# United States Patent [19]

**Crowe**

[11] **3,827,494**

[45] **Aug. 6, 1974**


[54] **ANTI-FRICTION BALL VALVE OPERATING MEANS**


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



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[52] **U.S. Cl.** ..... **166/224,** 137/460

[51] **Int. Cl.** ..... **E21b 43/12**

[58] **Field of Search** ..... 166/72, 224, 224 S, 313, 166/315; 137/458, 630, 460; 251/315



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*Primary Examiner*—James A. Leppink

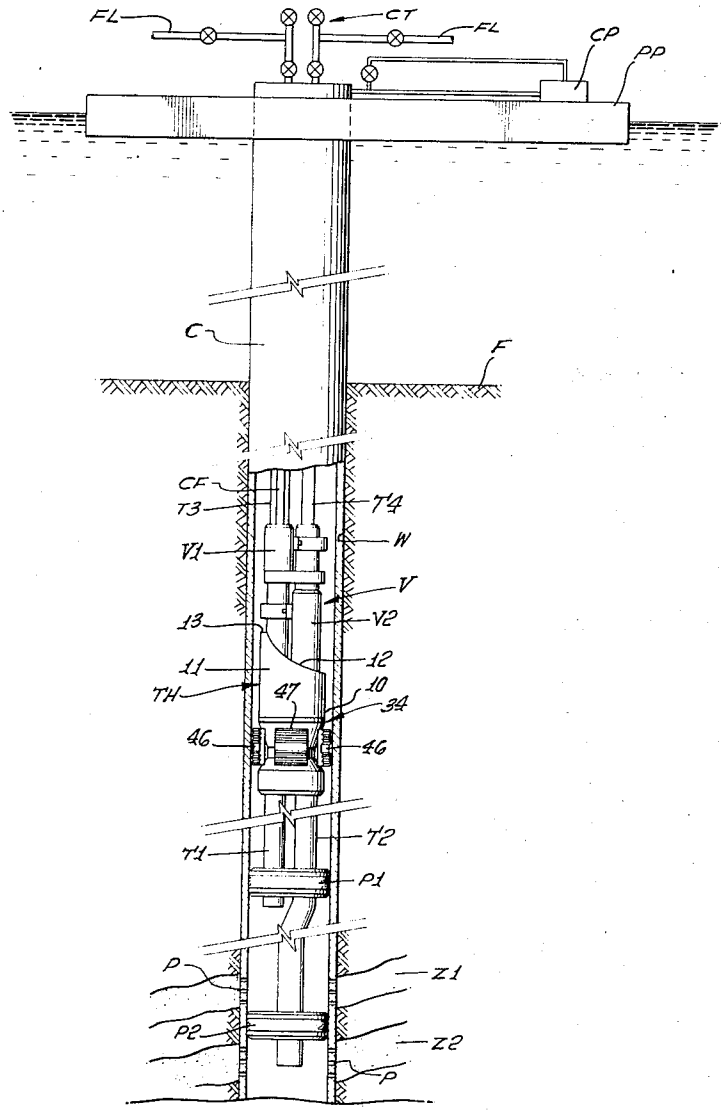
*Attorney, Agent, or Firm*—Bernard Kriegel



[57] **ABSTRACT**

A ball valve is supported in a subsurface shutoff valve for wells in a ball guide which transmits the closing force for rotating the ball through fingers which engage the ball adjacent to its axis of rotation on a small radius so that there is a low frictional moment arm. The ball valve is opened by control fluid pressure and closed by a spring and well fluid pressure, and the spring acts to overcome the hydrostatic pressure of the control fluid.


**30 Claims, 16 Drawing Figures**



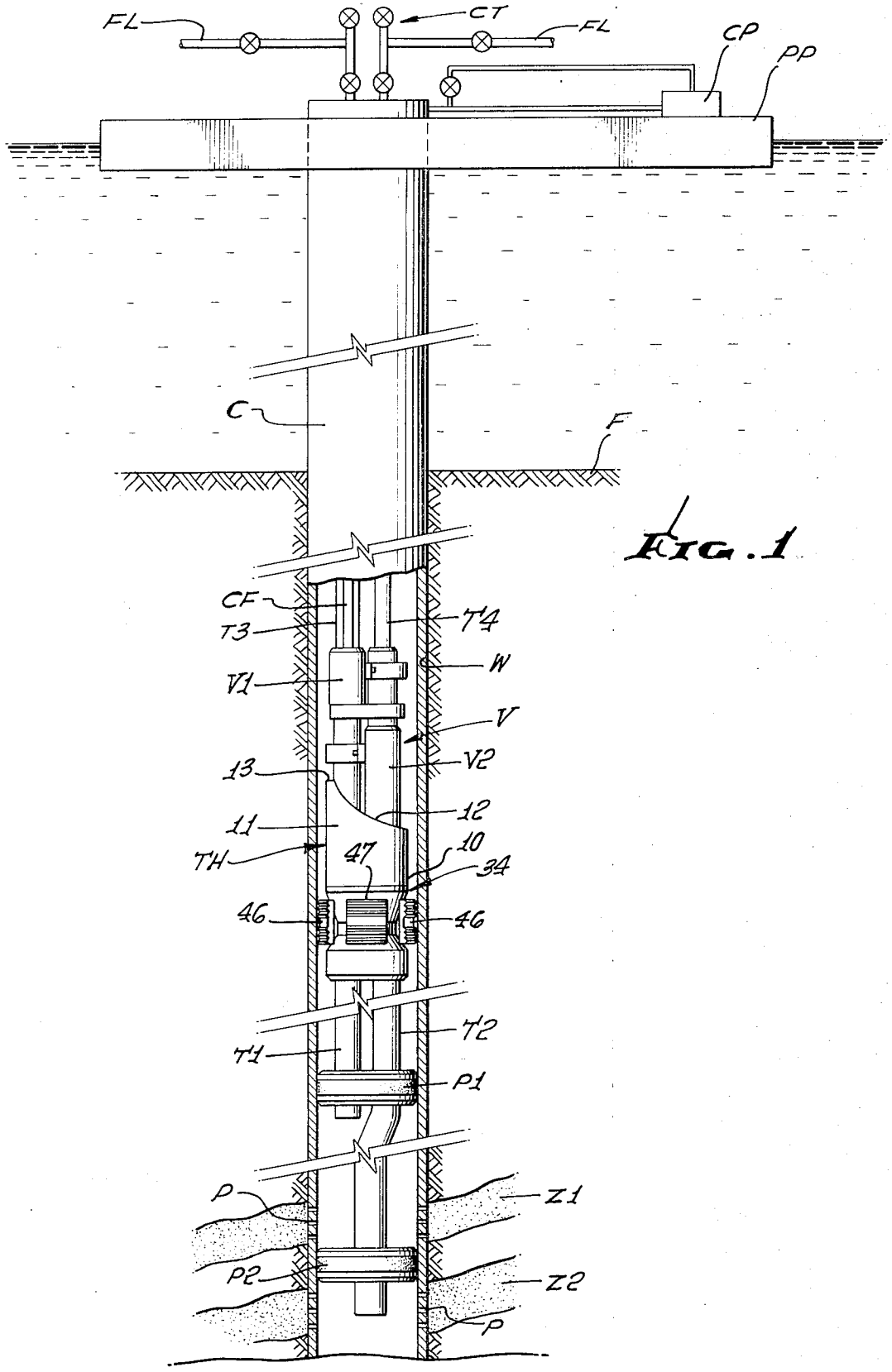

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P2
Z2
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FIG. 1

FIG. 2a.

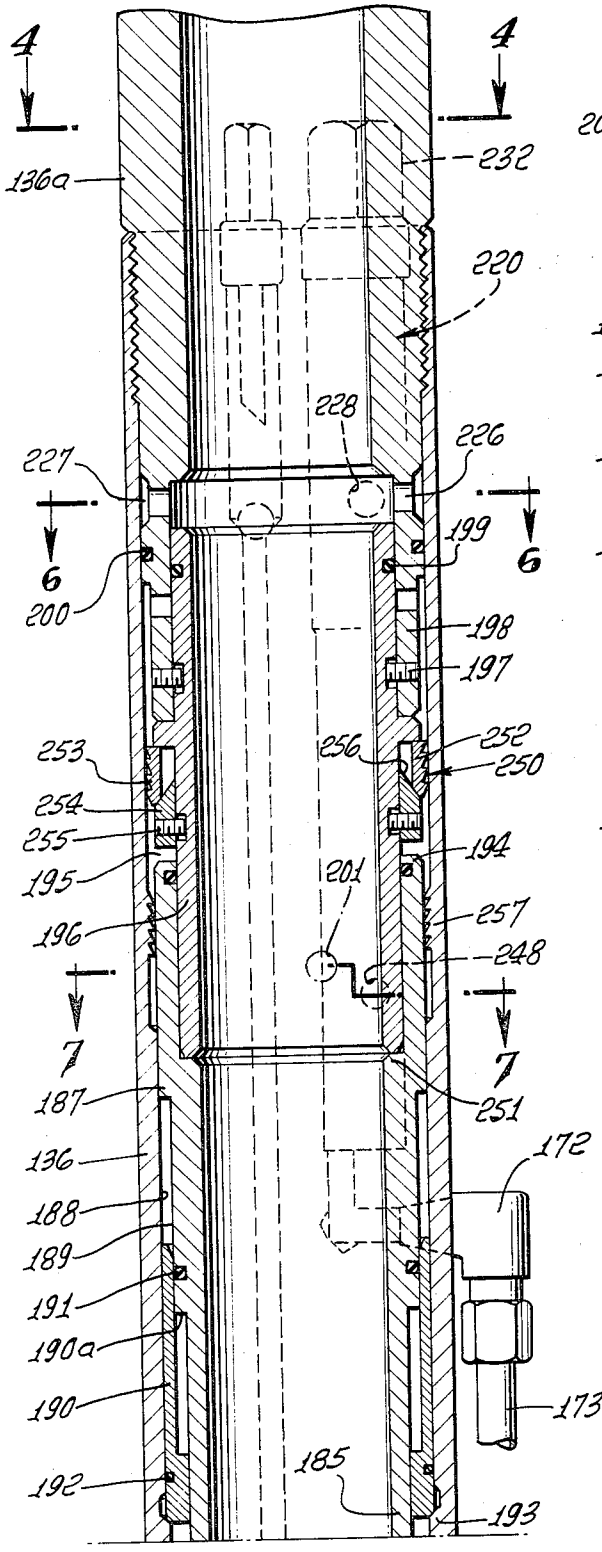

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FIG. 2b.

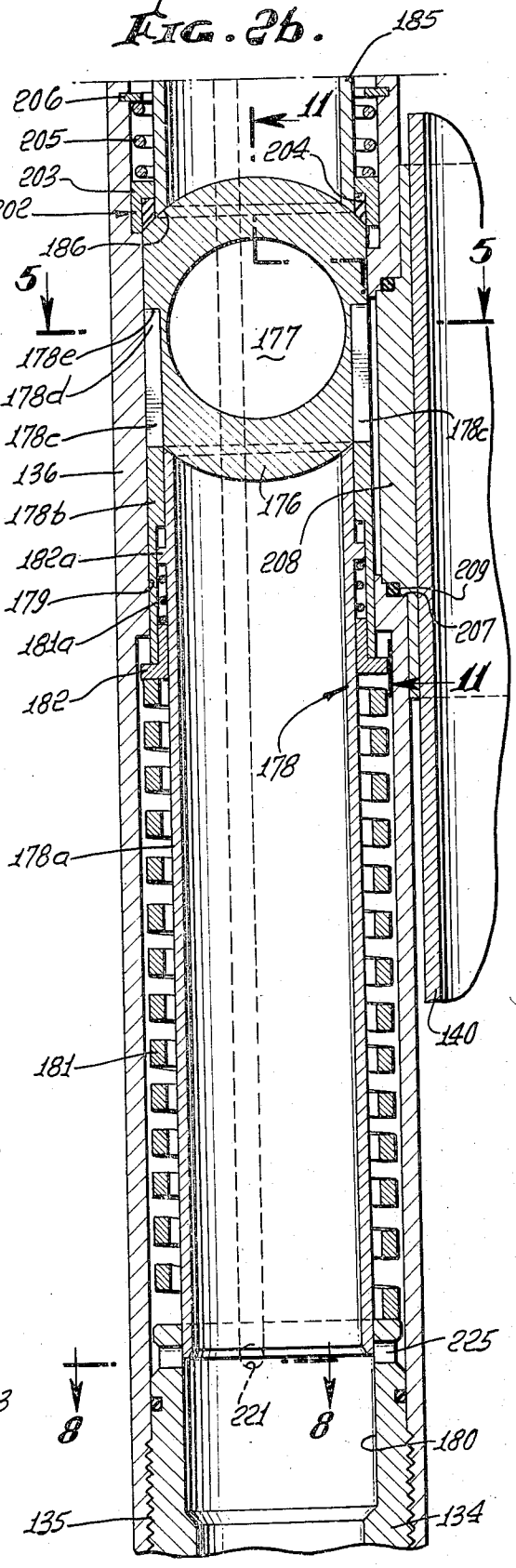

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FIG. 3a.

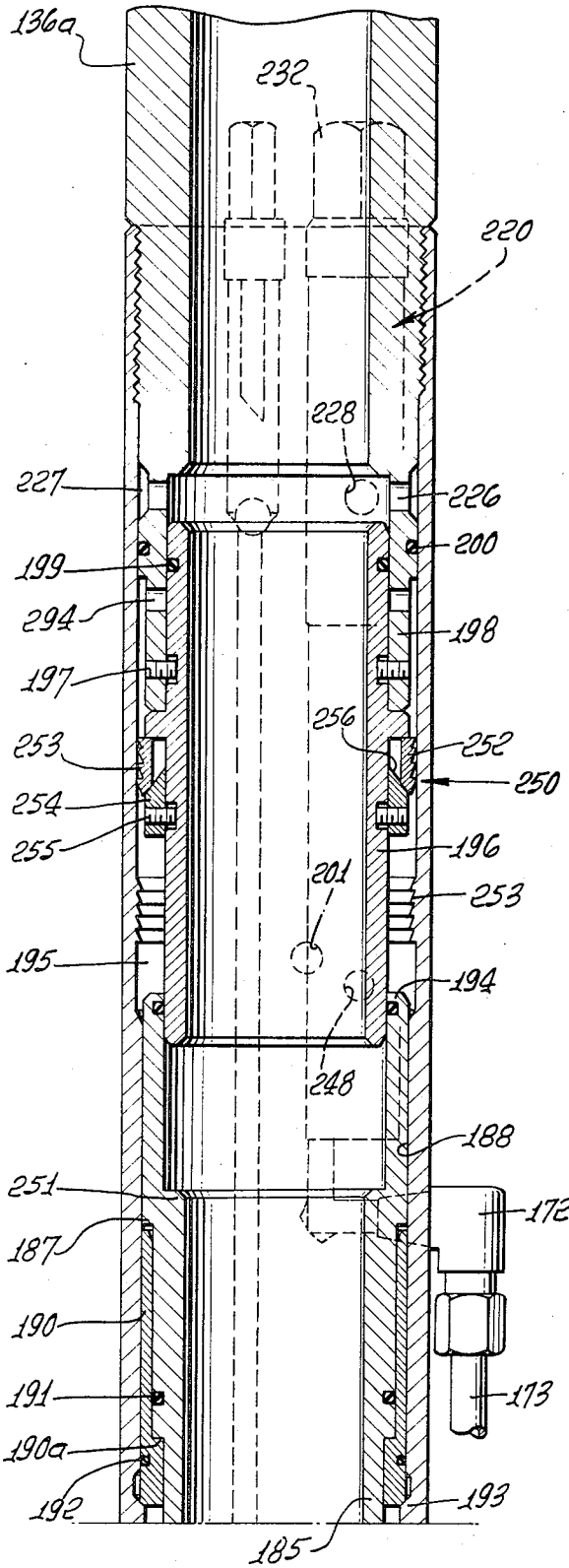

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FIG. 3b.

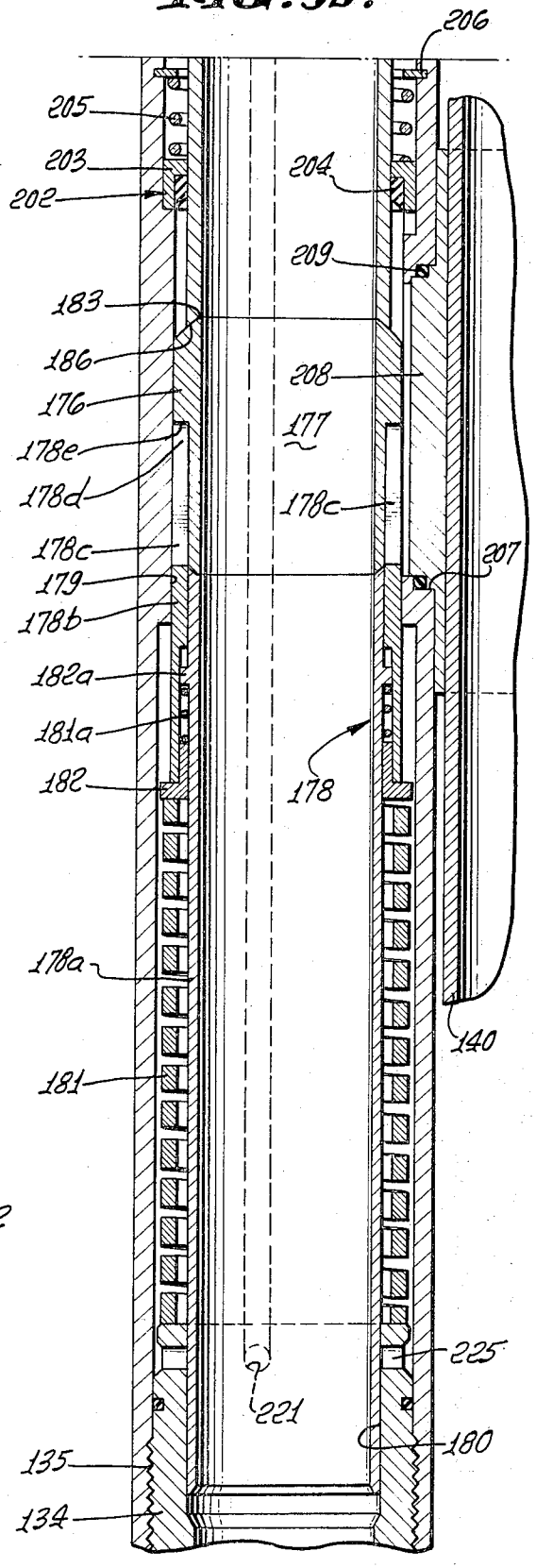

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FIG. 4.

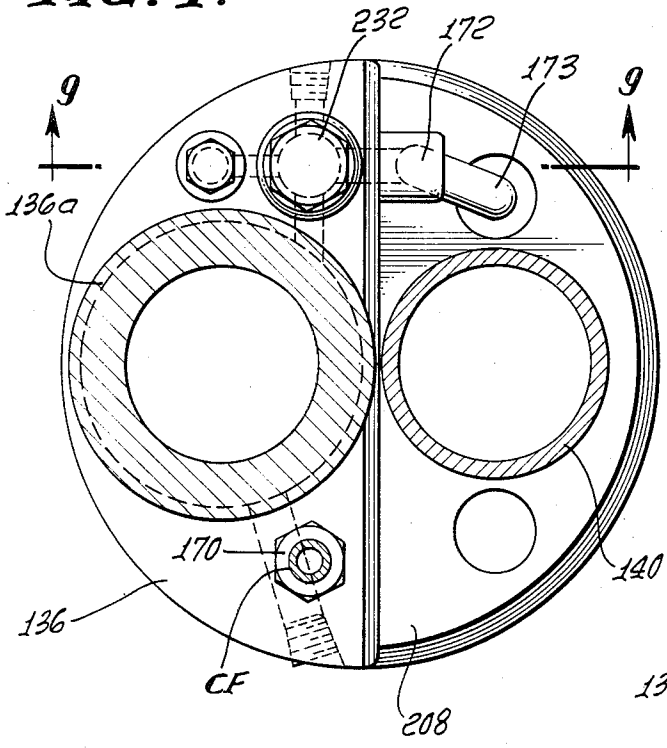



FIG. 5.

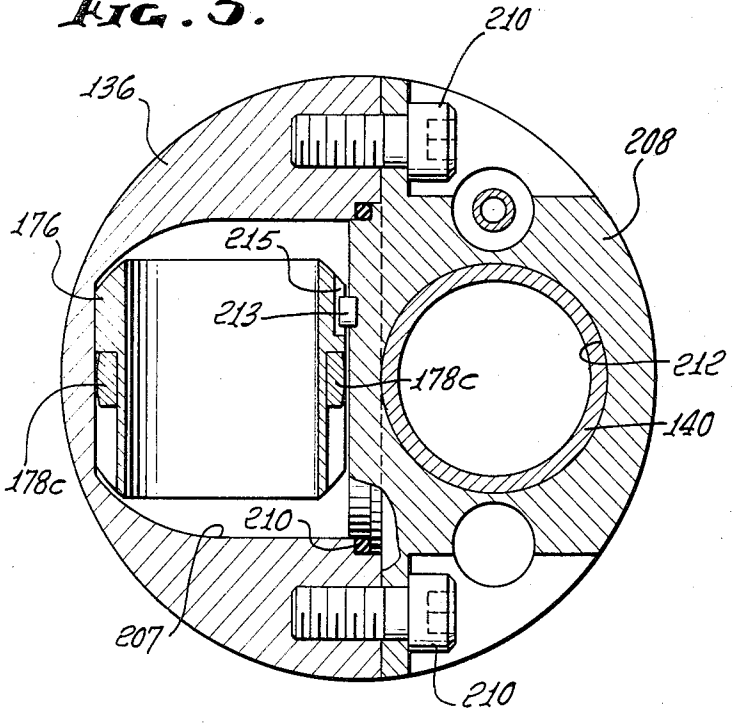



FIG. 9.

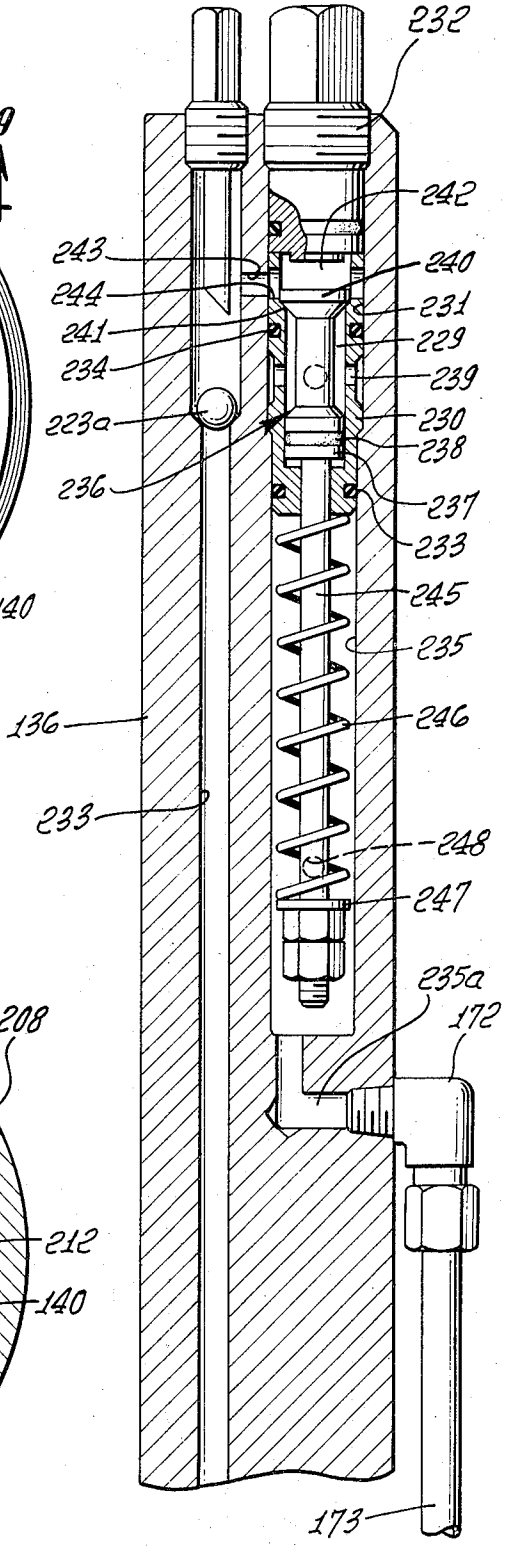


FIG. 6.

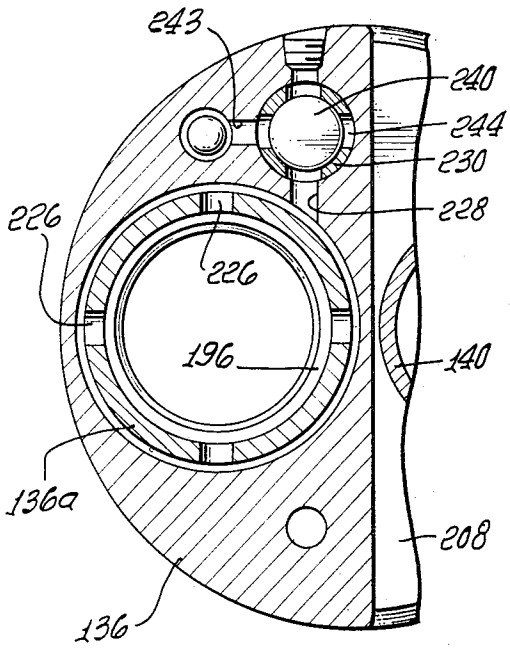



FIG. 7.

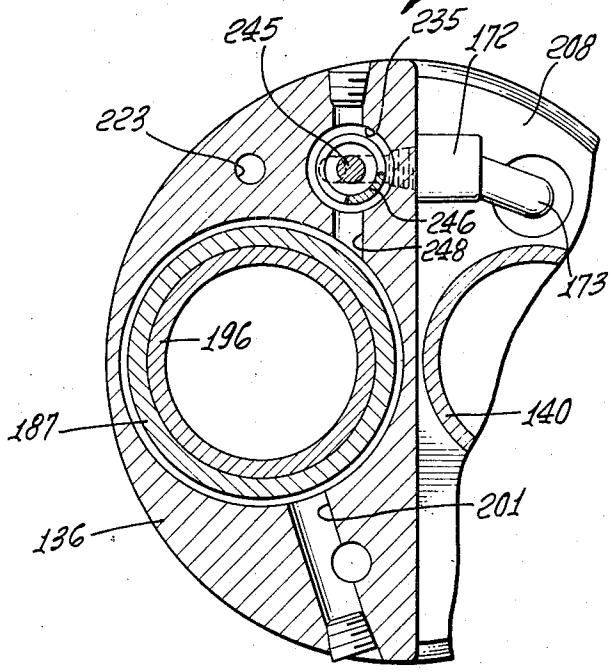



FIG. 8.

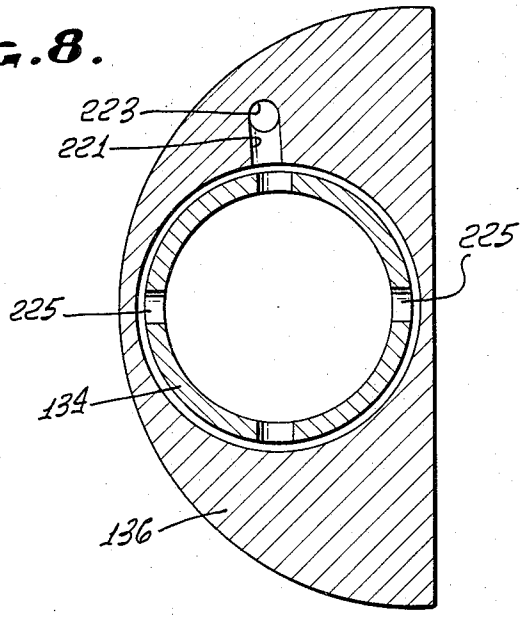



FIG. 10.

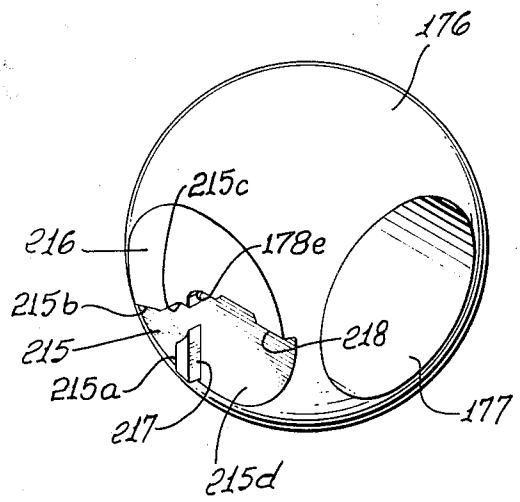


FIG. 12.

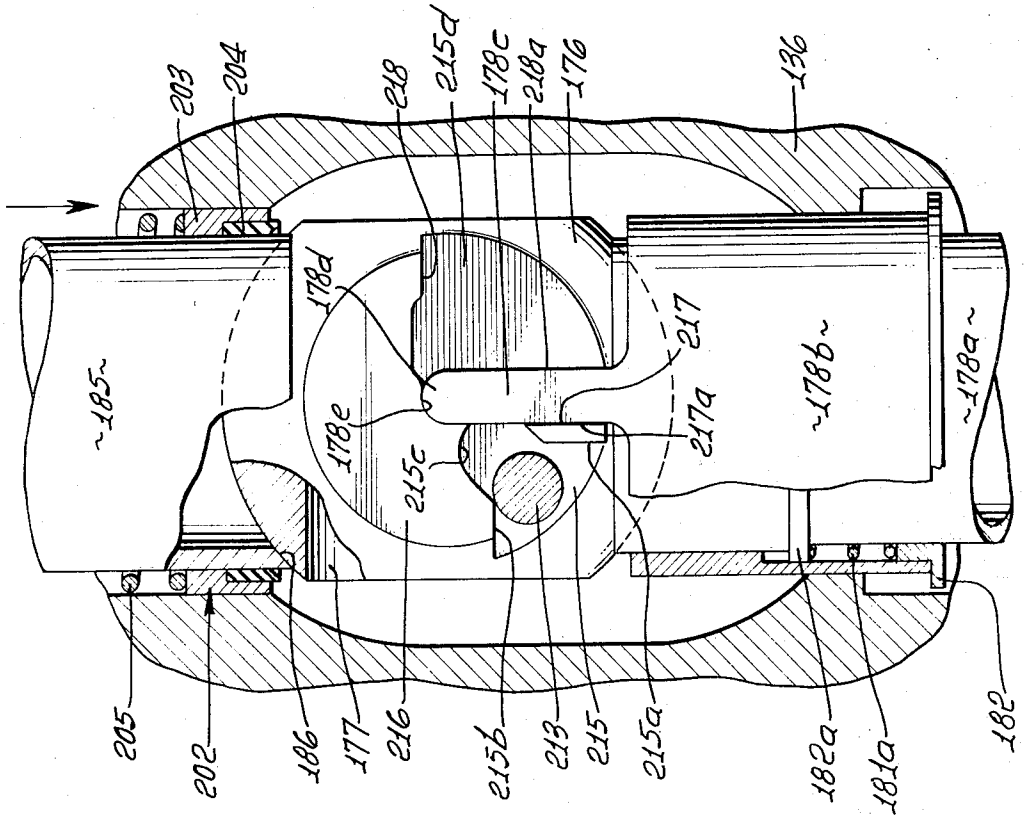
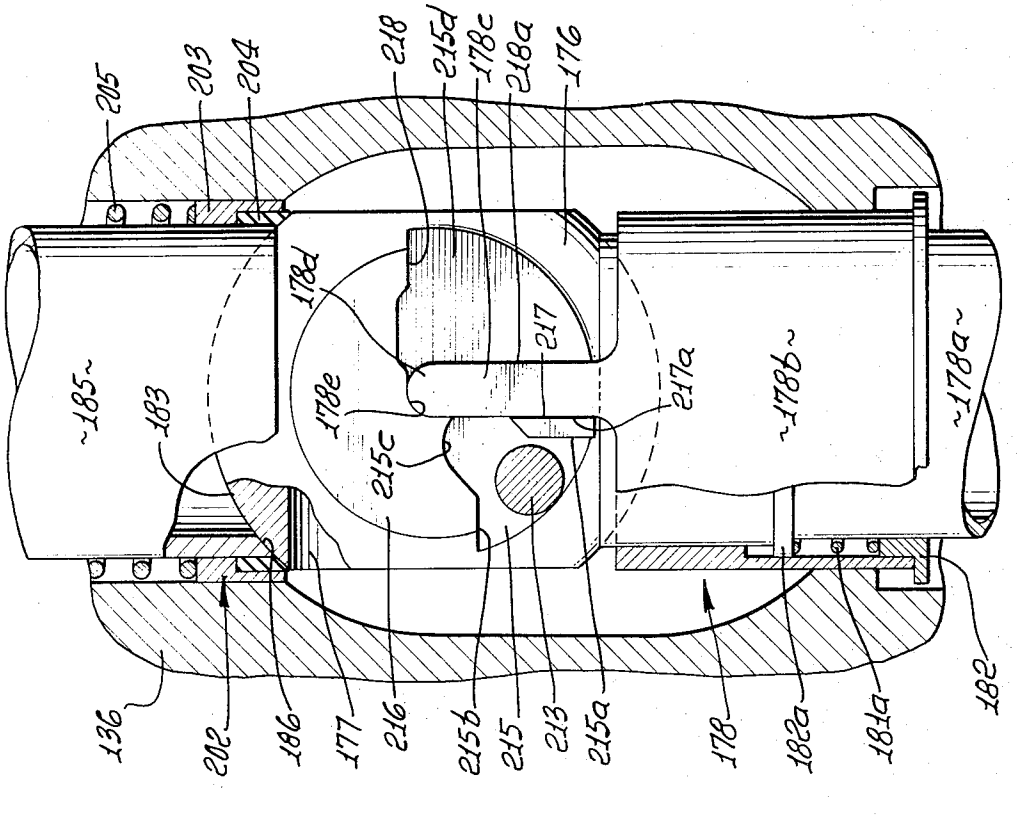

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FIG. 11.


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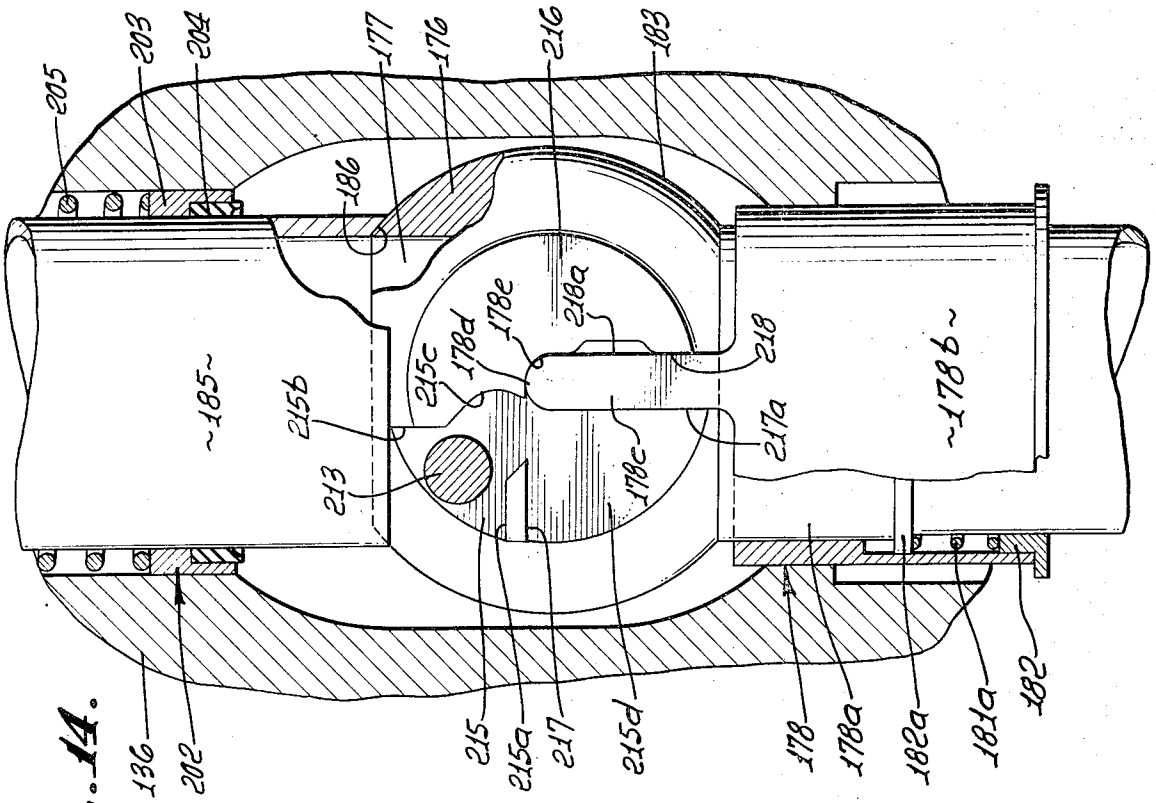

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178d
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218a
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178c
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~178b~
136
202
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215a
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215d
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181a
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FIG. 14.

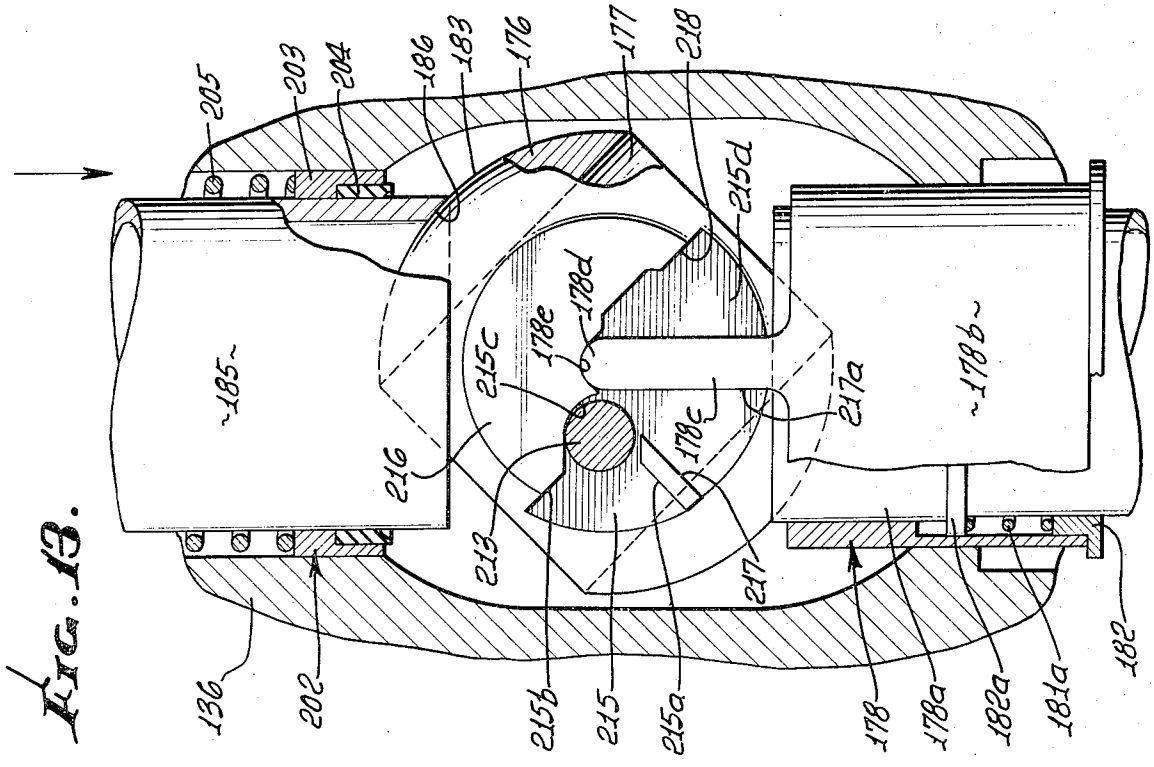

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215d
178d
178e
215c
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178c
217a
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136
202
215b
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215a
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178
178a
182a
181a
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FIG. 13.

# ANTI-FRICTION BALL VALVE OPERATING MEANS

## BACKGROUND OF THE INVENTION

Subsurface safety or shutoff valves are provided to automatically shut in a well when desired or when damage occurs, thereby preventing uncontrolled production or loss of well fluids. Such valves, typically, involve installing the shut-off valve in the production pipe string or landing the valve in a seat supported in the well casing as part of a tubing hanger which suspends the production tubing in the well.

Such valves which utilize a ball valve as the shiftable valve member utilize an upper actuating and sealing sleeve and a lower actuating and sealing sleeve slidably disposed in the valve housing and having an annular sealing end engaged with the ball to prevent fluid from by-passing the ball. Control fluid pressure is applied to the upper actuating sleeve, from a source at the top of the well, to open and hold the valve open. When control pressure is reduced or lost, the valve is closed by well fluid pressure acting on the lower actuator sleeve. A spring also acts on the lower actuator sleeve to also urge it in a valve closing direction and overcome the static pressure of the control fluid acting to hold the valve open.

The ball and the actuator sleeves in such valves experience substantial frictional resistance to rotation of the ball which must be overcome before the hydrostatic pressure of control fluid can be compensated for in the valve closing operation. In addition, substantial frictional resistance to opening of the valve is caused if the valve must be opened in the presence of significant differential pressure across the closed valve.

In my pending application for Letters Patent of the United States, Ser. No. 286,151, filed Sept. 5, 1972, there is disclosed a Full Opening Safety Valve incorporating by-pass valve means for equalizing the differential pressure across the ball valve when it is closed.

## SUMMARY OF THE INVENTION

The present invention involves reducing the frictional resistance to closing the valve caused by the effect of the pressure of control fluid acting to hold the valve closed.

More particularly, the force applied to the ball to cause its movement to a closed position is transmitted through a ball guide or support rather than through the end sealing surface on the lower actuating sleeve. The ball guide or support engages the ball at opposite sides adjacent to its axis of rotation on the ends of support fingers formed on a small radius so that the frictional moment arm is relatively low and the ball rotates more easily. Thus, a larger proportion of the force which tends to close the valve is transmitted through the ball to the upper actuating sleeve and on to the control fluid to overcome hydrostatic pressure.

The invention also provides a ball supporting structure which is effective and minimizes tolerance problems, due to the simplicity of the ball supporting and rotating structure which is enabled by supporting the ball near to its axis of rotation and at opposite sides. The supporting fingers are also employed as rotational stops for the ball to limit its rotation to the open and closed position, without having such stops formed as part of the valve body or housing structure.



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 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. The subsurface valve of the invention may also be incorporated in a plural valve assembly for controlling plural well zones, the valve assembly being landed in a tubing hanger which supports the production tubing in the well casing.

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 barge for producing a multiple zone well through plural safety valve apparatus incorporating the invention;

FIGS. **2***a* and **2***b*, together, constitute a longitudinal section through a safety valve incorporating the invention, and showing the valve in a closed condition, FIG. **2***b* being a downward continuation of FIG. **2***a*;

FIGS. **3***a* and **3***b*, together, constitute a longitudinal section corresponding to FIG. **2***a* and **2***b*, but showing the valve open, FIG. **3***b* being a downward continuation of FIG. **3***a*;

FIG. **4** is a transverse section, as taken on the line **4—4** of FIG. **2***a*;

FIG. **5** is a transverse section, as taken on the line **5—5** of FIG. **2***b*;

FIG. **6** is a transverse section, as taken on the line **6—6** of FIG. **2***a*;

FIG. **7** is a transverse section, as taken on the line **7—7** of FIG. **2***a*;

FIG. **8** is a fragmentary transverse section, as taken on the line **8—8** of FIG. **2***b*;

FIG. **9** is a fragmentary vertical section, as taken on the line **9—9** of FIG. **4**;

FIG. **10** is a detail view in perspective, showing the ball valve;

FIG. **11** is a fragmentary detail view, partly in elevation and partly in section, showing the ball valve in a closed position;

FIG. **12** is a view generally corresponding to FIG. **11**, but showing the ball valve moved downwardly towards an open position, but prior to rotation;

FIG. **13** is a view generally corresponding to FIG. **12**, but showing the ball valve partially rotated to an open position; and

FIG. **14** is a view generally corresponding to FIG. **13**, but showing the ball valve in a full open position.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will now be described as applied to the safety valve means of an offshore well which is being produced from multiple earth zones, but it will be understood that the invention is also applicable to single string valves and onshore installations.

As seen in the drawings, referring first to FIG. 1, a well bore W extends downwardly into the earth below the ocean floor F through vertically spaced well fluid producing zones Z1 and Z2. A casing C is set in the well bore and perforations P in the casing establish communication between the productive zones Z1 and Z2 and the casing C. Set in the casing C is an upper packer P1 located above the productive zone Z1 and a lower packer P2 located in the casing between the productive zones Z1 and Z2. A first production tubing string T1 extends through the packer P1 and opens into the casing therebelow to communicate with the productive zone Z1, and a second production tubing string T2 extends downwardly through the upper packer P1 and downwardly through the lower packer P2, into the casing therebelow, for communication with the productive zone Z2. The tubing strings T1 and T2 may extend a number of thousands of feet downwardly in the casing to the packers P1 and P2, and the tubing strings T1 and T2 are supported by tubing hanger means TH which is set or anchored in the well casing and forms a seat for a shutoff valve assembly V which comprises dual shutoff valves V1 and V2 for the respective tubing strings T1 and T2. The tubing hanger TH and the valve assembly V are located below the ocean floor or the mud line of a body of water, at a desired or required depth of say 500 to 1000 feet, more or less. The casing C extends upwardly through the water to a production platform or barge PP, as shown in the diagrammatic illustration. However, as is well known, the well may be completed at the ocean floor and one or a number of additional casings (not shown) may be set in larger diameter well bores, and the casing C may be suspended or hung from a casing hanger located at the ocean floor, in which case, a conductor pipe or other casing (not shown) may extend to the production platform PP. In any event, upper production fluid tubings T3 and T4 extend upwardly from the respective valves V1 and V2 of the valve assembly V and are connected with the usual Christmas Trees CT on the platform PP, whereby the flow of well fluids from the well zones Z1 and Z2 may be controlled or manually shutoff. Flow lines FL are provided to conduct well fluids from the Christmas Trees to suitable reservoirs or tanks (not shown).

As will be later described, the respective subsurface valves V1 and V2, which are normally closed, are adapted to be held open, to enable the flow of production fluids therethrough, by means of control fluid pressure supplied through a control fluid conduit CF, or through a pair of such conduits, from a source of control fluid pressure CP. So long as the control fluid pressure is adequate to maintain the subsurface valves V1 and V2 open, well fluids may flow from the zones Z1 and Z2 to the respective flow lines FL, but, if it is desired for any reason to close either of the shutoff valves V1 or V2, or in the event of damage of the control fluid tubing, the control fluid pressure may be reduced so that the subsurface valves V1 and V2 are automatically closed, thereby shutting the wall in at a location below the ocean floor, to prevent continued production fluid flow.

The tubing hanger assembly TH and the tubing strings T1 and T2 are adapted to be lowered from the platform PP downwardly through the casing C on a setting tool, as more particularly described in my prior application Ser. No. 243,806, filed Apr. 13, 1972, and the valve assembly V is adapted thereafter to be lowered through the casing C into the tubing hanger TH on the upper tubing strings T3 and T4. Likewise, the valve assembly V can be retrieved from the tubing hanger TH, so that under normal circumstances requiring the repair or service of the subsurface valve assembly V, it is not necessary to pull the entire dual tubing strings T1 and T2.

The tubing hanger TH comprises a body 10 having an upper section 11 adapted to receive the valve assembly V in an orientation determined by sloped guide walls 12 leading angularly and downwardly from a peak 13, whereby the tubing strings T1 and T2 communicate through the valves V1 and V2, respectively, with the upwardly extending tubing strings T3 and T4.

As seen in FIGS. 3, 6 and 8 the control fluid conduit CF is connected by a fitting 170 to the upper valve housing 136 of the valve V1 and passage means later to be described in the housing 136 conduct control fluid to an outlet fitting 172 which is connected to a conduit 173 leading to an inlet fitting 174 for the lower valve V2. However, if preferred, plural control fluid tubings CF may be employed to supply control fluid pressure to the valves V1 and V2.

The valve assembly of the present invention comprises the outer body 136 and an upper tubular sub 136*a* which is connected with the lower end of the tubing string T3. The upper body 136*a* is threadedly connected at 175, at its lower end to the body 136 which in turn is threadedly connected at 135 to a flow tube 134 which seats in a bore or receptacle in the tubing hanger body 10, as described in said pending applications.

A ball valve 176 is disposed within the body 136 and has a passage 177 for the flow of well fluid when the ball valve is in the open position, with the passage 177 aligned with the body 136, the ball valve being rotatable 90°, as will be later described, to a closed position, in which flow of well fluid through the body 136 is prevented.

Normally, the ball valve 176 is biased to a closed position by a lower sealing and actuating sleeve assembly 178 which is reciprocable in the valve body 136 between an upper position, as seen in FIG. 2*b*, and a lower portion, as seen in FIG. 3b. The sleeve assembly 178 includes an inner, elongated sealing sleeve 178*a* and an outer ball supporting and actuating sleeve 178*b* disposed about the inner sleeve 178*a* and piloted in a reduced bore 179 in the body 136. The lower end of the sleeve 178a extends into a bore 180 in the upper end of the tube 134. A coiled compression spring 181 is disposed between the upper end of the tube 134 and a seating shoulder or ring 182 at the lower end of the sleeve 178*b*, and biases the sleeve 178*b* and the ball valve 176 upwardly. Externally, the ball valve 176 has a spherical sealing surface 183, sealingly engageable by a companion sealing end surface 184 at the upper end of the sleeve 178*a* under the influence of fluid pressure acting on the sleeve 178*a* and a coiled spring 181*a* which is interposed between the seating ring 182 and

an opposed seating flange **182***a* which projects outwardly from the sleeve **178***a*.

Above the ball valve **176** is an upper valve actuating and sealing sleeve **185** having a lower end sealing surface **186** which is complemental to the spherical valve surface **183** of the ball valve **176.** At its upper end, the sleeve **185** has an enlarged piston section **187** which is slidably disposed within a cylinder portion **188** of the valve body **136.** Below the piston section **187** is a cylindrical section **189** smaller than the outside diameter of the piston section **187.** Between the cylindrical section **189** and the cylindrical wall **188** is a sleeve **190** engaged by an external seal **192** engaging with the cylinder wall **188.** At its lower end, the sleeve **190** abuts with an upwardly facing shoulder **193.** The difference between the annular cross-sectional area of the upper end **194** of the piston section **187** constitutes the net piston area of the piston section **187** exposed, as will be later described, to control fluid pressure to hold the ball valve **176** open. The piston section **187** extends into an annular space **195** defined between the cylindrical wall **188** and a sleeve **196** which is connected by suitable shear screws **197** to a skirt **198** on the lower end of the upper body section **136***a*, the sleeve **196** carrying a seal ring **199** engageable within the skirt **198,** and the skirt **198** having a seal ring **200** engageable in the cylindrical wall **188.** The control fluid passage previously referred to communicates through a port **201** with the annular space **195** which constitutes a control fluid pressure chamber in which control fluid pressure is operable on the net piston area of the piston section **187** of the sleeve **185** to provide a downward force adapted to overcome the upward force applied to the ball valve **176** by the lower valve actuating sleeve **178,** when the ball valve **176** is to be opened by moving the ball valve from the position of FIG. **4***b* to the position of FIG. **5***b*, as the upper sleeve **185** is forced downwardly. When the over-riding control fluid pressure is relieved, the pressure of production fluid acts upwardly across the secondary sleeve **190** when the latter shoulders at **190***a*, as well as on the sleeve **178.**

Preferably, the valve assembly includes resilient sealing means **202** engageable with the ball valve **176** when it is in the closed position. In the embodiment now being described, the resilient sealing means **202** comprises a seal carrier ring **203** having an annular elastomeric seal ring **204** engageable with the ball valve **176** externally of the seating surface **186** at the lower end of the sleeve **185.** The seal carrier ring **203** is normally biased downwardly by a coiled compression spring **205** which seats against a seating ring **206** carried within the valve body **136.**

The respective valve assemblies V1 and V2 are full opening valve assemblies through which remedial operations can be performed when the ball valve is opened. In the illustrated valve in order to provide a ball valve **176** of maximum diameter, the ball valve **176** is installed in the body **136** through a side opening **207** which is closed by a closure member **208** which fits within the opening **207,** and is sealed therein by a suitable seal ring **209.** Referring to FIG. **5,** it will be noted that the closure and valve support member **208** is adapted to be secured to the valve body **136** by a suitable number of fasteners **210,** and the closure member **208** includes a guide section **211** having a bore **212** through which a tubular member **140** constituting a portion of the other production fluid flow path may extend. It will be understood that the application of the invention to the dual valve assembly is only illustrative and that the novel features of the invention may also be incorporated in a single string valve, as well as in valves wherein the ball and its support are otherwise installed in the body.

In order to support the ball valve **176** and cause rotation thereof between the sleeves **185** and **178***a* according to this embodiment, while minimizing friction between the spherical ball surface and the sealing end surface of the sealing sleeve **178***a*, the valve closure member **208** has a pin or lug **213** (FIG. **5**) projecting therefrom and the ball valve **176** has at its adjacent side a slot or notch **215** in which the pin or lug **213** is engageable for rotating the ball valve **176** between the opened and closed positions, as best illustrated in FIGS. **11** through **14.** In these views, the side of the ball valve **176** opposed by the closure **208** is illustrated. The structure which supports the ball valve **176** for rotation about a horizontal axis comprises elongated, parallel fingers **178**c extending longitudinally from the upper end of the support sleeve **178**b at opposite sides thereof. The fingers **178***c* terminate in end portions **178**d formed on a small radius struck from a center corresponding substantially with the axis of rotation of the ball valve **176.** At its opposite sides, the ball valve **176** has flat surfaces **216** in one of which the notch **215** is formed and in both of which recesses or notches **215***d* are provided, these notches **215***d* each being bordered by a wall portion **178***e* formed on a radius substantially corresponding to the respective supporting finger ends **178***d* of the fingers **178***c*, whereby the ball valve **176** is supported on the complemental arched surfaces for rotation between the open and closed positions in response to longitudinal movement of the ball valve. In FIG. **11,** the valve is shown fully closed and sealed by the sleeve **178***a* and **185,** as well as by the resilient sealing means **202.** In FIG. **12,** the valve **176** has been shifted downwardly away from the resilient seal means **202** through an initial increment of non-rotatable longitudinal movement. In FIG. **13,** the ball valve **176** is in the partially opened position. In FIG. **14,** the ball valve **176** is in the fully opened position.

More particularly, the slot or notch **215***d* on at least one side of the ball valve member **176** is bounded by walls disposed in right-angularly spaced locations, which form a stop surface **217** and a stop surface **218** cooperable with fixed stop lug surfaces **217***a* and **218***a* on the longitudinal edges of a finger **178***c* to limit rotation of the ball **176** between the extremes of FIGS. **11** and **14.** When the ball valve member **176** is in the position of FIG. **11,** the stop surface **217** engages the vertical stop surface **217***a*, thereby limiting rotation of the valve member **176** to the position at which the valve is closed. The stop surface **218** engages the stop surface **218***a*, as shown in FIG. **14,** to limit rotation of the valve member **176** to the position at which the valve is open. Such rotation between the open and closed positions is caused by longitudinal or vertical movement of the valve member **176** relative to the body **136.** As previously indicated, the ball member **176** is actuated or shifted longitudinally by longitudinal movement of the upper actuator sleeve **185** and the lower actuator sleeve **178**b, as indicated by the arrows in FIGS. **12** and **13.** The slot **215** into which the pin **213** projects, is formed in such a manner as to cause such rotation of the valve member **176** as the latter moves vertically or

longitudinally within the body **136.** Thus, the slot **215** is formed in the valve member **176** by opposed walls which are disposed at a right angle to one another and designated **215***a* and **215***b* and which respectively are parallel to the stop surfaces **217** and **218.** At the apex of the angle defined between the walls **215***a* and **215***b*, the slot opens radially inwardly at **215***c*. Thus, the relationship between the pin **213** and the wall **215***b* is such that the ball valve **176** will be rotated from the position of FIG. **11** to the position of FIG. **14** when the valve member **176** moves downwardly relative to the pin **213,** and, conversely, the flat wall **215**a will engage the pin **213** and rotate the ball valve member from the position of FIG. **14** to the position of FIG. **11** upon upward movement of the valve member **176.** However, it will be noted that when the valve member **176** is in the position of FIG. **14,** the pin **213** clears the flat wall **215***b* so as to allow freedom of longitudinal movement of the ball valve **176** after the stop surface **218** engages the stop **218***a*, and correspondingly limited free downward movement of the ball valve **176** is permitted when the ball valve is opened, as seen in FIG. **11,** where the pin **213** clears the slot wall **215***a*, and the stop surface **217** engages the stop **217***a*. Such free or lost motion connection of the ball valve **176** and the ball rotating pin **213** relieves the connection of damaging forces when the ball valve is in either of its positions, and in addition saves the resilient seal **202** from relative rotative movement of the ball valve **176.**

When the ball valve **176** is closed and is to be opened by applying control fluid pressure to the piston chamber **195,** there may be substantial differential pressure across the valve tending to hold it closed, and in accordance with the invention, in order to equalize the pressure across the valve, equalizing valve means **220** are provided, as best seen in FIG. **9,** for establishing communication between a port **221** below the ball valve **176** (FIG. **2**b) and a port **228** above the valve **176** (FIG. **2***a*), via the elongated passage **223** in the valve body **136.** The port **221** communicates with the annular space **224** between the body **136** and the lower valve actuating sleeve **178** which communicates with the passage through the lower tubular member **134** through radial ports **225** (FIG. **7**) in the upper end of the lower tubular member **134,** when the valve **176** is closed, as seen in FIG. **2***b*. Above the ball valve **176,** the skirt **198** of the upper valve body section **136**a has a number of radial ports **226** (FIG. **5**) communicating between the flow passage through the valve assembly and an annulus **227** which in turn communicates through a port **228** with a chamber **229** of the equalizing valve means **220.**

This equalizing valve chamber **229** is provided by a tubular insert **230** retained in a bore **231** in the body **136** by a sealing plug **232.** Seals **233** and **234** on the insert **230** engage in the bore **231** and reduced bore **235.** A valve member **236** is reciprocable in the insert **230** and has its lower end **237** provided with a seal **238** slideably engaging within the insert **230** below inlet ports **239** in the insert which establish communication between the port **228** and the valve chamber **229,** so that above the seal **238,** the chamber **229** is exposed to the flow passage through the upper valve body **136***a*. At the upper end of the equalizing valve member **236** is a head **240** engageable with a seat **241** under the influence of pressure below the ball valve **176** supplied to an inlet chamber **242,** above the head **240,** via the passage **233** and via a radial port **243** in the body **136** and ports **244** in the insert **230.** A rod **245** slideably extends downwardly through the lower end of the insert **230** and into the bore **235,** and a coiled spring **246** engages the insert **230** and an adjustable spring seat **247** on the rod to provide a downward bias closing the head **240** against the seat **241.** Leading into the bore **235** of the equalizing valve **220** is a port **248** which communicates with the control fluid chamber **195** of the shutoff valve means.

It will now be apparent that so long as the pressure differential across the closed ball valve **176** is such that well pressure in the equalizing valve chamber **242** and the force of spring **246** cause a downward force holding the valve head **240** seated, in excess of the force upwardly caused by control fluid pressure in the bore **235,** there will be no communication between the ports **221** and **228,** respectively, below and above the ball valve **176.** However, as control fluid pressure is increased to open the shutoff valve **176,** the increased pressure acts upwardly on the effective piston area at the lower end of the equalizing valve member **236** and will open the equalizing valve head **240,** whereby pressure will equalize between the lower ports **221,** through passage **223,** ports **243** and **244,** valve chambers **242** and **229,** ports **239,** and the upper equalizing port **228.**

The effective areas in the equalizing valve means **220** and the force of the spring **246** are selected, as compared with the effective area of the shutoff valve actuating piston section **187** of the sleeve **185,** so that the equalizing valve means **220** will open first, and thereby relieve the main shutoff valve means from the effect of differential pressure thereacross.

In order to assure that no back flow can occur when the shutoff valve **176** is open and the well is flowing therethrough, a back flow preventing valve **223**a is provided between the equalizing valve chamber **242** and the passage **223.**

In order to enable control fluid pressure to be supplied to both of the valve assemblies V1 and V2 in the valve means V, as previously indicated, the control fluid pressure chamber or bore **235** of the equalizing valve means **220** of the upper valve V1 has a passage **235***a* leading to the fitting **172,** which in turn communicates with the lower valve assembly V2.

In the use of shutoff valves, such as the valve assembly V1 or V2, to control flow from a plurality of well zones, it may occur, under various circumstances, such as seal failure, that one or more of the shutoff valves will not open under applied control fluid pressure. In such event, it may be necessary to pull the shutoff valve means from the well in order to repair and replace the shutoff valve means. In the present apparatus, however, as more particularly described in my prior application, Ser. No. 243,806, filed Apr. 13, 1972, means are provided whereby the valve V1 or the valve V2 may be opened mechanically and locked open to allow continued production from one or both of the well zones Z1 and Z2. In addition, the present apparatus enables the use of an auxiliary or secondary shutoff valve, adapted to be run into and anchored in the locked open valve assembly V1 or V2.

As seen in FIGS. **2***a* and **3***a*, the sleeve **196** is held by the shear screws **197** in an initial upper position as previously described, and the sleeve **196** cooperates with the body **136** to form the control fluid pressure chamber or annular space **195.** Initially released lock means

250 are provided, whereby, when the sleeve **196** is shifted downwardly, it will be locked in the lower position. When the sleeve **196** is shifted downwardly, it engages a shoulder **251** on the sleeve **185** and shifts the latter downwardly to open the ball valve **176.** A sleeve shifting tool (not shown) provides means for shifting the sleeve **196** downwardly, as more particularly disclosed in said pending application.

The lock means **250** includes a resiliently contractable, split lock ring **252** having external upwardly facing buttress teeth **253.** Beneath the lock ring **252** is an expander **254** which is secured to the sleeve **196** by fasteners **255** and has an expander surface **256** engageable within the lock ring **250** to expand the latter when it is lockingly engaged with internal teeth **257** within the body **136.**

From the foregoing, it will now be understood that the ball valve **176** is opened after the equalizing valve means, so that the ball valve supporting and actuating means are relieved of the necessity of sustaining or overcoming large friction forces caused by differential pressure across the valve, Moreover, since the ball valve **176** has a slight lost-motion longitudinally of the assembly at the end of its rotation between open and closed positions, the ball supporting and rotating means are relieved of loading when the valve is closed, without requiring precision manufacture.

Closure of the shutoff valve **176** is, moreover, in accordance with a feature of the invention, facilitated by virtue of the manner in which the ball is supported on the tips or ends **178***d* of the fingers **178***c* and the companion arched surfaces **178***e* on the ball **176.** Such a supporting arrangement produces a friction moment arm which is much smaller than when, as in the case of prior valve constructions the ball and the well fluid responsive actuator sleeve frictionally engage over an annular area defined between the inner and outer peripheries of the actuator sleeve. The present structure is such that the valve closing spring is better able to overcome the effect of hydrostatic control fluid pressure, since the spring force is not so dissipated by friction.

In addition, the supporting structure is simple and avoids tolerance problems encountered when the ball stop surfaces are engageable with companion stop surfaces carried on or made a part of the valve body.

I claim:

**1.** In a subsurface safety valve for wells: an elongated valve body having a flow passage therethrough for the flow of well fluid, said body having means at its upper end for fluid communication with an upwardly extending tubing string, said body having at its lower end for fluid communication with a downwardly extending tubing string, shutoff valve means in said body including a ball valve member rotatable between a first position closing said flow passage and a second position at which said flow passage is open, and actuator means for moving said ball valve member between said positions, said actuator means including an actuator sleeve longitudinally shiftable in said body and having an end surface sealingly engageable with said ball valve member, and a support member concentric with and shiftable relative to said sleeve and engaged with said ball to support the same for rotation relative to said sleeve.

**2.** In a subsurface safety valve as defined in claim **1,** said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation.

**3.** In a subsurface safety valve as defined in claim **1,** said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, and means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions.

**4.** In a subsurface safety valve as defined in claim **1,** said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions, and another actuator sleeve opposed to the first mentioned actuator sleeve with said ball valve member disposed between said actuator sleeves, said another actuator sleeve and said body defining a control fluid pressure chamber, and said another actuator sleeve having a control fluid pressure responsive area for moving said another actuator sleeve to move said ball valve member to said second position.

**5.** In a subsurface safety valve as defined in claim **1,** said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions, and another spring acting between said support sleeve and said actuator sleeve to bias said actuator sleeve in said one direction.

**6.** In a subsurface safety valve as defined in claim **1,** said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions, and another spring acting between said support member and said actuator sleeve to bias said actuator sleeve in said one direction, said first mentioned spring being stronger than said another spring.

**7.** In a subsurface safety valve as defined in claim **1,** said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions, and another actuator sleeve opposed to the first mentioned actuator sleeve with said ball valve member disposed between said actuator sleeves, said another actuator sleeve and said body defining a control fluid pressure chamber, and said another actuator sleeve having a control fluid pressure responsive area for moving said another actuator sleeve to move said ball valve member to said second position, and another spring acting between said support mem-

ber and said actuator sleeve to bias said actuator sleeve in said one direction.

8. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions, and another actuator sleeve opposed to the first mentioned actuator sleeve with said ball valve member disposed between said actuator sleeves, said another actuator sleeve and said body defining a control fluid pressure chamber, and said another actuator sleeve having a control fluid pressure responsive area for moving said another actuator sleeve to move said ball valve member to said second position, and another spring acting between said support member and said actuator sleeve to bias said actuator sleeve in said one direction, said first mentioned spring being stronger than said another spring.

9. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, and means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions including a pin on one of said ball valve members and said body and pin engaging walls on the other of said ball valve member and said body engageable with said pin to rotate said ball valve member in opposite directions upon longitudinal movement of said ball valve member.

10. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, and means responsive to longitudinal movement of said support member to rotate said ball valve member to one said positions including a pin on one of said ball valve members and said body and pin engaging walls on the other of said ball valve member and said body engageable with said pin to rotate said ball valve member in opposite directions upon longitudinal movement of said ball valve member, said pin and said walls clearing when said ball valve member is in said positions enabling slight free longitudinal movement of said ball following rotation to said positions.

11. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, and means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions including a pin on one of said ball valve members and said body and pin engaging walls on the other of said ball valve member and said body engageable with said pin to rotate said ball valve member in opposite directions upon longitudinal movement of said ball valve member, and cooperative stop means on said support member and on said ball valve member for limiting rotation of said ball valve member between said positions.

12. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support member to move the latter longitudinally in one direction, means responsive to longitudinal movement of said support member to rotate said ball valve member to one of said positions, and cooperative stop means on said support member and on said ball valve member for limiting rotation of said ball valve member between said positions.

13. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including fingers extending longitudinally on said body to the region of the axis of rotation of said ball, and means mounting said ball valve member on said fingers for rotation of said ball valve member.

14. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including fingers extending longitudinally in said body to the region of the axis of rotation of said ball valve member and having arcuate end surfaces, said ball valve member having arcuate surfaces engaged with said arcuate surfaces of said ends of said fingers.

15. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including fingers extending longitudinally in said body and having arcuate portions in the region of the axis of rotation of said ball valve member, said ball valve member having arcuate surfaces engaged with said arcuate portions of said fingers.

16. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including portions extending longitudinally in said body to the region of the axis of rotation of said ball valve member, said ball valve member and said portion having means supporting said ball for rotation.

17. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including portions extending longitudinally in said body to the region of the axis of rotation of said ball valve member, said ball valve member and said portion having means supporting said ball for rotation, said ball valve member and said portions having means for limiting rotation of said ball valve member to said positions.

18. In a subsurface safety valve as defined in claim 1, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including portions extending longitudinally in said body to the region of the axis of rotation of said ball valve member, said ball valve member and said portion having means supporting said ball for rotation, said ball valve member

and said portions having means for limiting rotation of said ball valve member to said positions, and said body and said ball valve member having means for rotating said ball between said position responsive to longitudinal movement of said ball valve member.

**19.** In a subsurface safety valve as defined in claim **1**, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including portions extending longitudinally in said body to the region of the axis of rotation of said ball valve member, said ball valve member and said portion having means supporting said ball for rotation, said ball valve member and said portions having means for limiting rotation of said ball valve member to said positions, and said body and said ball valve member having means for rotating said ball between said position responsive to longitudinal movement of said ball valve member and for enabling slight free longitudinal motion of said ball valve member at said positions.

**20.** In a subsurface safety valve as defined in claim **1**, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation including portions extending longitudinally in said body to the region of the axis of rotation of said ball valve member, said ball valve member and said portion having means supporting said ball for rotation, said ball valve member and said portions having means for limiting rotation of said ball valve member to said positions, said body having a lateral opening adjacent said ball valve member larger than the latter, a closure for said opening, and means on said closure and on said ball valve member for rotating said ball valve member between said positions responsive to longitudinal movement of said ball valve member.

**21.** In a subsurface safety valve as defined in claim **1**, said support member having means at opposite sides of said ball valve member supporting said ball valve member in the region of its axis of rotation, said actuator means including a spring acting on said support sleeve to move the latter longitudinally one direction, means responsive longitudinal movement of said support sleeve to rotate said ball valve member to one of said positions, and another actuator sleeve opposed to the first mentioned actuator sleeve with said ball valve member disposed between said actuator sleeves, said another actuator sleeve and said body defining a control fluid pressure chamber, and said another actuator sleeve having a control fluid pressure responsive area for moving said another actuator sleeve to move said ball valve member to said second position, and bypass valve means operable by the pressure of said control fluid pressure for equalizing fluid in said flow passage across said ball valve member when in its first position before said ball valve member is moved to its second position.

**22.** In a subsurface safety valve for wells, an elongated body having a flow passage therethrough for the flow of well fluids, said body having means at its upper end for fluid communication with an upwardly extending tubing string, said body having means at its lower end for fluid communication with a downwardly extending tubing string, a ball valve in said body having a spherical sealing surface and an opening therethrough, means supporting said ball valve for rotation between a first position at which said opening extends transversely of said flow passage and a second position at which said opening is aligned with said flow passage, means for rotating said ball valve between said positions responsive to longitudinal movement of said ball valve in opposite directions, actuator means for shifting said ball valve longitudinally including a first actuating and sealing sleeve sealingly engaging said spherical surface, control fluid pressure responsive means for shifting said first actuating and sealing sleeve in one longitudinal direction to move said ball valve to said second position, a second actuating and sealing sleeve sealingly engaging said spherical surface, means for shifting said second actuating and sealing sleeve longitudinally to overcome control fluid pressure and move said ball valve longitudinally in the other direction to move said ball valve to said first position, and said means supporting said ball valve including means supporting said ball valve on said second actuating and sealing sleeve.

**23.** In a subsurface safety valve as defined in claim **22**, said means supporting said ball valve on said second actuating sleeve including a support sleeve shiftably carried by said second actuating and sealing sleeve and having support portions engaging said ball valve at opposite sides of said ball valve in the region of its axis of rotation.

**24.** In a subsurface safety valve as defined in claim **22**, said means for shifting said second actuating and sealing sleeve longitudinally to overcome control fluid pressure including a spring acting on said means supporting said ball valve on said second actuating and sealing sleeve.

**25.** In a subsurface safety valve as defined in claim **22**, said means for shifting said second actuating and sealing sleeve longitudinally to overcome control fluid pressure including a spring acting on said means supporting said ball valve on said second actuating and sealing sleeve, and another spring acting between said means supporting said ball valve on said second actuating and sealing sleeve and said second actuating and sealing sleeve to maintain said second actuating and sealing sleeve in sealing engagement with said spherical surface.

**26.** In a subsurface safety valve for wells: an elongated valve body having a flow passage therethrough for the flow of well fluid, said body having means at its upper end for fluid communication with an upwardly extending tubing string, said body having means at its lower end for fluid communication with a downwardly extending tubing string, shut-off valve means in said body including a ball valve member rotatable between a first position closing said flow passage and a second position at which said flow passage is open, and actuator means for moving said ball valve member between said positions, said actuator means including a longitudinally shiftable support member in said body below said ball valve member and supporting said ball valve member for rotation, means for rotating said ball valve member between said positions responsive to longitudinal movement of said ball in opposite directions, means for shifting said support member longitudinally in one direction to rotate said ball in one direction including a spring acting upwardly on said support member, and control fluid pressure operated means for shifting said ball valve member and said support member longitudinally in the other direction to rotate said ball valve member in the other direction.

27. In a subsurface safety valve for wells as defined in claim 26, a lower sleeve in said body having an area responsive to well fluid pressure for urging said ball valve member longitudinally upwardly.

28. In a subsurface safety valve for wells as defined in claim 26, said control fluid pressure operated means including an upper sleeve in said body having a piston area, said body having a control fluid pressure chamber in which said piston area is exposed and an inlet for control fluid.

29. In a subsurface safety valve for wells as defined in claim 26, said control fluid pressure operated means including an upper sleeve in said body having a piston area, said body having a control fluid pressure chamber in which said piston area is exposed and an inlet for control fluid, and including a lower sleeve in said body having an area responsive to well fluid pressure for urging said ball valve member longitudinally upwardly.

30. In a subsurface safety valve for wells as defined in claim 26, one of said sleeves having sealing means engaged with said ball valve member.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,827,494 Dated August 6, 1974

Inventor(s) TALMADGE L. CROWE

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

Column 3, line 67: "wall" should be --well--.

Column 9, line 51: after "having" insert --means--.

Signed and sealed this 7th day of January 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents