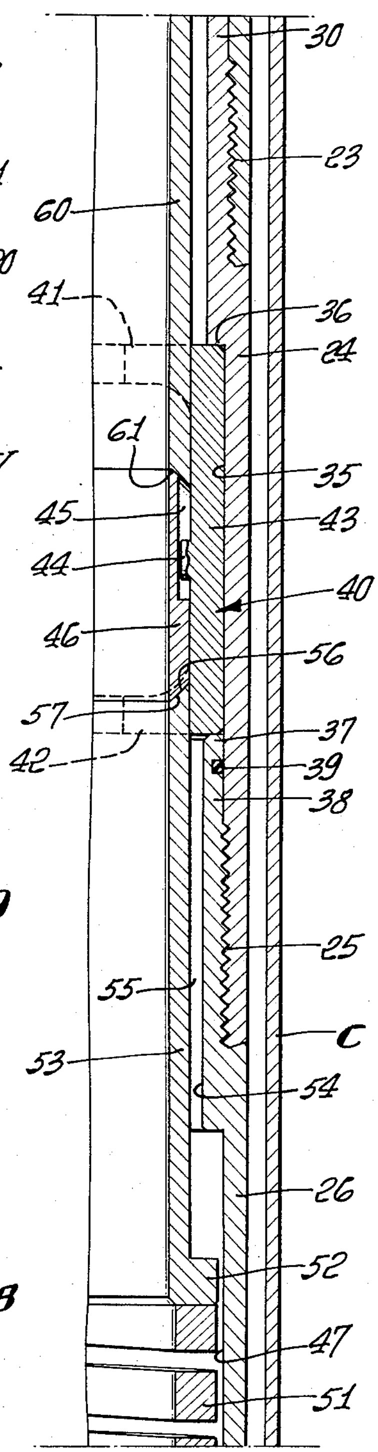


FIG. 2c.

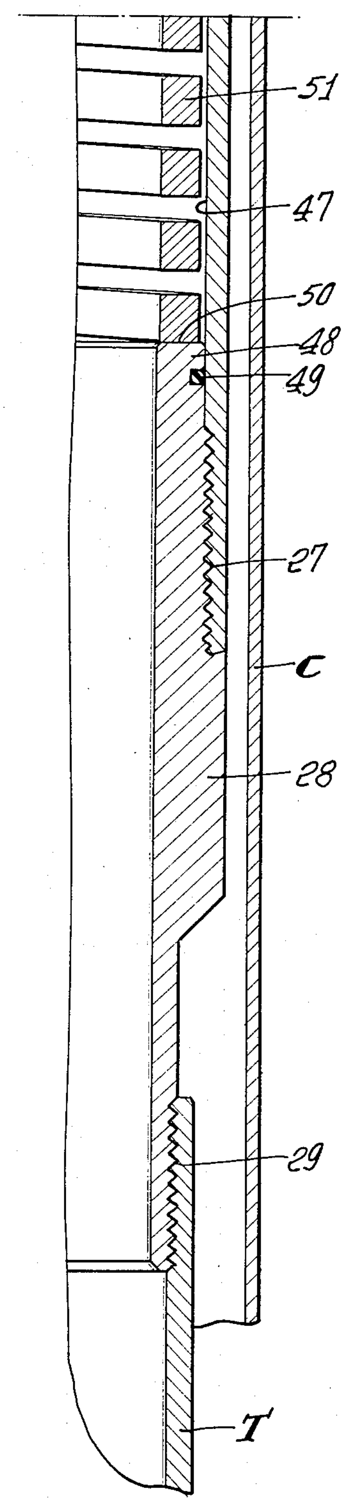


FIG. 3a.

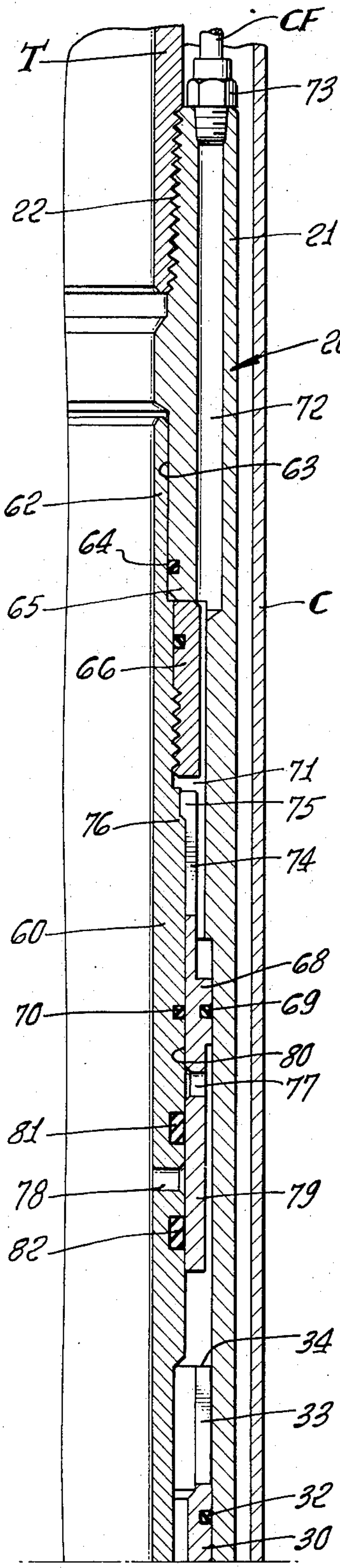


FIG. 3b.

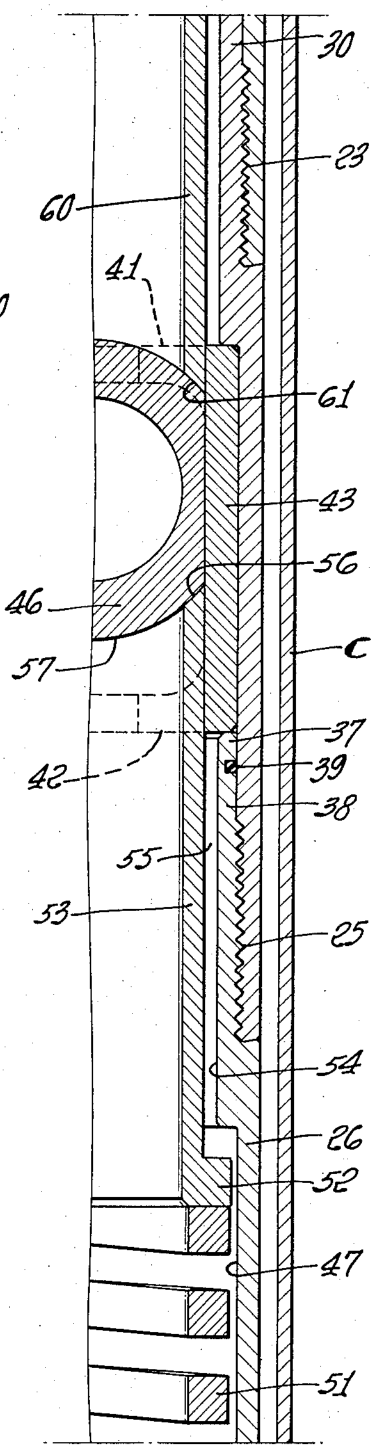


FIG. 3c.

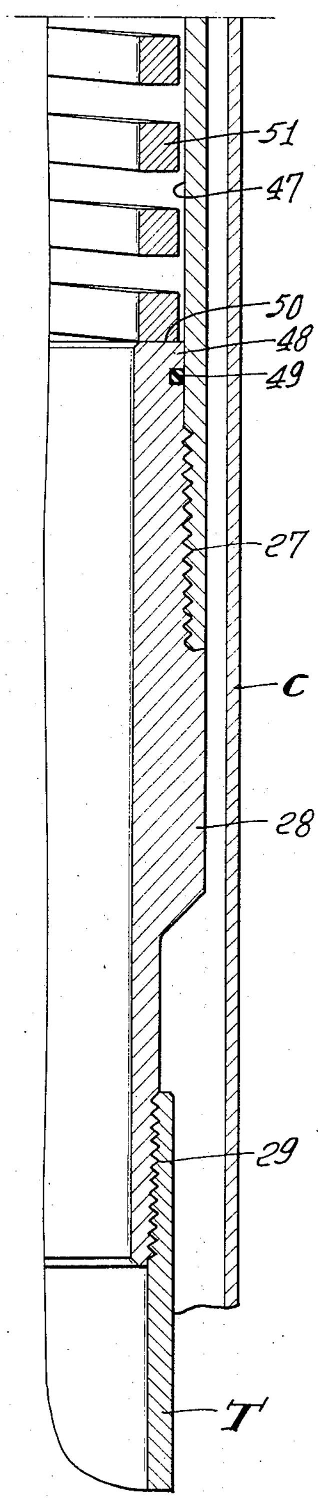


FIG. 4a.

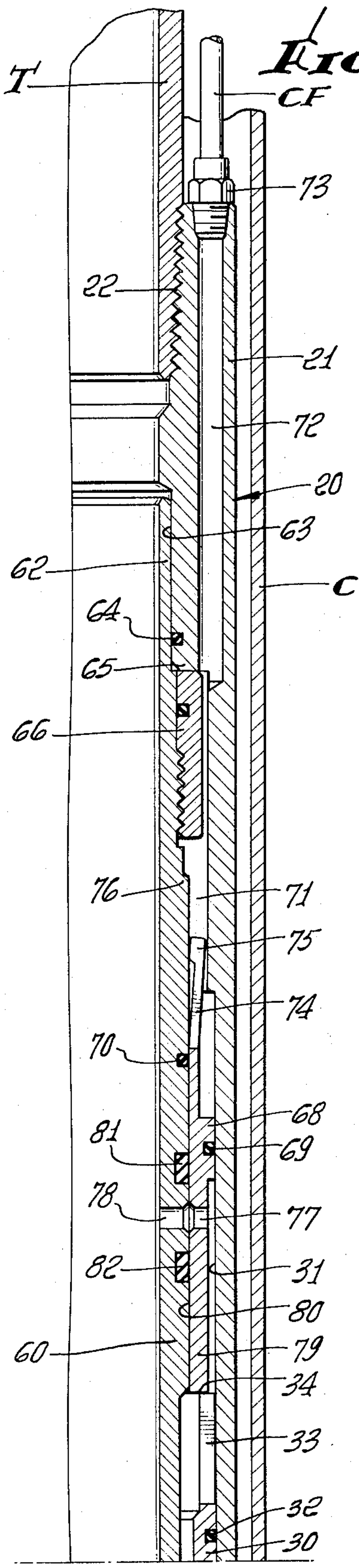

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FIG. 4b.

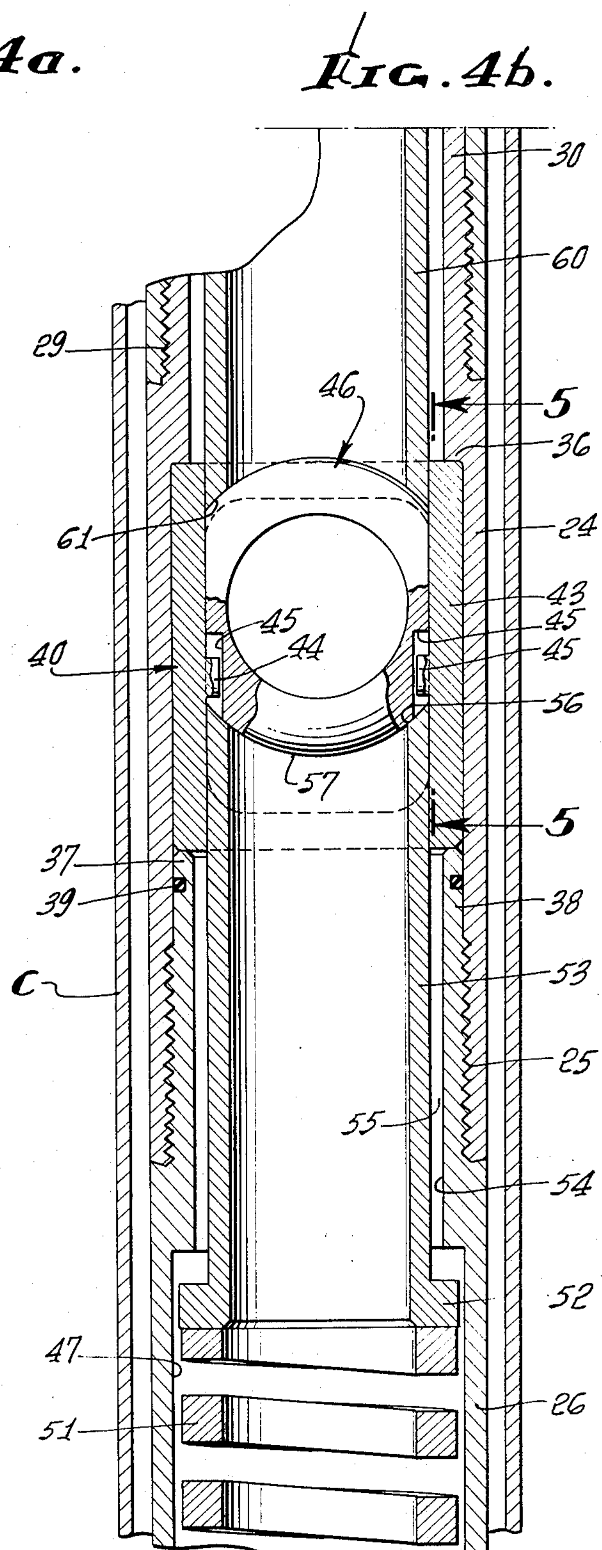
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FIG. 6.

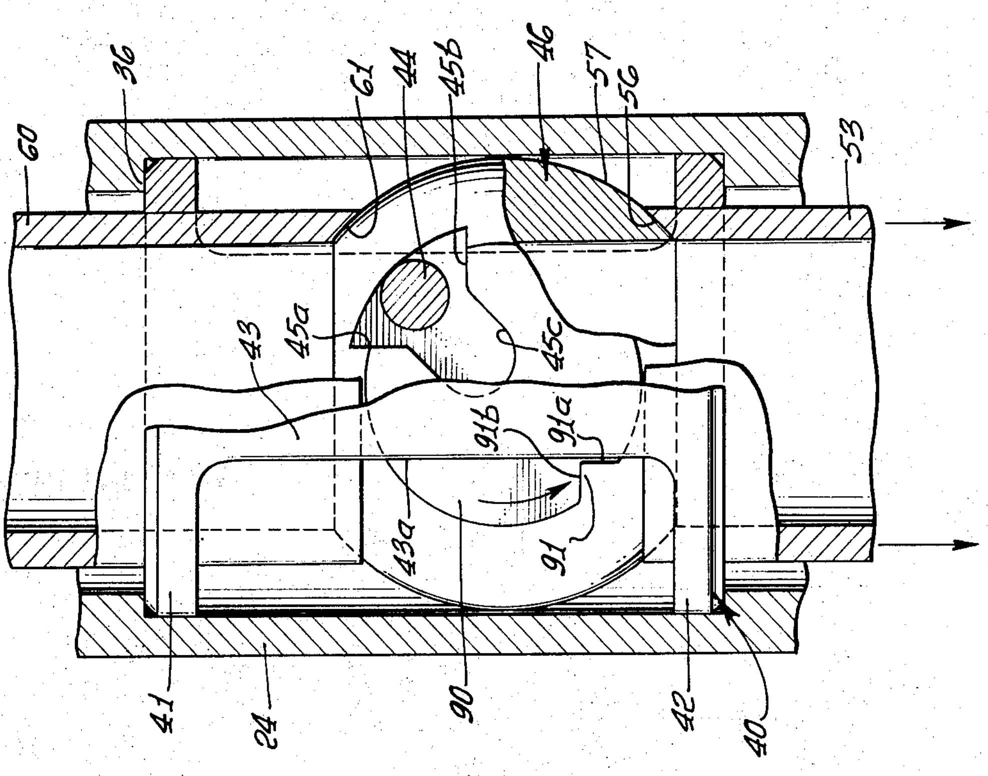


FIG. 5.

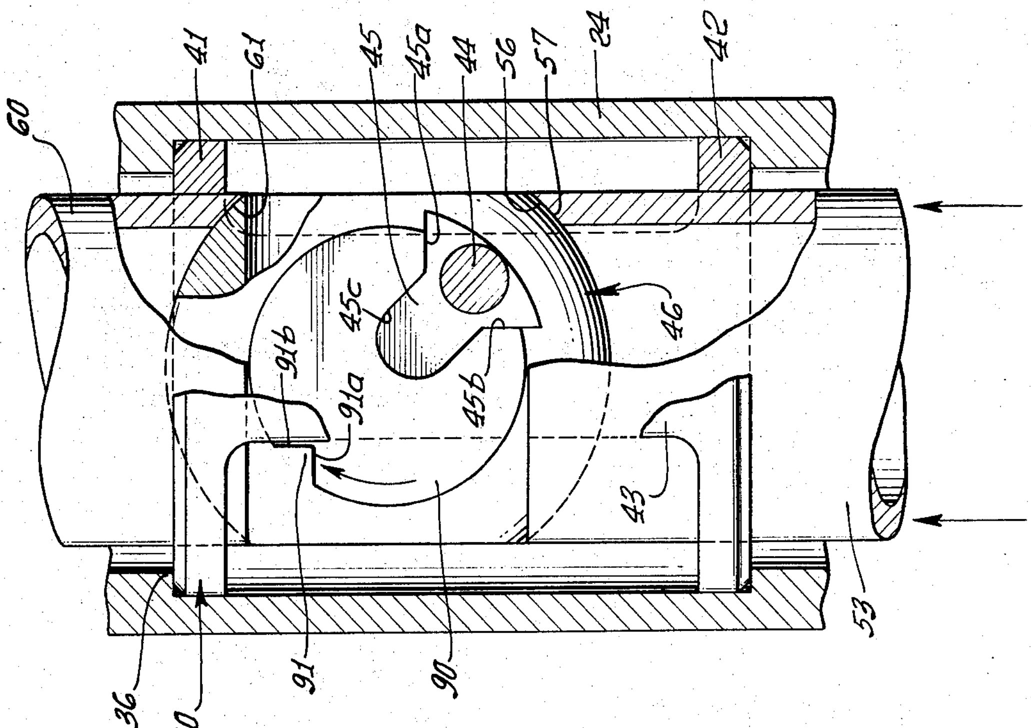


FIG. 10d.

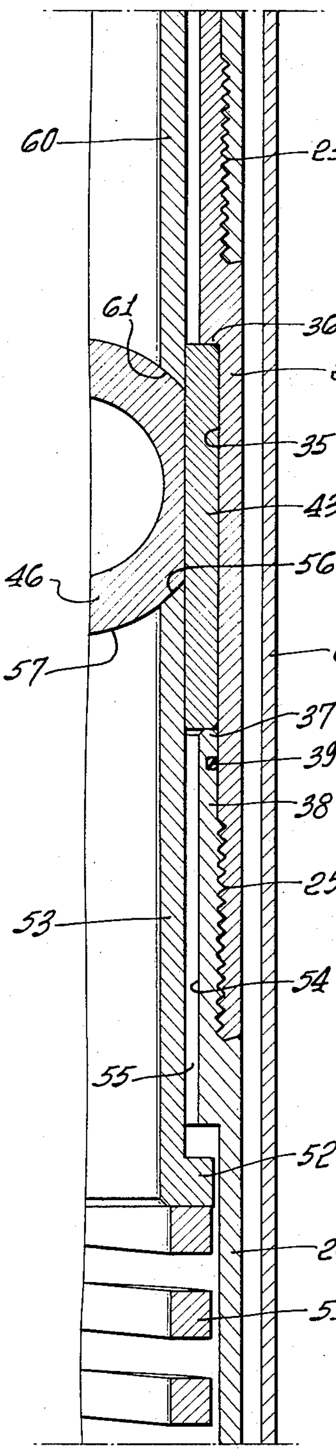


FIG. 10e.

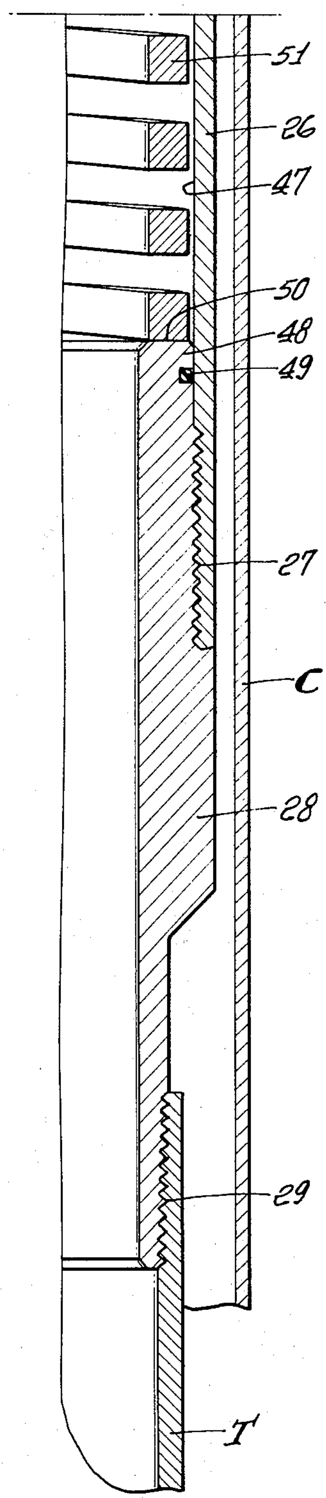


FIG. 8.

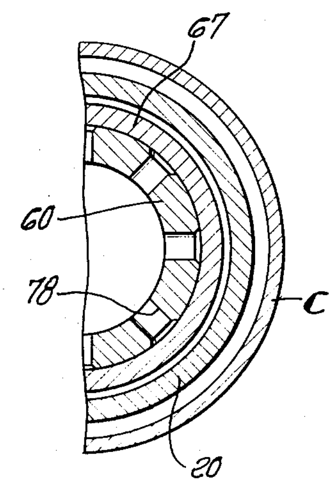


FIG. 9.

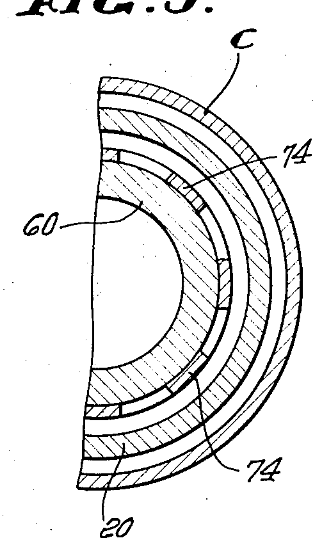


FIG. 10a.

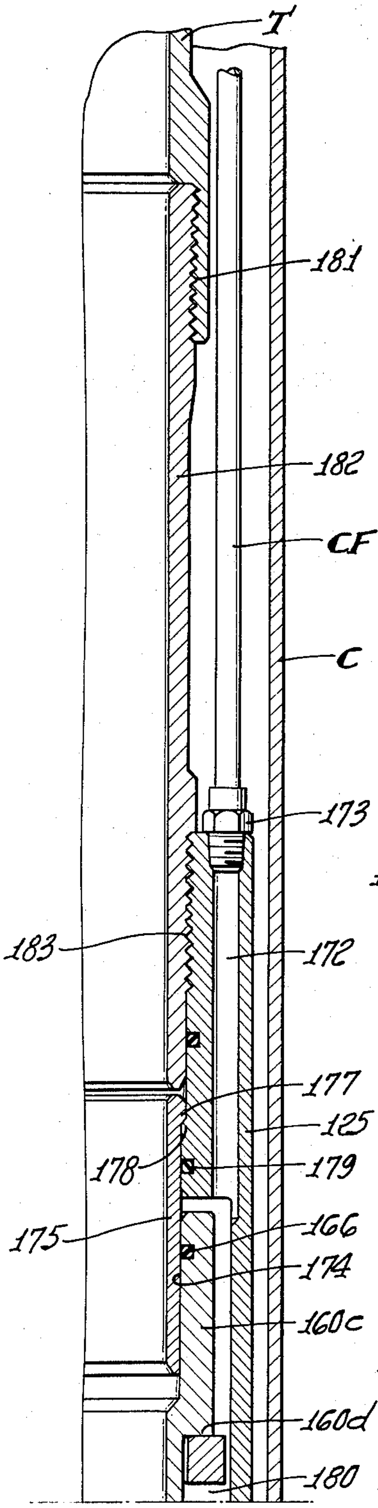


FIG. 10b.

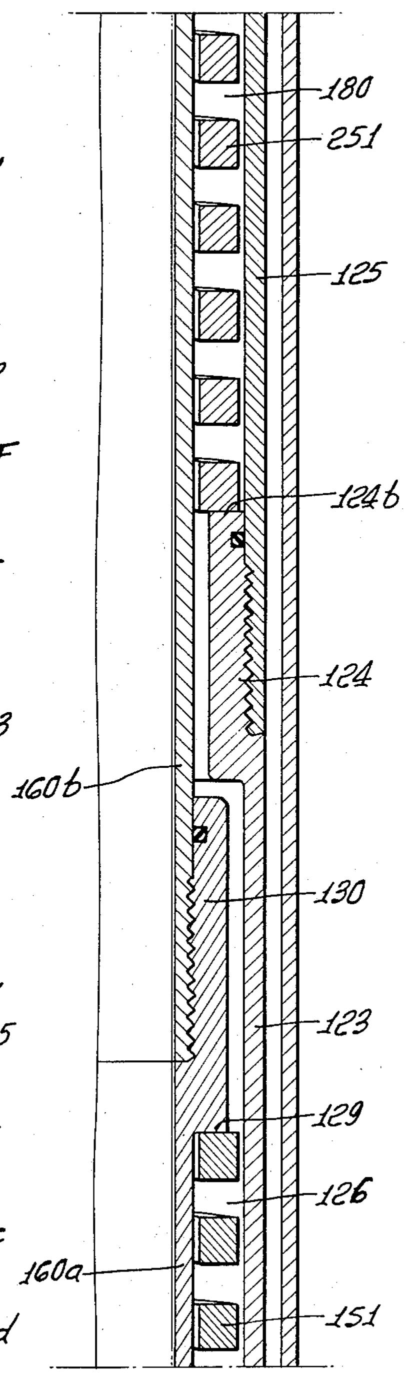


FIG. 10c.

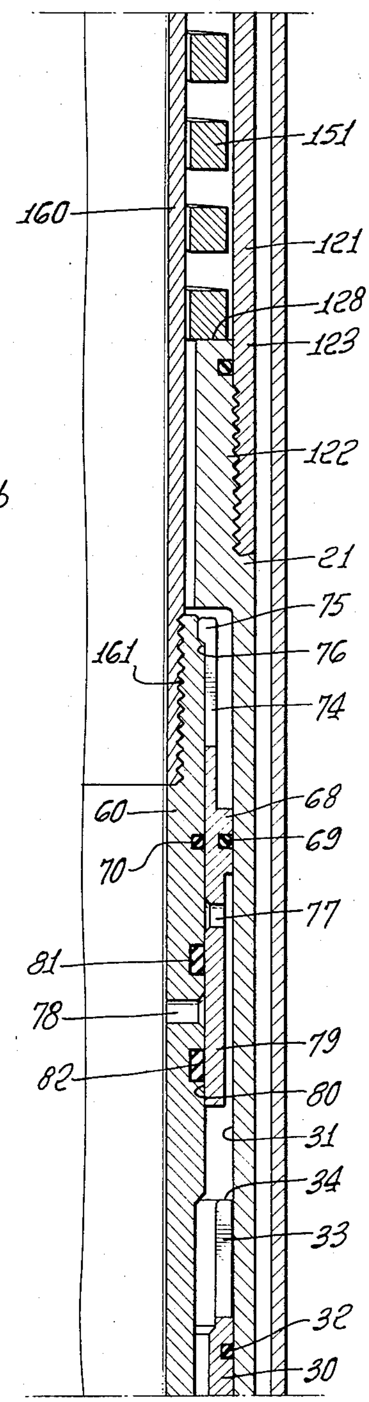


FIG. 11a.

FIG. 11b.

FIG. 11c.

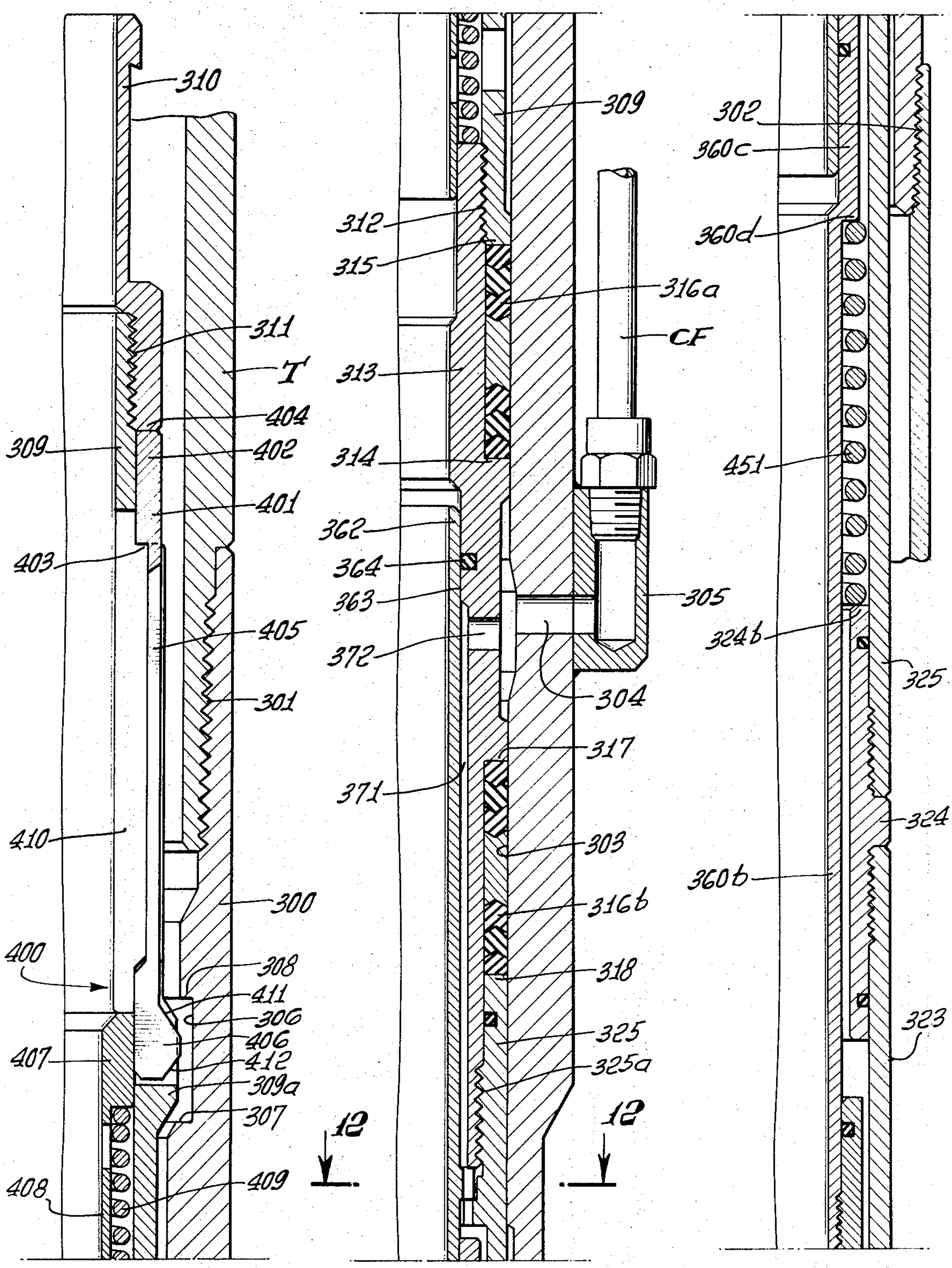


FIG. 11d.

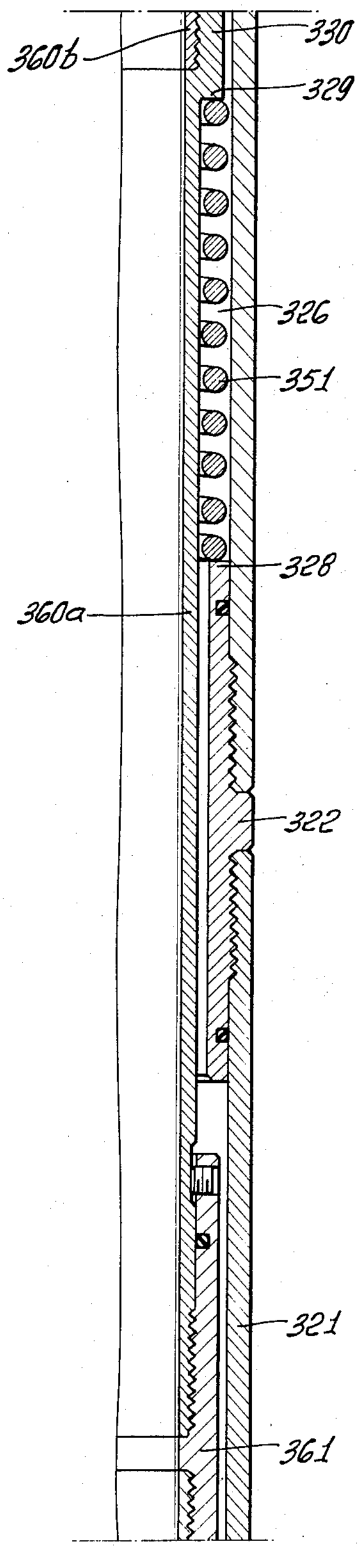


FIG. 11e.

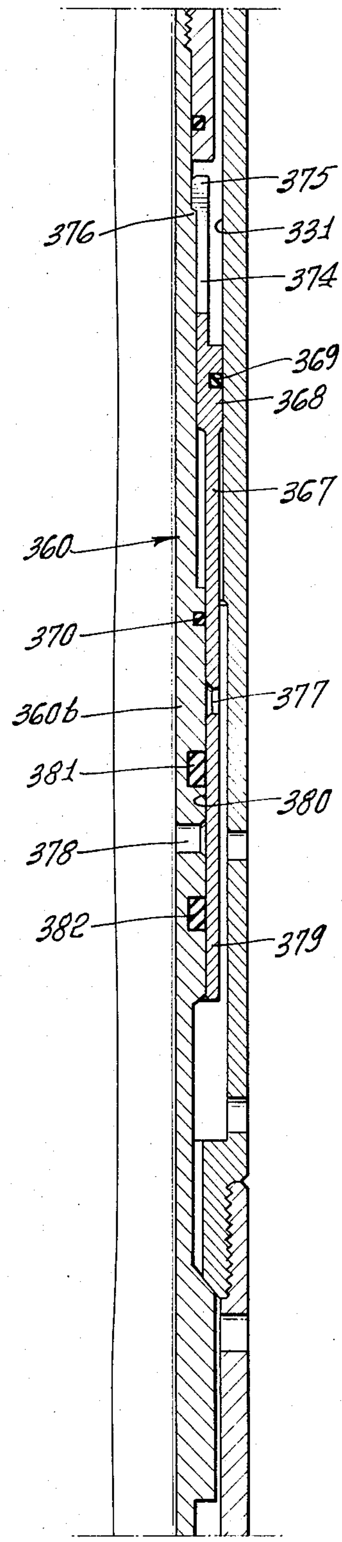
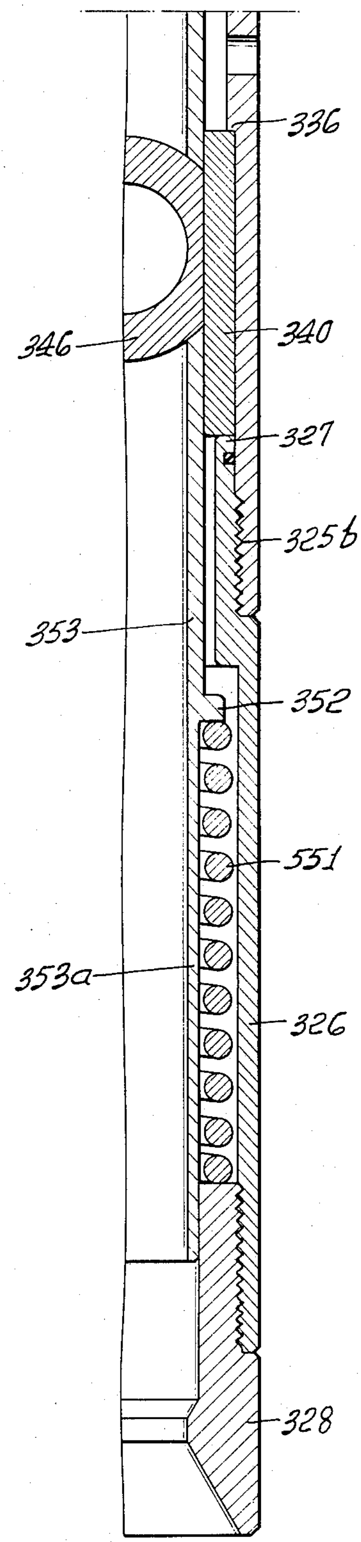


FIG. 11f.



SUBSURFACE SAFETY VALVE

In the production of well fluids, such as oil and/or gas, from wells situated at remote locations, it has become the practice to employ automatic shutoff valves which are responsive to the pressure of well fluids so as to be actuated from an opened condition to a closed condition in the event of loss of well fluids as may be caused by various circumstances. For example, it may occur that a well located at sea may suffer damage which will allow well fluids to flow into the sea, not only resulting in loss of well fluids until the well can be killed, but also resulting in contamination of the sea water and the sea shore when oil escapes into the sea and drifts ashore. It is also desirable to prevent the uncontrolled loss of well fluids from remotely located onshore wells where damage may occur to the well head equipment resulting in the uncontrolled flow of the well until it can be killed.

Various valves have been heretofore developed for the purpose of automatically shutting off such a flowing well, at a subsurface location in the production pipe string, including sleeve type valves and ball type valves which have a substantially full bore opening therethrough and thereby cause no substantial restriction to flow. However, such ball valves experience operating difficulties, particularly when they are being opened and the well fluid pressure below the valve which is holding the valve closed is substantial. causing a high friction loading between the sealing faces and the surface of the ball with which they are sealingly engaged. Indeed, the operating means for shifting the ball to an open position may in some instances be destroyed.

More recently, as shown and described in the application for U.S. Letters Patent of T. L. Crowe, Ser. No. 243,806, filed Apr. 13, 1972, for Dual Safety Valve Method and Apparatus, ball valves for use as subsurface safety valves for wells have been developed, wherein the ball is more easily shifted from its closed to its open position by reason of the incorporation in the valve assembly of by-pass or equalizing valve means responsive to the pressure of control fluid to establish communication between the flow passage at opposite sides of the ball valve before the ball valve is opened. In addition, the ball is supported for rotation by means which allow slight lost motion between the valve and the support during the first and last stages of ball rotation between open and closed positions, so that the ball support is not subjected to pressure differentials which may load the ball.

The present invention involves the provision of an automatic subsurface shutoff valve of the ball type, wherein the ball is easy to manipulate from the closed to the open position, notwithstanding high well fluid pressure tending to hold the valve closed.

The present invention involves the provision of a control fluid operated by-pass valve incorporated in the control fluid pressure chamber of the shutoff valve assembly, so that as control fluid pressure is being supplied to open the subsurface valve, the pressure differential across the shutoff valve is first equalized, and then the shutoff valve is shifted to the open position.

In addition to the foregoing, the present invention provides a subsurface shutoff valve assembly wherein actuation of the ball valve to the closed position is assisted by a spring, so that even in the absence of sufficient well pressure to assure closure of the shutoff valve, the latter will be nevertheless closed and the

sealing effectiveness of the valve will be maintained. Depending upon the anticipated subsurface well pressure and on the depth at which the subsurface shutoff valve is to be located in the production pipe string, an additional spring or additional springs are employed to supplement the spring force of the first-mentioned spring in overcoming the hydrostatic pressure of control fluid acting on the mechanism and tending to hold the valve open, but the supplemental springs do not apply a force to the mechanism which maintains the sealing contact between the ball shifting and sealing sleeve which is actuated by the first-mentioned spring. Thus, the valve is more smoothly and easily operable.

The subsurface valve of the invention may be incorporated in a string of production tubing and run into the well in the tubing string, and control fluid is supplied through an auxiliary control tubing extending into the well along side the production tubing. Alternatively, if the well is to be produced through the casing above the shutoff valve, the shutoff valve assembly may be run into and latched in place in a seating nipple and may be retrieved from the seating nipple by wireline tools. In this latter case, the control tubing from an appropriate source of control fluid pressure is connected to the seating nipple.

This invention possesses many other advantages, and has other purposes which may be made more clearly apparent from a consideration of forms in which it may be embodied. These forms are shown in the drawings accompanying and forming part of the present specification. They will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed descriptions are not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIG. **1** is a diagrammatic view illustrating an offshore well in which a subsurface automatic shutoff valve has been installed;

FIGS. **2***a*, **2***b* and **2***c* together constitute a longitudinal quarter section showing one form of automatic shutoff valve embodying the invention, with the valve in the open condition, FIGS. **2***b* and **2***c* respectively constituting successive downward continuations of FIG. **2***a;*

FIGS. **3***a*, **3***b* and **3***c* together constitute a longitudinal quarter section corresponding to FIGS. **2***a* through **2***c*, but showing the valve in the closed condition, FIGS. **3***b* and **3***c* respectively constituting successive downward continuations of FIG. **3***a;*

FIGS. **4***a* and **4***b* together constitute a fragmentary longitudinal section of the portions of the valve assembly seen in FIGS. **2***a* and **2***b* and **3***a* and **3***b* showing the valve in the closed position but in a pressure balanced condition, with the by-pass valve open, FIG. **4***b* being a downward continuation of FIG. **4***a;*

FIG. **5** is a fragmentary detail view in vertical section, with certain parts broken away, as taken on the line **5—5** of FIG. **4***b;*

FIG. **6** is a view corresponding to FIG. **5**, but showing the valve rotated to the open position;

FIG. **7** is a detailed view in perspective of the ball valve;

FIG. **8** is a horizontal section as taken on the line **8—8** of FIG. **2***a;*

FIG. **9** is a horizontal section as taken on the line **9—9** of FIG. **2***a;*

FIGS. **10***a*, **10***b*, **10***c*, **10***d* and **10***e* together constitute a longitudinal quarter section of another form of a subsurface automatic shutoff valve embodying the invention, and shown in a closed condition, FIGS. **10***b* through **10***e* respectively constituting a successive downward continuations of FIG. **10***a;*

FIGS. **11***a*, **11***b*, **11***c*, **11***d*, **11***e* and **11***f* together constitute a longitudinal quarter section of still another form of a subsurface automatic shutoff valve embodying the invention, and shown in a closed condition, FIGS. **11***b* through **11***f* respectively constituting successive downward continuations of FIG. **11***a;* and

FIG. **12** is a horizontal section as taken on the line **12—12** of FIG. **11***b*.

As seen in the drawings, referring first to FIG. **1**, an automatic shutoff valve assembly V is installed in a string of well production tubing T which extends downwardly through a well casing C which is set in a well bore W. The tubing T and casing C extend upwardly through a body of water to a platform P. On the platform is a conventional valved tubing head H from which a flow line F extends, the flow line being adapted to conduct well fluids to a suitably located reservoir. A packer **10** is set in the casing C and forms a seal between the tubing T and the casing below the valve assembly V and the latter is adapted to remain open, as will later be described, only so long as it is supplied with suitable control fluid pressure from a pressure source **11** through a string of control fluid tubing CF which extends downwardly through the casing C from the pressure source **11** to the valve assembly V.

Referring to FIGS. **2***a* through **9**, one form of subsurface valve assembly V is shown. In this form, the valve assembly comprises an elongated tubular outer body **20** including an upper body section **21** which is threadedly connected at **22** to the lower end of the tubing string T above the valve assembly, the upper body section **21** being threadedly connected at **23** at its lower end to an intermediate body section **24** which extends downwardly and which is threadedly connected at **25** to a lower body section **26**, the latter being threadedly connected at **27**, at its lower end, to a connector sub **28** which is in turn threadedly connected at **29**, at its lower end, to the tubing string T extending downwardly in the well bore below the valve assembly. The intermediate body section **24** has an upwardly extended cylindrical section **30** disposed within a complemental bore **31** in the upper body section **21**, and suitable seal means **32** carried by the cylindrical section **30** sealingly engages within the bore **31**. Above the seal **32**, the cylindrical end **30** has a suitable number of upwardly extended and circumferentially spaced fingers **33** providing an upwardly facing shoulder **34**, the purpose of which will be later described. The intermediate body section **24** has an internal bore **35** and a downwardly facing internal shoulder **36** which is opposed by an upwardly facing shoulder **37** provided at the upper end of the lower body section **26**. Beneath the shoulder **37**, the body section **26** has a cylindrical end section **38** which carries a side ring seal **39** engaged within the bore **35**. Interposed between the downwardly facing shoulder **36** and the upwardly facing shoulder **37** is a valve carrier or supporting member **40** which, as best seen in FIGS. **5** and **6**, consists of circumferentially extended upper and lower end rings **41** and **42**, respectively, and a pair of diametrically spaced longitudinally extended valve supporting ribs or bars **43** interconnecting the end rings **41** and **42.** The bars **43** have inwardly extended opposing pins **44** each engaged in a slot **45** in the adjacent side of a ball valve member **46**, whereby, as weill be later more fully described, the ball valve **46** is adapted to be actuated between the open or flowing condition of FIGS. **2***a* through **2***c* and Fig. **6**, and the closed or non-flowing condition of FIGS. **3***a* through **3***c* and FIG. **5.**

The lower body section **26** has an internal bore **47** which receives an upper cylindrical end portion **48** of the connector sub **28**, the latter having a side ring seal **49** sealingly engaged in the bore **47**, below the upper end surface **50** of the sub **28**. This end surface **50** constitutes an abutment or seat for a coiled compression spring **51** which is disposed within the bore **47** and has a diameter within its convolutions preferably greater than the flow passage in the valve assembly.

The spring **51** is a valve actuating spring and seats or abuts at its upper end with a lower end flange or abutment **52** on a lower valve operating and sealing sleeve **53** which is reciprocable within a reduced bore **54** in the lower body section **26** which has longitudinally extended and circumferentially spaced channels **55** to enable the free flow of fluid, as will be later described. At its upper end, the valve operating and sealing sleeve **53** has an annular, spherical seating surface **56** adapted for abutting and sealing engagement with a companion spherical valve surface **57** on the valve member **46.**

Reciprocable within the outer body **20** above the valve member **46**, is an upper valve actuating and sealing sleeve **60** which has at its lower end a spherical valve engaging and sealing surface **61** engageable with the spherical surface **57** of the valve member **46.** The upper valve sleeve **60** extends upwardly in radially inwardly spaced relation within the outer, upper body section **21**, and has at its upper extremity a cylindrical end section **62** extending reciprocably into a bore **63** of the outer body section **21**, the latter having a side ring seal **64** slidably and sealingly engaging the cylindrical section **62** of the sleeve **60** above a radially inwardly extended cylinder head portion **65** of the body section **21.** Provided on the valve sleeve **60**, below the cylinder head **65** is a radially outwardly extended piston **66.**

Carried by the sleeve **60** within the bore **31** of the body section **21** is a by-pass valve sleeve **67**, in accordance with the invention, having an intermediate annular piston section **68** provided with an external seal **69** slidably engaging within the bore **31.** An internal seal **70** is carried by the sleeve **60** and slidably engages within the by-pass valve sleeve **67.** Thus, it is now apparent that between the annular piston **68** and the cylinder head **65** there is defined a longitudinally extended annular pressure chamber **71** to which control fluid is admitted through an elongated passage **72** in the outer body section **21** which opens into the pressure chamber **71** at the cylinder head **65** and to which the control fluid conduit or tubing CF is connected by a suitable fitting **73.** The effective pressure responsive area of the sleeve **60** in the chamber **71** is the difference between outside diameter of the sleeve **60** on which the valve sleeve **67** is disposed and the reduced diameter, upper end **62** of the sleeve **60.**

The above-mentioned by-pass valve sleeve **67** is adapted to be normally held in the position shown in FIG. **2***a* by means of a plurality of upwardly extended, normally inwardly retracted but resiliently outwardly expansible collett or latch fingers **74** which have inwardly extended lugs **75** at their upper ends engageable with an outwardly projecting shoulder **76** on the sleeve **60.** Beneath the piston section **68,** the by-pass valve sleeve **67** has a suitable number of radial by-pass ports **77** which in one position of the sleeve **67,** as seen in FIG. **2***a*, are spaced above a suitable number of radial ports **78** in the sleeve **60,** but in a second position, as seen in FIG. **4***a*, when the latch fingers **74** are released and the by-pass valve sleeve **67** has been shifted downwardly, the ports **77** and **78** are in communication. The lower unported section **79** of the by-pass valve sleeve **67** provides an inner cylindrical surface **80** engaged by upper seal ring means **81** and lower seal ring means **82** between which the ports **78** are disposed, so that, in the normal position of FIG.**2***a*, well fluid pressure cannot by-pass the valve sleeve **67.**

When the valve actuating and sealing sleeve **60** is in the position of FIGS. **2***a* and **2***b*, which is a lower position relative to the valve body **20,** the valve member **46** is in the open position, and the end sealing surface **61** of the sleeve **60** is biased into engagement with the spherical surface **57** of the valve member **46** by the pressure of control fluid in the chamber **71** acting downwardly on the sleeve **60.** This downward force is transmitted through the valve member **46** to the lower valve operating and sealing sleeve **53** through the sealing surface **56** at the upper end of the latter and the spherical surface **57** of the valve member **46** and compresses the spring **51.** Under these circumstances, the ball valve member **46** is in the open position, and the relationship of the ball valve actuating pins **44** and the slot **45,** previously referred to, is best seen in FIG. **6,** it being understood that the ball valve member **46** has identical slots **45** at its opposite sides engaged by diametrically opposite pins. More particularly, the ball valve member **46** on each of its opposite sides has a chordal flat surface **90** adjacent to the diametrically opposite bars **43** of the ball carrier **40.** The slot **45** extends radially with respect to the axis of rotation to the ball valve member **46,** and in radial alignment with the slot **45,** a stop lug **91** projects outwardly from the flat surface **90** and provides a pair of right angularly related stop surfaces **91***a* and **91***b*. When the ball valve member **46** is in the position of FIG. **6,** the stop surface **91***a* engages the vertical side wall **43***a* of the adjacent bar **43,** thereby limiting rotation of the valve member **46** in the direction of the arrow to the position at which the valve is open. The stop surface **91***b* on the stop lug **91** engages the bar surface **43***a*, as shown in FIG. **5** to limit rotation of the valve member **46** to the position at which the valve is closed. Such rotation between the open and closed positions is caused by longitudinal or vertical movement of the valve member **46** within the carrier **40,** the two longitudinal extremes being shown in FIGS. **5** and **6.** As previously indicated and as will later be more fully described, the ball member **46** is actuated or shifted longitudinally by longitudinal movement of the upper actuator sleeve **60** and the lower actuator sleeve **53,** as indicated by the arrows in FIGS. **5** and **6.** The slot **45** is formed in such a manner as to cause such rotation of the valve member **46** as the latter moves vertically or longitudinally within the carrier **40.** Thus, as seen in FIGS. **5, 6** and **7,** the slot **45** is formed in the valve member **46** by opposed walls which are disposed at a right angle to one another and designated **45***a* and **45***b* and which respectively are parallel to the stop surfaces **91***a* and **91***b*. At the apex of the angle defined between the walls **45***a* and **45***b*, the slot opens radially inwardly at **45***c*. Thus, the relationship between the pin **44** and the wall **45***a* is such that the ball valve **46** will be rotated from the position of FIG. **5** to the position of FIG. **6** when the valve member **46** moves downwardly relative to the pin **44,** and, conversely, the flat wall **45***b* will engage the pin **44** and rotate the ball valve member from the position of FIG. **6** to the position of FIG. **5** upon upward movement of the valve member **46.** However, it will be noted that when the valve member **46** is in the position of FIG. **5,** the pin **44** clears the flat wall **45***b* so as to allow freedom of longitudinal movement of the ball valve **46** after the stop surface **91***b* engages the bar wall **43***a*, and correspondingly limited free downward movement of the ball valve **46** is permitted when the ball valve is open, as seen in FIG. **6,** and the pin **44** clears the slot wall **45***a* when the stop surface **91***a* engages the side wall **43***a* of the bar **43.** Such free or lost motion connection of the ball valve **46** and the rotating pin **44** relieves the connection of damaging forces when the ball valve is in either of its closed or opened positions.

The operation of the form of the invention described above is as follows:

The tubing string T with the valve assembly V installed therein is run into the well to the desired location, the packer **10** sealing off the annulus between the tubing and the casing C and the control fluid conduit is simultaneously run into the well with the tubing T. Under normal conditions, the valve assembly V will be in the condition shown in FIGS. **3***a* through **3***c*, as it is being run into the well, wherein the actuator spring **51** biases the actuator and valve seating sleeve member **53** upwardly into sealing engagement with the ball valve **46,** so that the latter is held by the force of the spring **51** in the closed position of FIG. **5.** Upward movement of the upper actuator sleeve **60** is limited by engagement of the upper end of the piston **66** in the control fluid pressure chamber **71** with the cylinder head **65,** and the ball valve **46** is therefore compressively engaged between the lower actuator sleeve **43** and the upper actuator sleeve **60** under the influence of the spring **51** and the differential pressure caused by fluid in the well acting on the differential pressure responsive area of the lower actuator sleeve **53** when its sealing surface **56** is in sealing engagement with the ball valve **46.**

When it is desired that the subsurface valve be opened to enable the well to be produced, control fluid pressure is introduced into the chamber **71** via the control fluid tubing CF from the source **11.** Such control fluid pressure acts on the piston **68** of the by-pass valve sleeve **67** to force the latter downwardly from the position of FIG. **3***a* to the position of FIG. **4***a*. The control fluid pressure acting on the piston **68** overcomes the resilient latch fingers **74** causing them to be cammed outwardly and released from the shoulder **76.** When the by-pass valve ports **77** in the valve sleeve **67** and **78** in the actuator sleeve **60** are in registry, fluid communication is established through the longitudinal passages **55** in the lower body section **26** and around the exterior of the ball valve **46,** through the open by-pass valve means, and into the tubing T above the closed ball valve **46.** Thus, when the fluid in the tubing T is equalized below and above the ball valve **46,** shifting of the latter from the closed position to the open position is facilitated and frictional co-engagement of the sealing sleeve surfaces **56** and **61** with the sealing surface **57** of the ball valve **46** is substantially reduced.

Thereupon, to open the ball valve **46**, control fluid pressure in the control fluid pressure chamber **71** may be increased, to overcome friction, if necessary, so as to act upon the piston area of the actuator sleeve **60** to force the latter downwardly from the position of FIG. **4***a* to the position of FIG. **2***a*. During such downward movement, the by-pass valve **67** is prevented from moving further downwardly by abutting engagement with the ends **34** of the circumferentially spaced stop fingers **33.** As the sleeve **60** moves downwardly, the ball valve **46** will be moved correspondingly downwardly, and when the wall **45***a* of the respective slot **45** contacts the stationary actuator pins **44,** the ball valve **46** will then be rotated counterclockwise until the stop surface **91***a* contacts the stop wall **43***a* of the ball valve carrier **40,** at which time, as seen in FIG. **6,** the flat wall **45***a* and the pin **44** are cleared for enabling all of the longitudinal forces to be transmitted from the actuator sleeve **60** through the sealing surfaces **61, 57** and **56** and applied to the spring **51,** without applying any of such force to the ball valve rotating pin and slot means. The well may then be produced so long as the pressure in the control fluid pressure chamber **71** causes a downward force on the sleeve **60** which exceeds the opposing upward force caused by the combination of the spring **51** and pressure acting on the lower actuating sleeve **53.**

If, for whatever reason, control fluid pressure is reduced, say by reason of damage occurring to the control fluid conduit CF between the valve assembly V and the platform P, or if it is desired, for some other reason control fluid pressure is reduced to shut the well in, then the spring **51** and well fluid pressure will act upwardly on the lower actuator sleeve **53,** overcoming the remaining downward force caused by control fluid pressure. As the actuator sleeve **53** moves the ball valve **46** upwardly, the pins **44** will contact the respective flat walls **45***b* of the slots **45,** to cause rotation of the valve **46** in a clockwise direction, from the position of FIG. 6 to the position of FIG. **5,** until the stop surface **91***b* on the ball valve **46** contacts the stop surface **43***a* on the ball carrier **40.** Thereafter, the closed ball valve and the respective actuator sleeves **53** and **60** may move upwardly until the piston **66** contacts the cylinder head **65,** and thereupon the ball valve **46** will be compressively engaged between the actuator sleeves **53** and **60** under the influence of the spring **51** and the well fluid pressure below the valve assembly.

It will be apparent from the foregoing, that the force of the spring **51** required to automatically close the valve, to some extent, depends upon the depth of the well at which the valve assembly V is located, i.e., on the hydrostatic pressure of the column of control fluid above the valve assembly. Thus, the spring **51** in the above-described embodiment must be strong enough to overcome the hydrostatic head of the control fluid. A modified form of the invention is shown in FIGS. **10***a* through **10***e* enabling the use of one or more supplemental springs located above the ball valve and acting to assist in overcoming the hydrostatic pressure of control fluid, with the result that the force of the spring below the ball valve may be significantly reduced, so as to merely move the lower actuator sleeve **53** against the ball valve with sufficient force to rotate the ball **46** to a closed position, when the upper actuator sleeve **60** moves upwardly, and to maintain initial sealing contact between the ball and actuator sleeve sealing surfaces. As shown in FIGS. **10***c*, **10***d* and **10***e*, the by-pass valve means, the ball valve means, the respective actuator sleeves, and the lower spring all correspond to the embodiment described above, and therefore the same reference characters are applied.

However, it will be noted that above the by-pass valve sleeve **67,** the upper body section **21** and the upper valve actuator sleeve **60** are modified and are composed of modules or spring units respectively including an outer tubular body **121** and an inner tubular body **160.** More particularly, the body section **21,** as seen in FIGS. **10***a* through **10***c*, is provided with an externally threaded neck **122** to which is connected an upwardly extended outer sleeve section **123,** at the upper end of which is an externally threaded neck **124.** The body **121** then includes an uppermost section **125** threaded to the neck **124** and having at its upper end the control pressure fluid inlet **172** connected by the control pressure fitting **173** to the control fluid conduit CF. The inner sleeve or body assembly **160** includes a lower tubular member **160***a* which is threadedly connected at **161** to the upper end of the sleeve **60** and extends upwardly within the outer body section **123** to define an annular space **126** therebetween. Within this annular space **126,** is a coiled compression spring **151** interposed between the upwardly facing end **128** of the threaded neck **122** and a downwardly facing shoulder **129** on an internally threaded coupling end **130** of the member **160a.**

Threaded into the coupling end **130** of the inner body member **160***a* is an upwardly extending tubular section **160***b*, this member **160***b* having at its upper end an enlarged end section **160***c* providing a downwardly facing shoulder **160***d* which is opposed to the upper end **124***b* of the neck **124** of the outer body section **123.** Between the shoulders **160***b* and **124***b* is another coiled compression spring **251** which exerts a force upwardly on the actuating sleeve extension **160.** Disposed within a bore **174** within the end **160***c* of the sleeve extension **160***b*, there is slidably engaged a sealing sleeve **175** engaged by a side ring seal **166** carried by the sleeve **160***c*. At its upper end, the sealing sleeve **175** has an outwardly extended shoulder **177** which seats on an internal shoulder **178** within the upper body extension **125,** another side ring seal **179** engaging the sealing sleeve **175** to confine control fluid pressure within the annular space **180** containing the spring **251.** In this embodiment, the tubing T is connected at **181** to a connector sub **182** which is threaded, as at **183,** into the upper end of the upper, outer body extension **125.** Accordingly, it will now be seen that the control fluid inlet **172** communicates with the annular space **180** and through the neck **124** with the annular space **126** which in turn communicates through the neck **122** with the by-pass valve piston chamber to expose the by-pass valve piston **68,** as seen in FIG. **10***c*, to control fluid pressure and the piston area of the actuator sleeve **60** is responsive to the pressure of control fluid to provide a downward force to overcome the combined force of the springs **51, 151** and **251.** Thus, the spring **51** below the ball valve **46** need not be so strong as to overcome the hydrostatic pressure of the control fluid. When the valve assembly V is to be utilized in deeper locations in the well bore where the control fluid pressure is greater, then additional spring modules comprising an inner actuator sleeve extension and an outer body extension, as well as a compression spring, may be employed.

The subsurface shutoff valve invention may also be incorporated in an assembly which is adapted to be run into the well and retrieved on a wireline tool, such an assembly being shown in FIGS. **11***a* through **11***f*.

In this embodiment, the production pipe T has a landing and seating nipple **300** threadedly connected at **301** and **302** in the pipe T. The seating nipple **300** has an inner cylindrical wall **303** and an inlet passage **304** leads into the nipple from a connector **305** to which control fluid is supplied from the control fluid conduit CF. Adjacent to its upper end, the nipple **300** has an internal annular groove **306** which is between a lower landing shoulder **307** which faces upwardly and a downwardly facing opposed shoulder **308.** A mandrel **309** has a running and recovery neck **310** connected to its upper end at **311** and is connected at **312** to an enlongated tubular body **313.**

This body **313** has an upper outwardly projecting shoulder **314** opposed to the lower end **315** of the mandrel **309** and forming an annular groove which receives packing means **316***a*, in the illustrated form of conventional chevron packing, to form a seal with the bore **303** above the inlet **304.** Below the inlet **304**, the body **313** has a downwardly facing shoulder **317** opposed to the upper end **318** of an upper, outer body section **325** to which the body **313** is threaded at **325***a*. Between the shoulders **317** and **318** is another packing means **316***b*, in the illustrated form of chevron packing, adapted to sealingly engage in the bore **303** below the inlet **304.** These packings **316***a* and **316***b* accordingly straddle the inlet **304** when the mandrel **309** is lowered into place in the bore **303** and lands with an outwardly projecting shoulder **309***a* engaging the above-mentioned shoulder **307** in the landing nipple **300.**

Latch means **400** are provided for releasably latching the mandrel **309** in the landing nipple **300.** Such latch means includes a collett latch member **401** having an upper ring **402** which is secured between an upwardly facing shoulder **403** on the mandrel **309** and the lower end **404** of the neck **310.** Depending from the ring **402** is a plurality of circumferentially spaced resilient latch fingers **405** which have outwardly projecting latch lugs **406** adapted to project radially outwardly into the groove **306** in the seating nipple **300** and prevent the valve assembly from being pushed upwardly in the landing nipple by fluid pressure beneath the valve assembly when the valve is closed.

The latch fingers **405** are held in the latching position shown in FIG. **11**a by an upper end ring **407** on a retainer sleeve **408** which is normally biased upwardly by a coiled spring **409** which is interposed between the end ring **407** and the upper end of the tubular body **313.** However, as is well known, a wireline retrieving tool may be engaged with the recovery neck **310** to retrieve the assembly from the landing nipple **300,** and such retrieving tools have a stinger engageable with the end ring **407** to shift the retainer sleeve **408** downwardly, below the lower extremities of the latch fingers **405.** When the retainer is depressed, the latch fingers **405** are free to flex radially inwardly in slots **410** formed in the mandrel **309,** as the assembly moves upwardly and the inclined surface **411** on the respective latch lugs **406** cams the fingers inwardly, upon engagement with the shoulder **308.** Correspondingly, the lower inclined surface **412** on the latch lugs **406** are adapted to cam the latch fingers inwardly when the valve assembly is being lowered on a running tool into the seating nipple **300** and the retainer sleeve **408** is held depressed by the stinger on the running tool.

The subsurface valve assembly in this form generally corresponds to the form shown in FIGS. **10***a* through **10***e*, in that a pair of coiled compression springs **351** and **451** are operative to apply an upward force to the upper valve actuating and seating sleeve **360,** and another coil spring **551** is located beneath the ball valve **346** and acts upwardly on the lower valve actuating and seating sleeve **353,** and therefore, the spring **551** need not be relied upon to overcome the hydrostatic pressure in the control fluid tubing CF. In this embodiment in FIGS. *n***a** through **11***f*, the upper and outer body section **325** is connected by a coupling **324** to a downwardly extending outer body section **323** which is in turn connected by coupling **322** to a further downwardly extending body section **321,** the latter being threadedly connected at **325***b* to the lower body section **326.** The ball valve carrier **340** is interposed between the downwardly facing shoulder **336** in the body section **321** and the upper end **337** of the lower body section **326.** The spring **551** engages an intermediate flange **352** on the lower actuator sleeve **353,** and the latter has a skirt portion **353***a* which is slidably disposed in a lower body end and spring seat **328,** so as to shroud the spring **551.** The inner sleeve or valve actuator **360** has its upper end **362** axially shiftably extending into the bore **363** of the body **313** and sealingly engaged by a seal **364** to confine control pressure fluid in the chamber **371** below the seal **364,** the control pressure fluid having access to the chamber **371** through a port **372** in the body **313.** The inner sleeve or body assembly **360** includes a lower tubular member **360***a* which is threadedly connected by a connector **361** to the upper end of the sleeve **360** and extends upwardly within the outer body section **323** to define an annular space **326** therebetween. Within this annular space **326,** is the coiled compression spring **351** interposed between the upwardly facing end **328** of the coupling **322** and a downwardly facing shoulder **329** on an internally threaded coupling end **330** of the member **360***a*.

Threaded into the coupling end **330** of the inner body member **360***a* is an upwardly extending tubular section **360***b*, this member **360***b* having at its upper end an enlarged end section **360***c* providing a downwardly facing shoulder **360***d* which is opposed to the upper end **324***b* of the neck **324** of the outer body connector **324.** Between the shoulders **360***b* and **324***b* is the coiled compression spring **451.**

Carried by the sleeve assembly **360** is a by-pass valve sleeve **367** having an intermediate annular piston section **368** provided with an external seal **369** slidably engaging within the bore **331** of the outer body section **321.** An internal seal **370** is carried by the sleeve section **360***b* and slidably engages the by-pass valve sleeve **367.** Thus, it is now apparent that between the annular piston **368** and the upper seal **364,** there is defined a longitudinally extended annular pressure chamber **371** to which control fluid is admitted through the port **372.** The effective pressure responsive area of the sleeve **360** in the chamber **371** is the difference between outside diameter of the sleeve **360***b* on which the valve sleeve **367** is disposed and the reduced diameter, upper end **362** of the sleeve **360***b*.

The above-mentioned by-pass valve sleeve **367** is adapted to be normally held in the position shown in FIG. **11e** by means of a plurality of upwardly extended, normally inwardly retracted but resiliently outwardly expansible collett or latch fingers **374** which have inwardly extended lugs **375** at their upper ends engageable with an outwardly projecting shoulder **376** on the sleeve **360*b***. Beneath the piston section **368**, the by-pass valve sleeve **367** has a suitable number of radial by-pass ports **377** which, in one position of the sleeve **367**, as seen in FIG. **11*e***, are spaced above a suitable number of radial ports **378** in the sleeve **360*b***, but in a second position, when the latch fingers **374** are released and the by-pass valve sleeve **367** has been shifted downwardly, the ports **377** and **378** are in communication. The lower unported section **379** of the by-pass valve sleeve **367** provides an inner cylindrical surface **380** engaged by upper seal ring means **381** and lower seal ring means **382** between which the ports **378** are disposed, so that, in the normal position of FIG. **11*e***, well fluid pressure cannot by-pass the valve sleeve **367**.

I claim:

1. In a subsurface shutoff valve for wells adapted to be supported in a well fluid production pipe: a body having a flow passage therethrough; shutoff valve means including a member shiftable between a first position closing said passage and a second position at which said passage is open; actuator means for shifting said member between said positions, including means defining a control fluid pressure chamber for moving said member to said second position and means responsive to the pressure of well fluid in the production pipe for biasing said member to said first position upon reduction in the pressure of control fluid in said chamber; and by-pass valve means for equalizing the well fluid across said shutoff valve means before said member is moved from said first position to said second position, said by-pass valve means having an actuator portion in said control fluid pressure chamber responsive to the pressure of control fluid to open said by-pass valve means.

2. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves.

3. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, and spring means acting on said actuator sleeve responsive to control fluid pressure for opposing said control fluid pressure.

4. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, and spring means acting on said actuator sleeve responsive to control fluid pressure for opposing said control fluid pressure, said spring means comprising a plurality of modular spring assemblies.

5. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball including means for enabling bodily longitudinal movement of said ball with respect to said body during the final increment of movement of said ball to said first and second positions.

6. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball including a support for said ball, said support and said ball having cooperative pin and pin engaging surfaces for rotating said ball between said first and second positions.

7. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball including a support for said ball, said support and said ball having cooperative pin and pin engaging surfaces for rotating said ball between said first and second positions and for enabling bodily longitudinal movement of said ball with respect to said body during the final increment of movement of said ball to said first and second positions.

8. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball between said first and second positions including a ball carrier in said body supporting said ball for rotary movement and for longitudinal movement with respect to said carrier, said carrier having opposed pins, and walls on said ball engageable with said pins for rotating said ball between said first and second positions responsive to longitudinal movement of said ball.

9. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball between said first and second positions including a ball carrier in said body supporting said ball for rotary movement and for longitudinal movement with respect to said carrier, said carrier having opposed pins, and walls on said ball engageable with said pins for rotating said ball between said first and second positions responsive to longitudinal movement of said ball, said pins and walls clearing upon rotation of said ball to either of said positions to enable further nonrotative longitudinal movement of said ball.

10. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball between said first and second positions including a ball carrier in said body supporting said ball for rotary movement and for longitudinal movement with respect to said carrier, said carrier having opposed pins, and walls on said ball engageable with said pins for rotating said ball between said first and second positions responsive to longitudinal movement of said ball, and stop means on said ball and said carrier for limiting rotation of said ball to said first and second positions.

11. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising actuator sleeves movable longitudinally in said body responsive to control fluid pressure in said chamber and to the pressure of well fluid, said actuator sleeves having sealing surfaces engaged with said spherical sealing surface of said ball, and including means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves, said means for rotating said ball between said first and second positions including a ball carrier in said body supporting said ball for rotary movement and for longitudinal movement with respect to said carrier, said carrier having opposed pins, and walls on said ball engageable with said pins for rotating said ball between said first and second positions responsive to longitudinal movement of said ball, and stop means on said ball and said carrier for limiting rotation of said ball to said first and second positions, said pins and walls clearing upon rotation of said ball to either of said positions to enable further non-rotative longitudinal movement of said ball.

12. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction.

13. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction, and spring means engaged between said body and said sleeve for biasing said sleeve in the other direction.

14. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction, and a plurality of modular spring means between said body and said sleeve for biasing said sleeve in the other direction.

15. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction, said by-pass valve means including a valve sleeve shiftable on said sleeve, said sleeves having ports communicating with one another when said valve sleeve is in a lower position, and seal means separating said ports when said valve sleeve is in an upper position, and piston means on said valve sleeve for moving the latter to said lower position responsive to control fluid pressure in said chamber.

16. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction, said by-pass valve means including a valve sleeve shiftable on said sleeve, said sleeves having ports communicating with one another when said valve sleeve is in a lower position, and seal means separating said ports when said valve sleeve is in an upper position, and piston means on said valve sleeve for moving the latter to said lower position responsive to control fluid pressure in said chamber, said sleeves having cooperative latch means releasably holding said valve sleeve in said upper position and releasable by the pressure of control fluid in said chamber acting on said piston means.

17. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction, said by-pass valve means including a valve sleeve shiftable on said sleeve, said sleeves having ports communicating with one another when said valve sleeve is in a lower position, and seal means separating said ports when said valve sleeve is in an upper position, and piston means on said valve sleeve for moving the latter to said lower position responsive to control fluid pressure in said chamber, said sleeves having cooperative latch means releasably holding said valve sleeve in said upper position and releasable by the pressure of control fluid in said chamber acting on said piston means, and co-engageable portions on said body and said valve sleeve for limiting downward movement of said valve sleeve beyond said lower position.

18. In a subsurface shutoff valve as defined in claim **1**, said means defining a control fluid pressure chamber comprising an actuator sleeve reciprocable in said body and engaged with said member to shift the same to one of said positions, said sleeve having piston means responsive to the pressure of fluid in said chamber to shift said sleeve in one direction, said by-pass valve means including a valve sleeve shiftable on said sleeve, said sleeves having ports communicating with one another when said valve sleeve is in a lower position, and seal means separating said ports when said valve sleeve is in an upper position, and piston means on said valve sleeve for moving the latter to said lower position responsive to control fluid pressure in said chamber, said sleeves having cooperative latch means releasably holding said valve sleeve in said upper position and releasable by the pressure of control fluid in said chamber acting on said piston means, and co-engageable portions on said body and said valve sleeve for limiting downward movement of said valve sleeve beyond said lower position, said actuator sleeve being further downwardly movable to move said member to its second position and to re-engage said releasable latch means.

19. In a subsurface shutoff valve as defined in claim **1**, said valve member being a ball having said flow passage therethrough and a spherical sealing surface, said actuator means comprising an upper actuator sleeve reciprocable in said body above said ball and having a lower end sealing surface engaging said sealing surface on said ball, said actuator sleeve having a piston area exposed to the pressure of control fluid in said chamber to move said actuator sleeve downwardly, a lower actuator sleeve reciprocable in said body below said ball and having an upper end sealing surface engaging said sealing surface on said ball, means for biasing said lower actuator sleeve upwardly, and means for rotating said ball between said first and second positions responsive to longitudinal movement of said actuator sleeves corresponding upwardly and downwardly.

20. In a subsurface shutoff valve assembly as defined in claim **19**, said means for biasing said lower actuator sleeve upwardly including a spring.

21. In a subsurface shutoff valve assembly as defined in claim **19**, said means for biasing said lower actuator sleeve upwardly including a spring, and a well fluid responsive piston area on said lower actuator sleeve.

22. In a subsurface shutoff valve assembly as defined in claim **19**, said means for biasing said lower actuator sleeve upwardly including a spring, and also including spring means acting on said upper actuator sleeve to bias the latter upwardly.

23. In a subsurface shutoff valve assembly as defined in claim **19**, said means for biasing said lower actuator sleeve upwardly including a spring, and also including spring means acting on said upper actuator sleeve to bias the latter upwardly, said spring means including a plurality of modular spring assemblies spaced longitudinally between said body and said upper actuator sleeve.

24. In a subsurface shutoff valve as defined in claim **1**, said body having means for threadedly connecting it in said well fluid production pipe.

25. In a subsurface shutoff valve as defined in claim **1**, said body having external cylindrical packing means in axially spaced relation and an inlet for said control fluid pressure chamber between said packing means said body also having wireline tool engageable running and retrieving means, and latch means releasable by said tool for engaging in and holding said packing means in sealing position in a seating nipple in said well fluid production pipe.

26. In a subsurface shutoff valve for wells adapted to be supported in a well fluid production pipe: an elongated outer tubular body; an elongated inner tubular assembly including an upper sleeve and a lower sleeve; a ball valve between said sleeves and having a flow passage therethrough, said ball valve and said sleeves having complemental spherical sealing surfaces; a support for said ball valve fixed in said outer body; cooperable means on said ball valve and said support for rotating said ball valve between first and second positions at which said flow passage is open and closed, respectively, in response to longitudinal movement of said sleeves and said ball valve in opposite directions in said outer body, said upper sleeve and said outer body defining a chamber for control fluid pressure; said upper sleeve having means responsive to the pressure of control fluid in said chamber for moving said sleeves and said ball valve downwardly; said lower sleeve having means responsive to the pressure of well fluid for moving said sleeves and said ball valve upwardly; and by-pass valve means including a valve member having a control fluid pressure responsive actuator portion in said chamber for shifting said valve member from a closed position to an open position in response to the pressure of control fluid in said chamber to equalize well fluid pressure across said ball valve when said ball valve is in said second position to relieve frictional co-engagement of said complemental sealing surfaces.

27. In a subsurface shutoff valve as defined in claim **26**, said cooperable means for rotating said ball comprising rotary drive means which are released to enable free further longitudinal movement of said sleeve and said ball when said ball is in said positions.

28. In a subsurface shutoff valve as defined in claim **26**, means for re-closing said by-pass valve means when said sleeves and said ball move longitudinally to position said ball in said second position.

29. In a subsurface shutoff valve as defined in claim **26**, a spring acting on said lower sleeve to bias the latter into engagement with said ball.

30. In a subsurface shutoff valve as defined in claim **26**, a spring acting on said lower sleeve to bias the latter into engagement with said ball, and a spring acting on said upper sleeve in opposition to the pressure of control fluid in said chamber.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,796,257 Dated March 12, 1974

Inventor(s) DELBERT L. HUDSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 28: change the "." to a --,--.

Column 4, line 3: change "weill" to --will--.

Column 10, line 15: change "na" to --lla--.

Signed and sealed this 29th day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents