United States Patent [19]

Crowe

[11] **3,797,573**

[45] **Mar. 19, 1974**

[54] **FULL OPENING SAFETY VALVE**

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

[22] Filed: **Sept. 5, 1972**

[21] Appl. No.: **286,151**

Related U.S. Application Data

[62] Division of Ser. No. 243,806, April 13, 1972.

[52] **U.S. Cl.** .... **166/224 S,** 166/.5, 166/129, 166/313

[51] **Int. Cl.** **E21b 33/10**

[58] **Field of Search** .... 166/.5, 313, 315, 80, 129, 166/224, 224 S; 137/458, 630; 251/315

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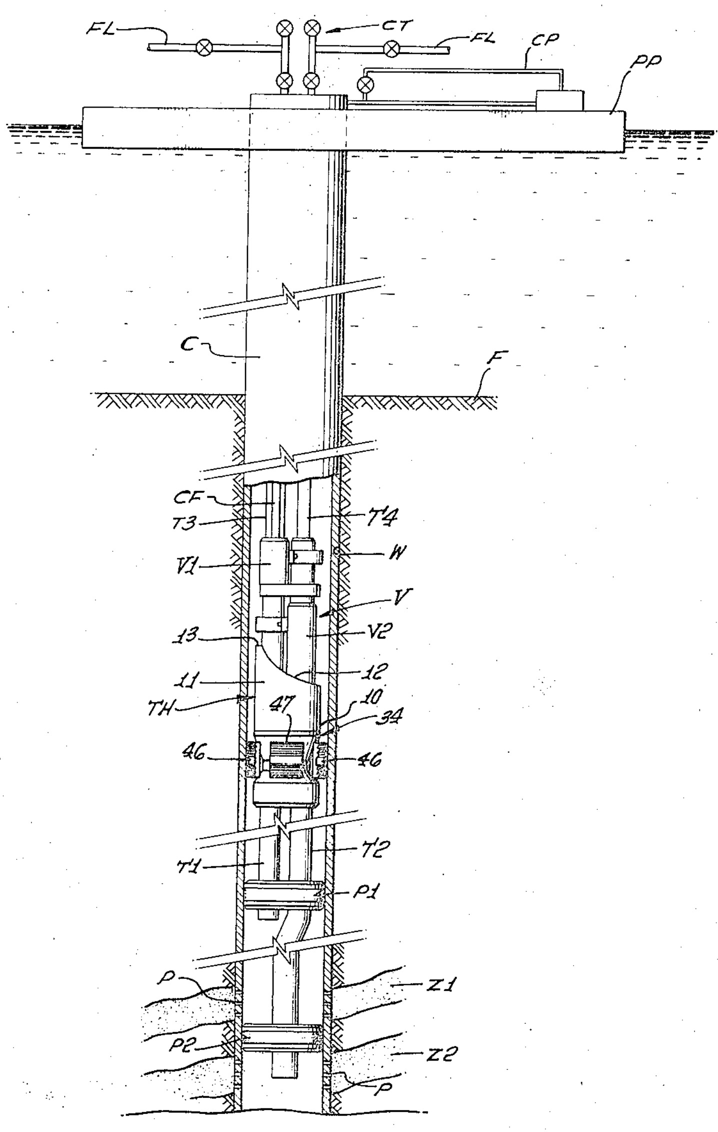
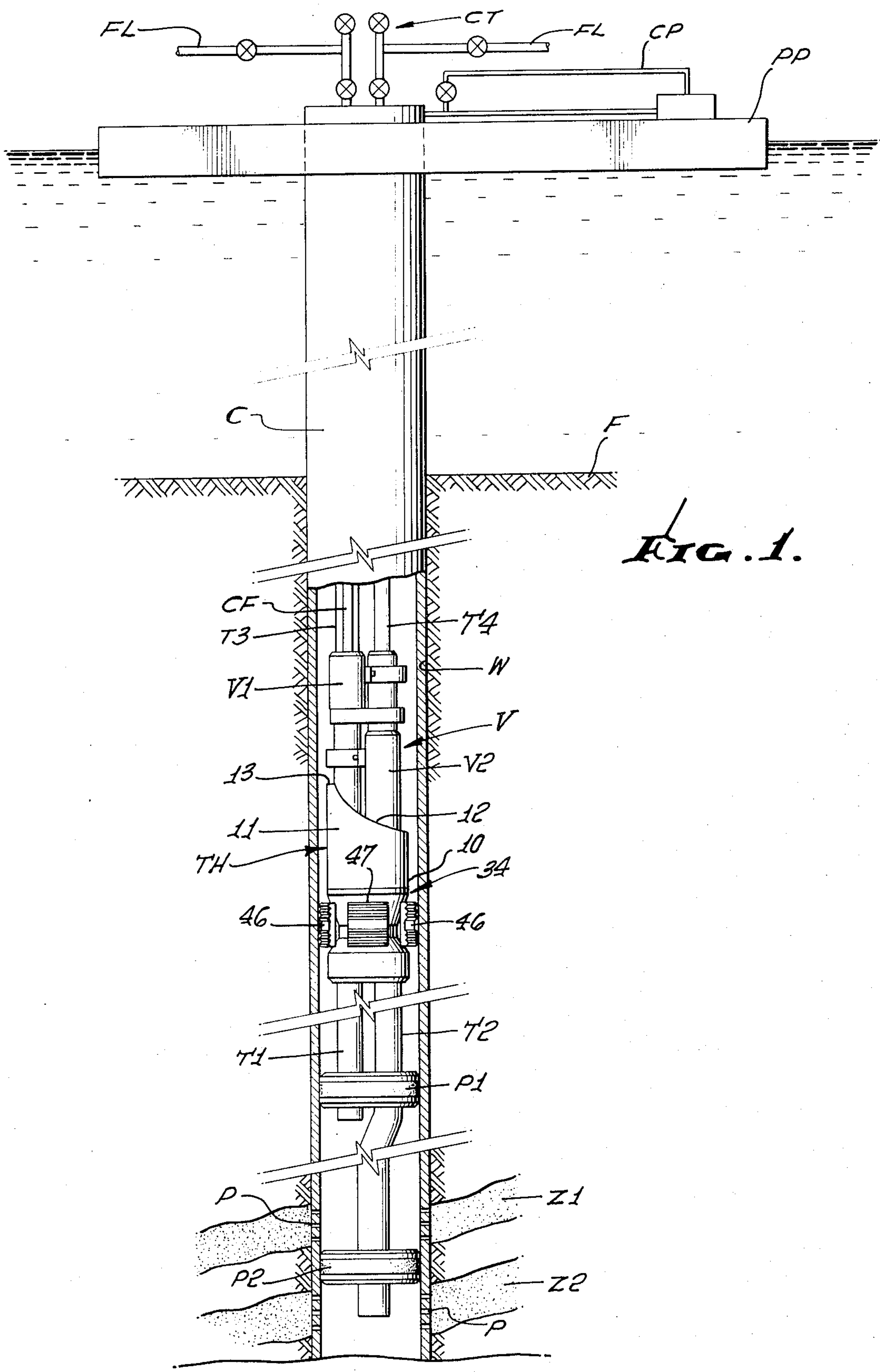
Primary Examiner—Werner H. Schroeder
Attorney, Agent, or Firm—Bernard Kriegel

[57] **ABSTRACT**

A full opening single or dual safety valve for wells, in which each valve assembly has a rotary ball valve having a flow passage as large as the flow passage through the valve body. The ball valve is installed in the body through a side window which is closed by a member which cooperates with the ball valve to move the latter between open and closed positions. The dual safety valve has releasable latch means for holding the safety valve in a receptacle of a tubing hanger which supports producing tubing strings in the well.

25 Claims, 24 Drawing Figures

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T4
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TH
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P1
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Z1
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Z2
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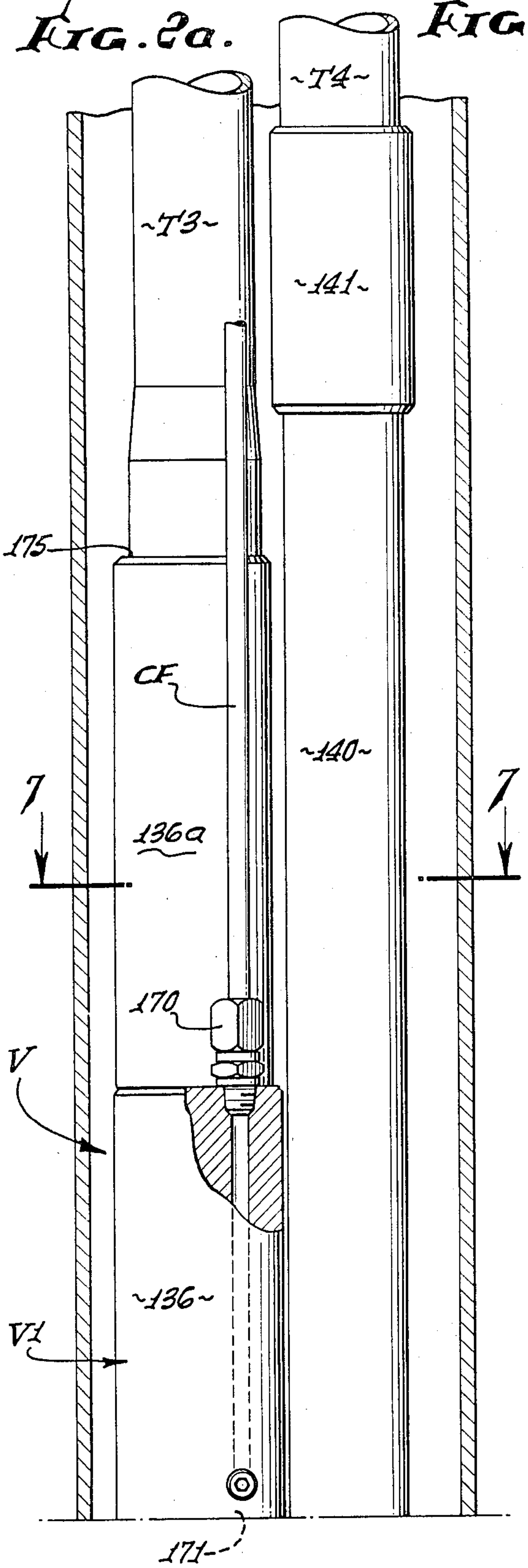
FIG. 1.

FIG. 2a.


~T3~
~T4~
~141~
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CF
~140~
7
7
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V
~136~
V1
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FIG. 2b.

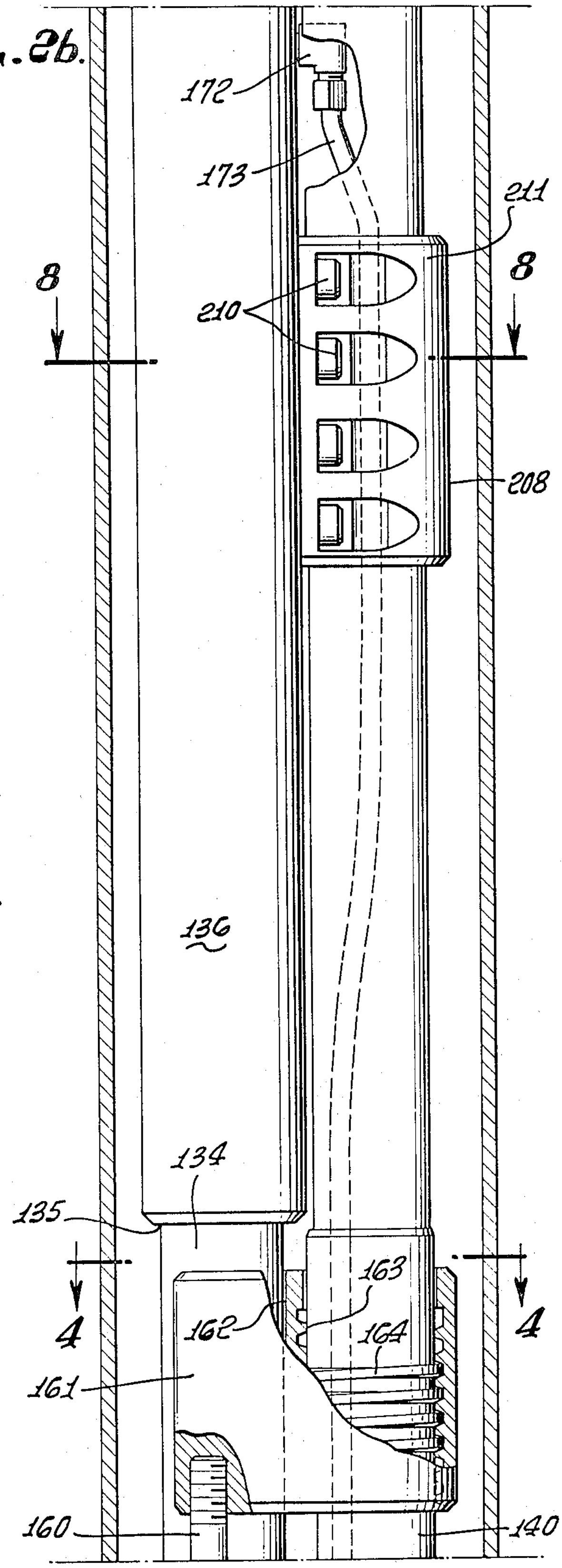
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FIG. 2c.

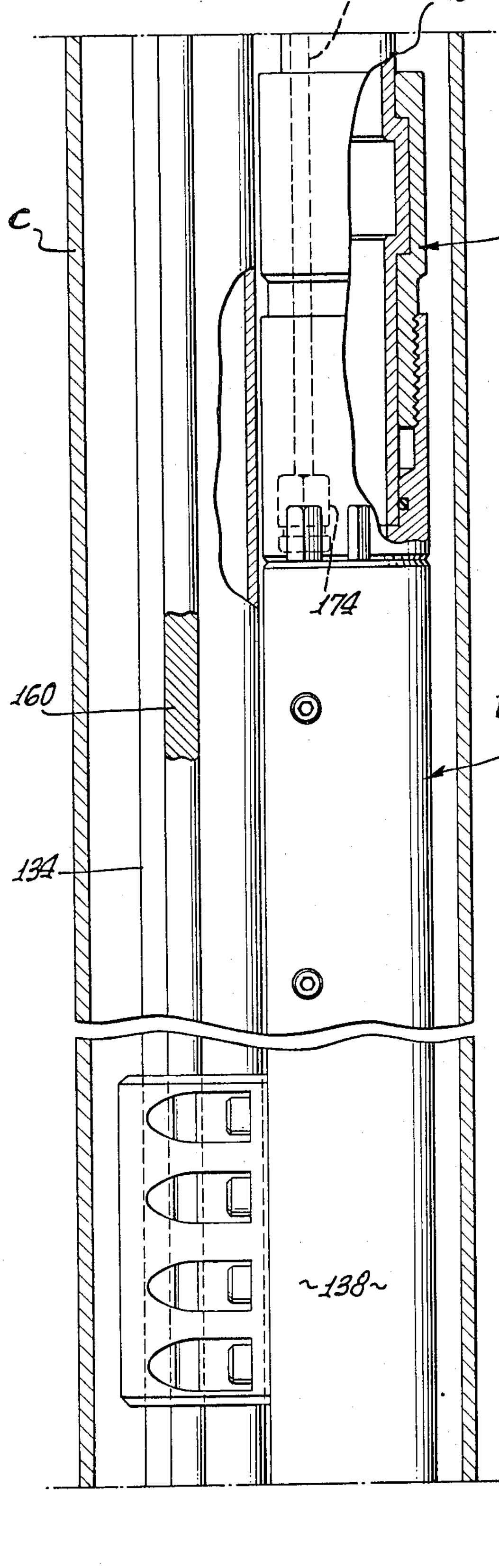
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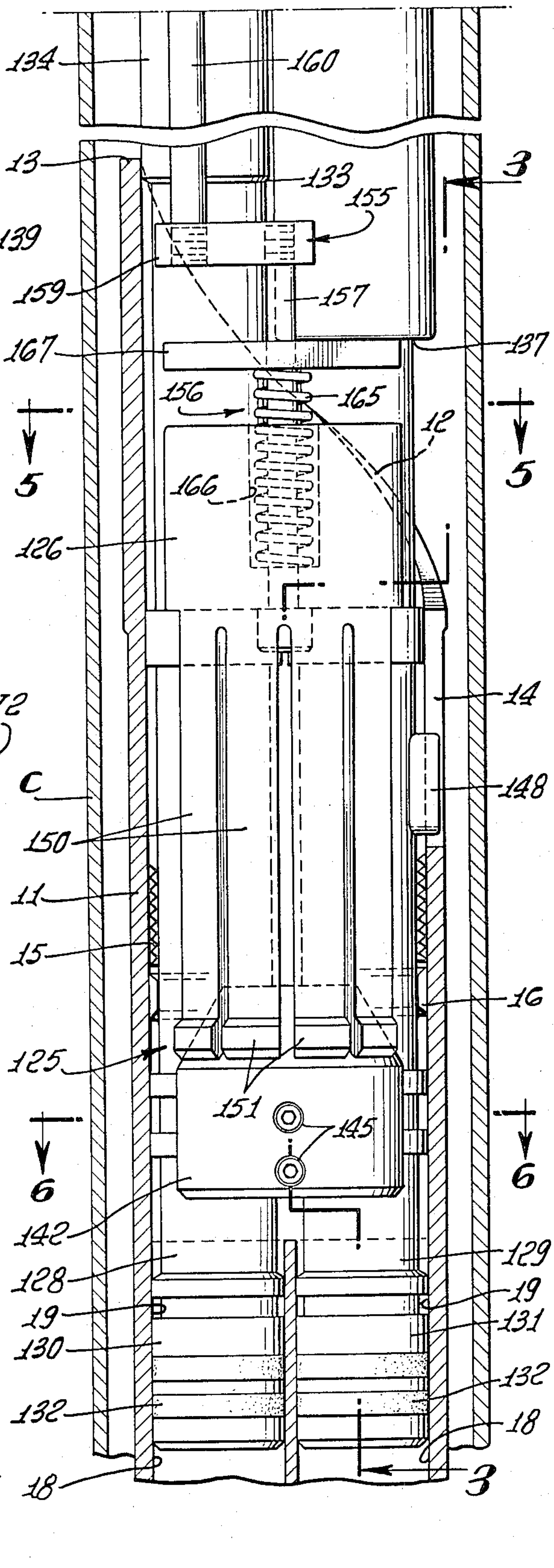
FIG. 2d.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150
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FIG. 3.

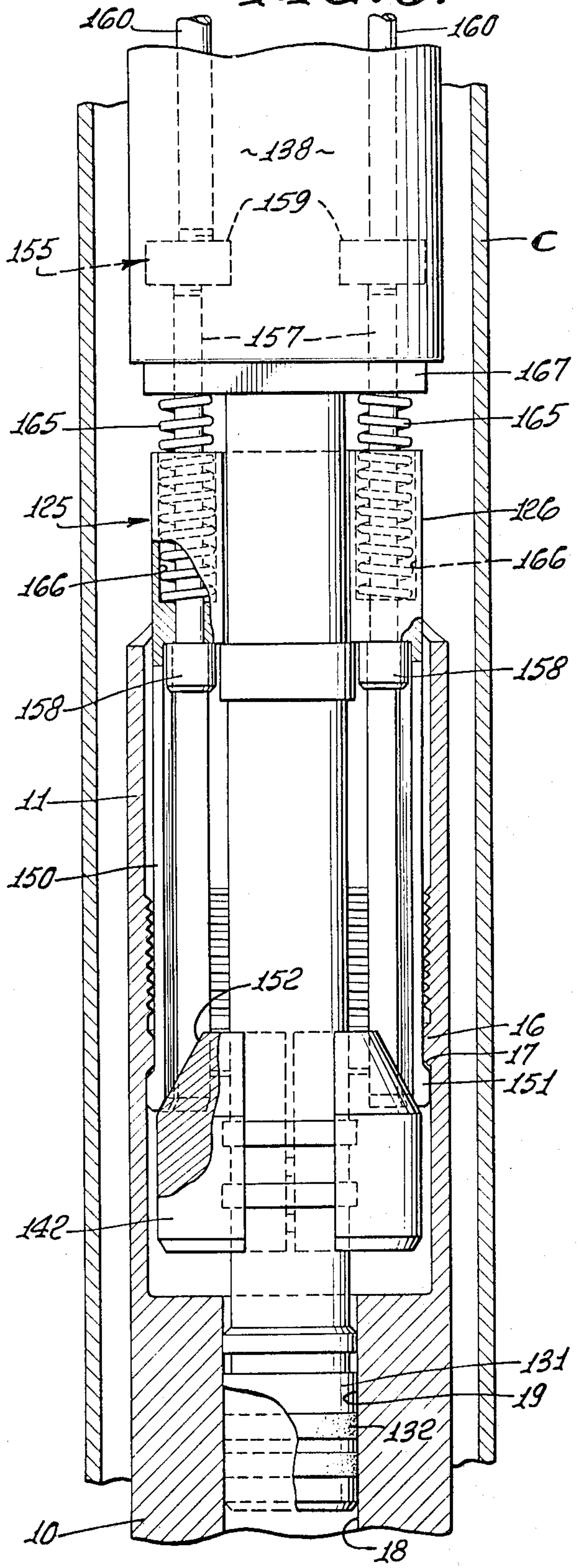

FIG. 4.

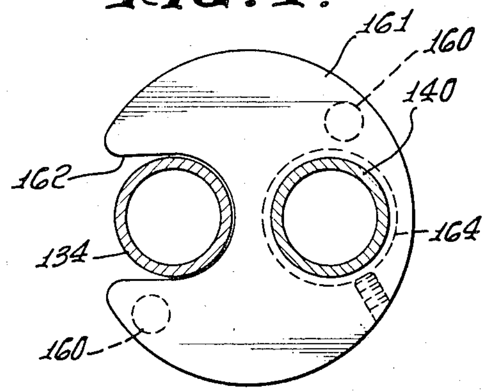

FIG. 5.

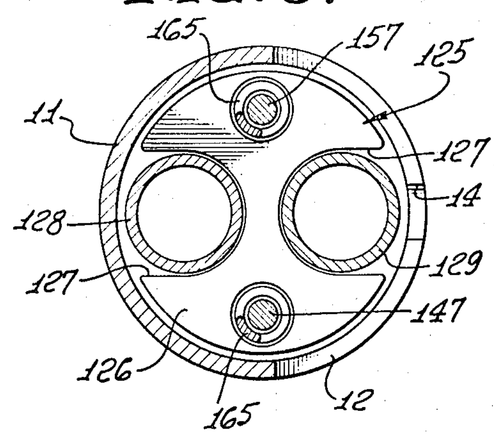

FIG. 6.

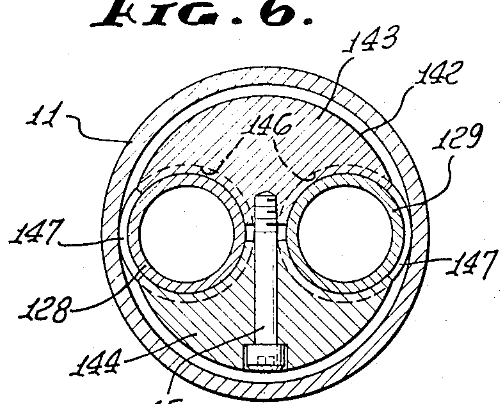

FIG. 7.

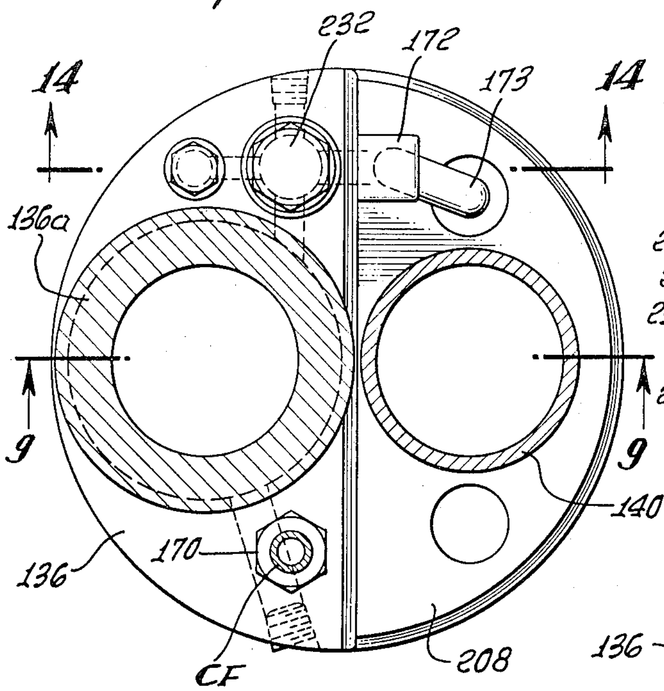

FIG. 8.

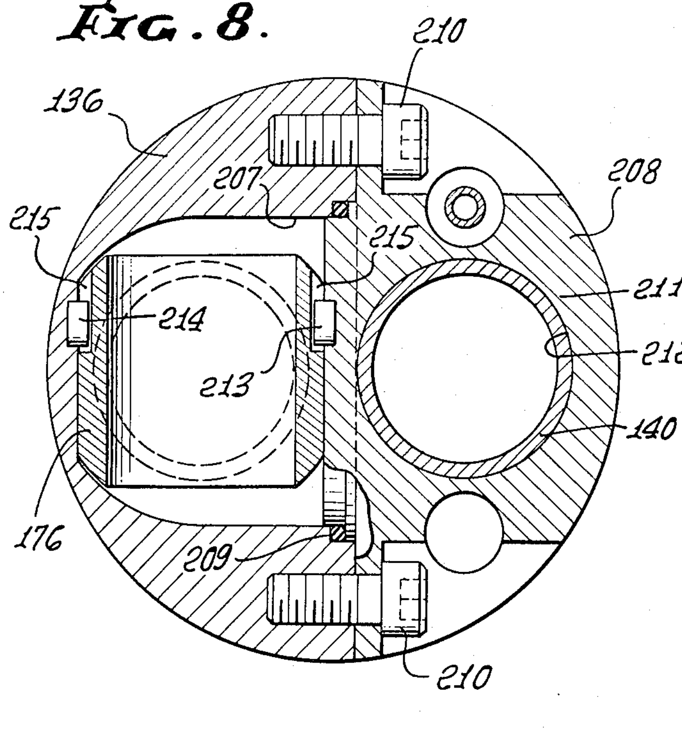

FIG. 14.

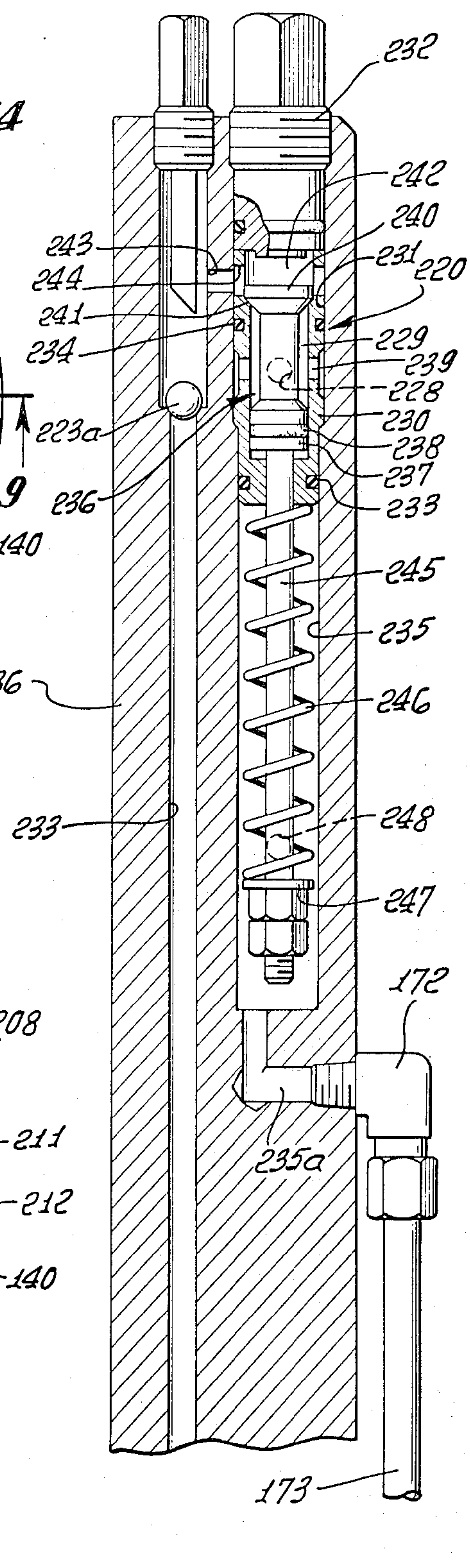

FIG. 9a.

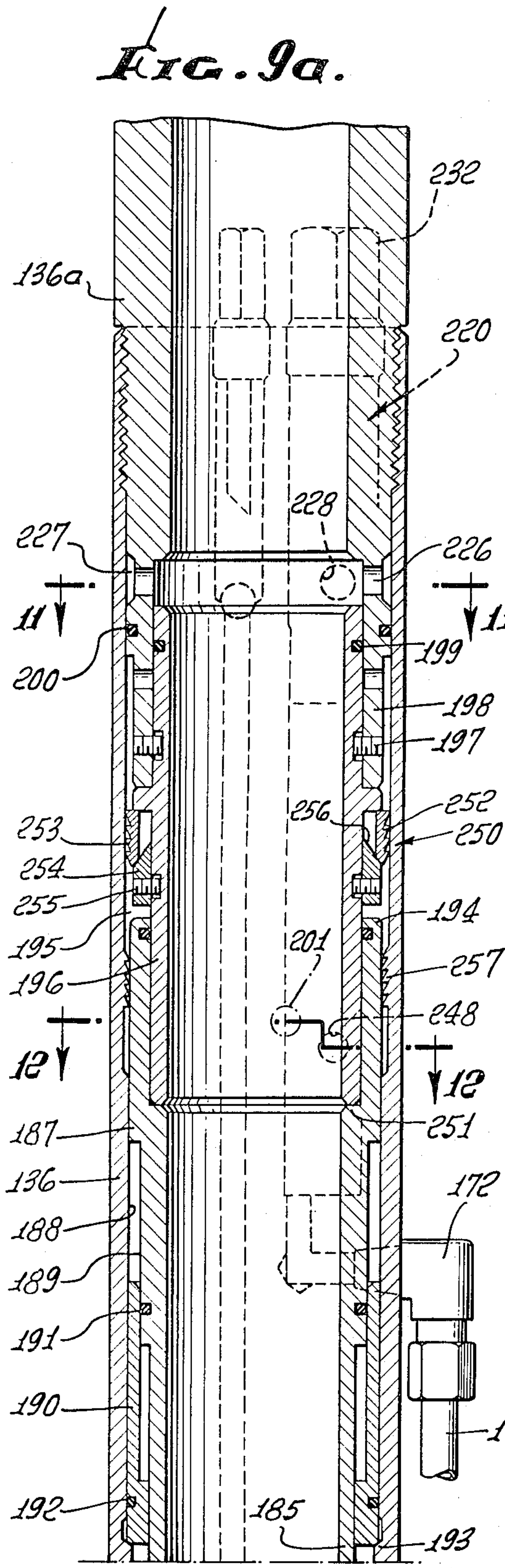
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FIG. 9b.

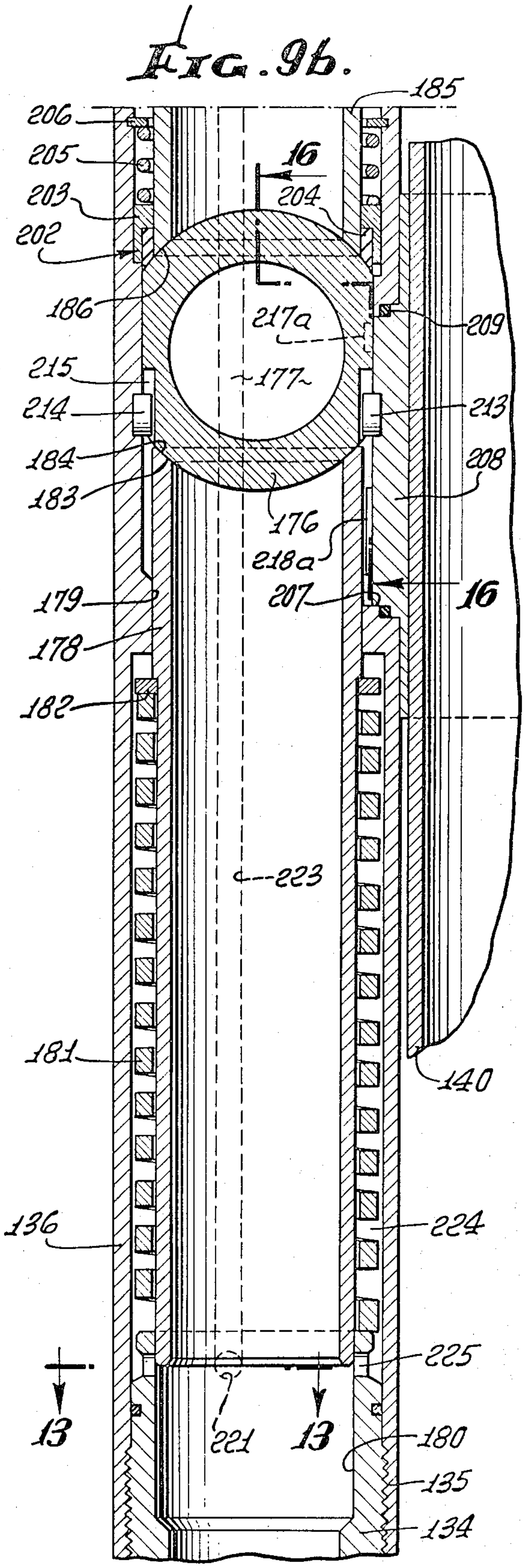
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FIG. 10a.

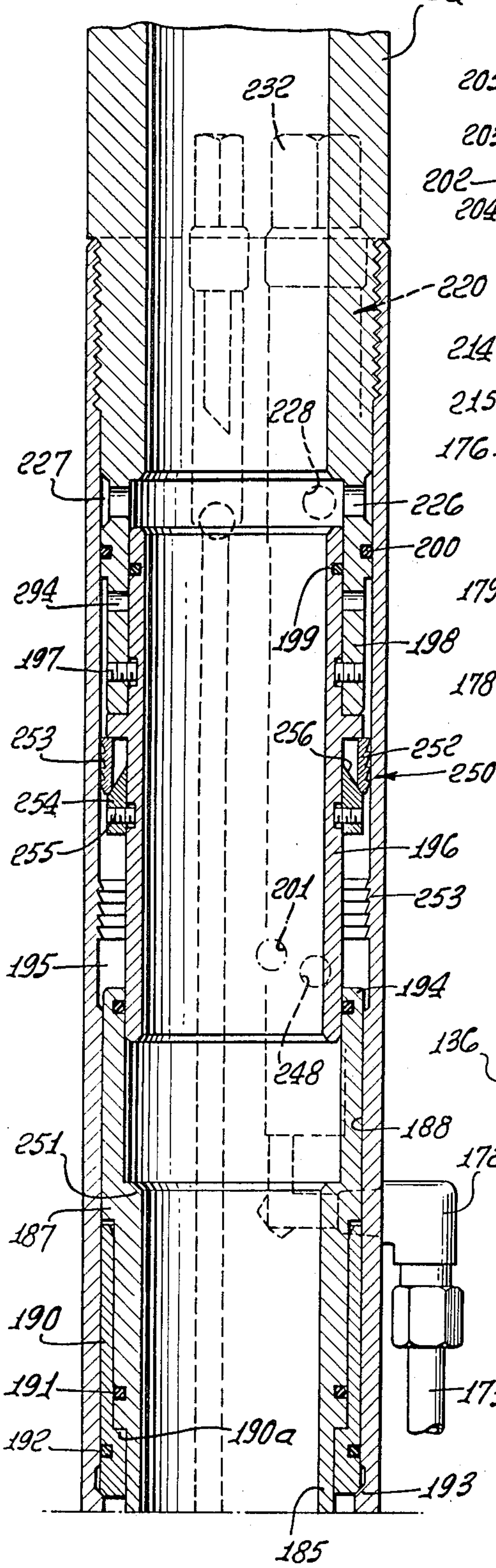

FIG. 10b.

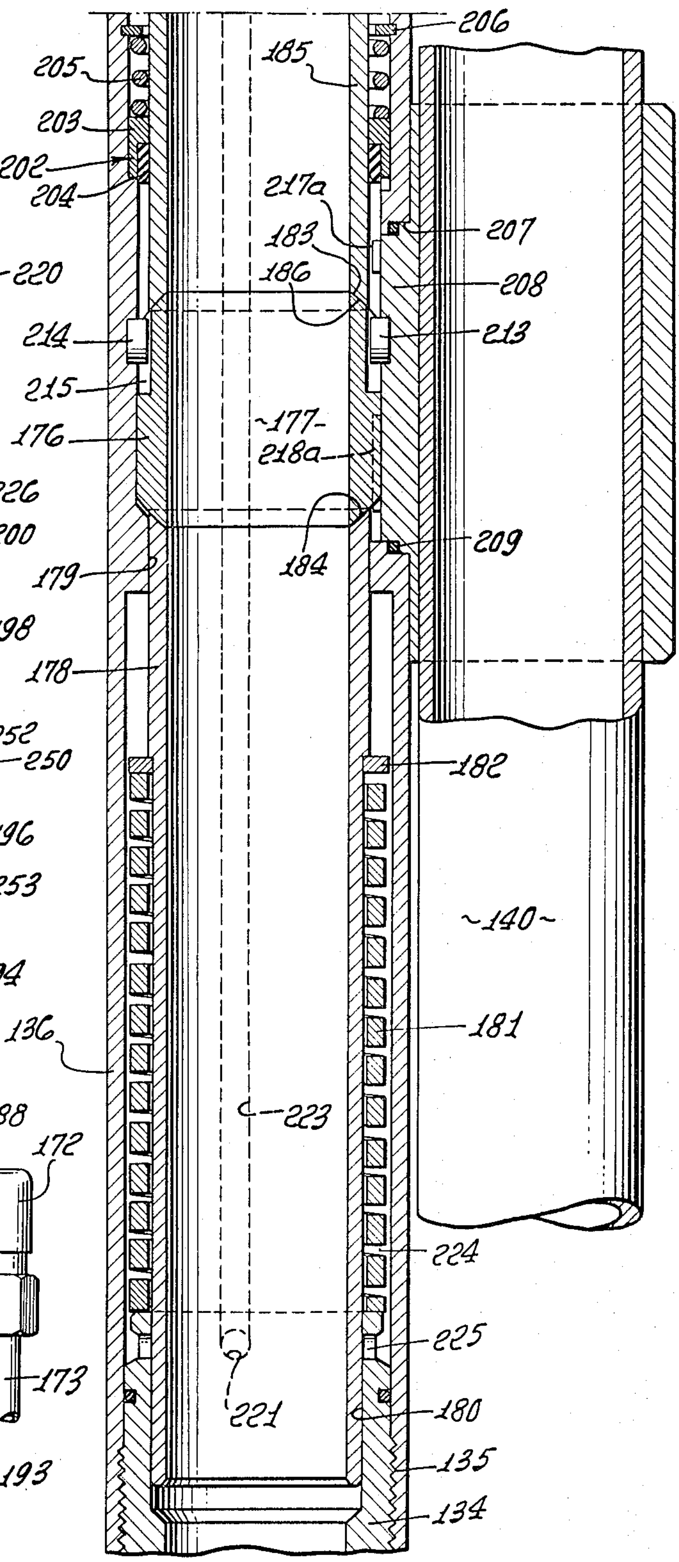

FIG. 11.

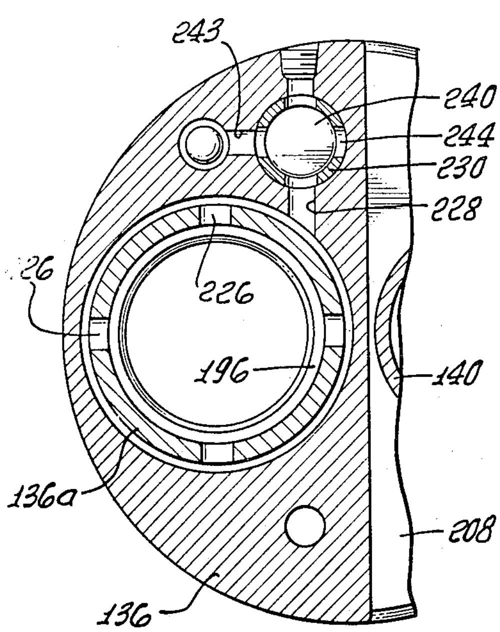

FIG. 12.

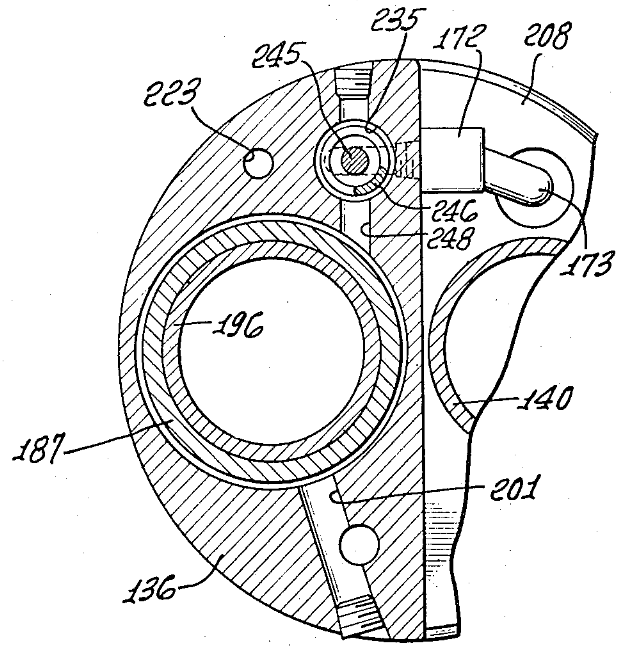

FIG. 13.

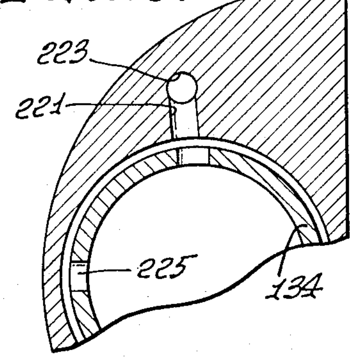

FIG. 15.

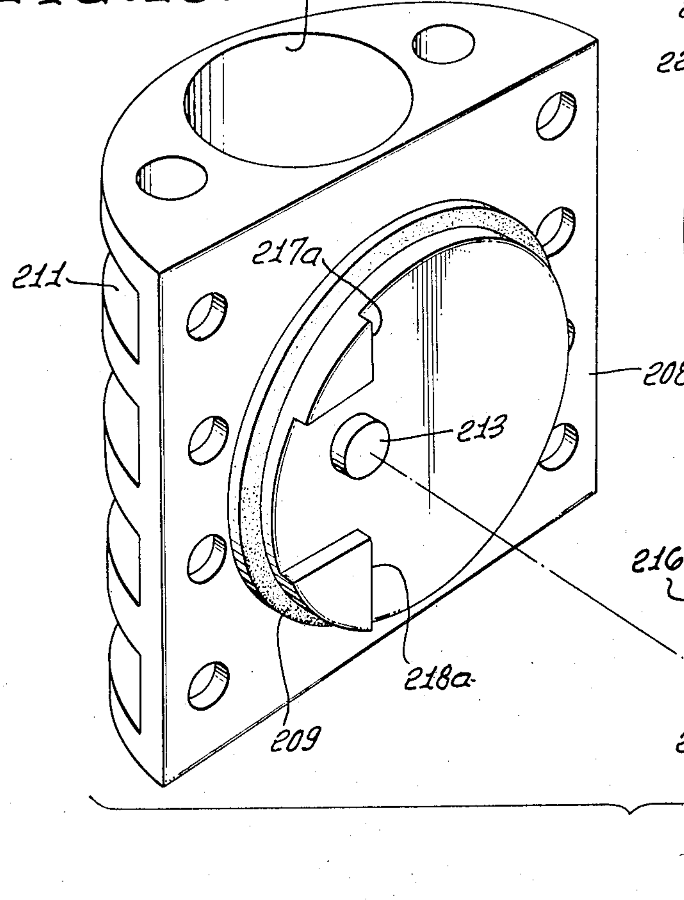

Fig. 17.

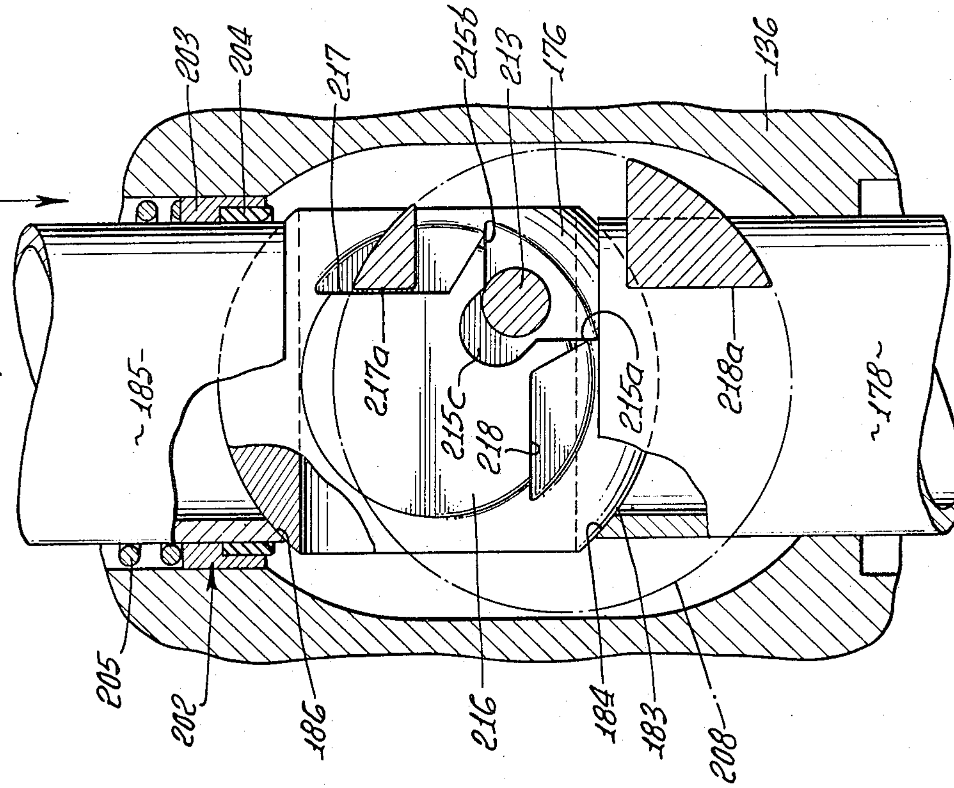
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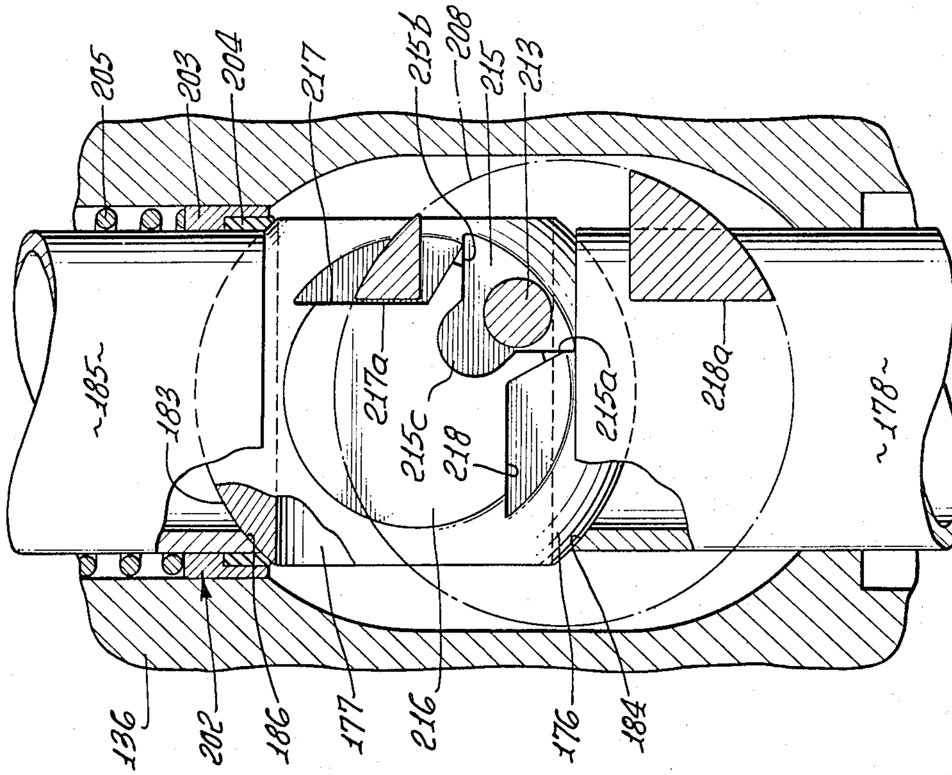
Fig. 16.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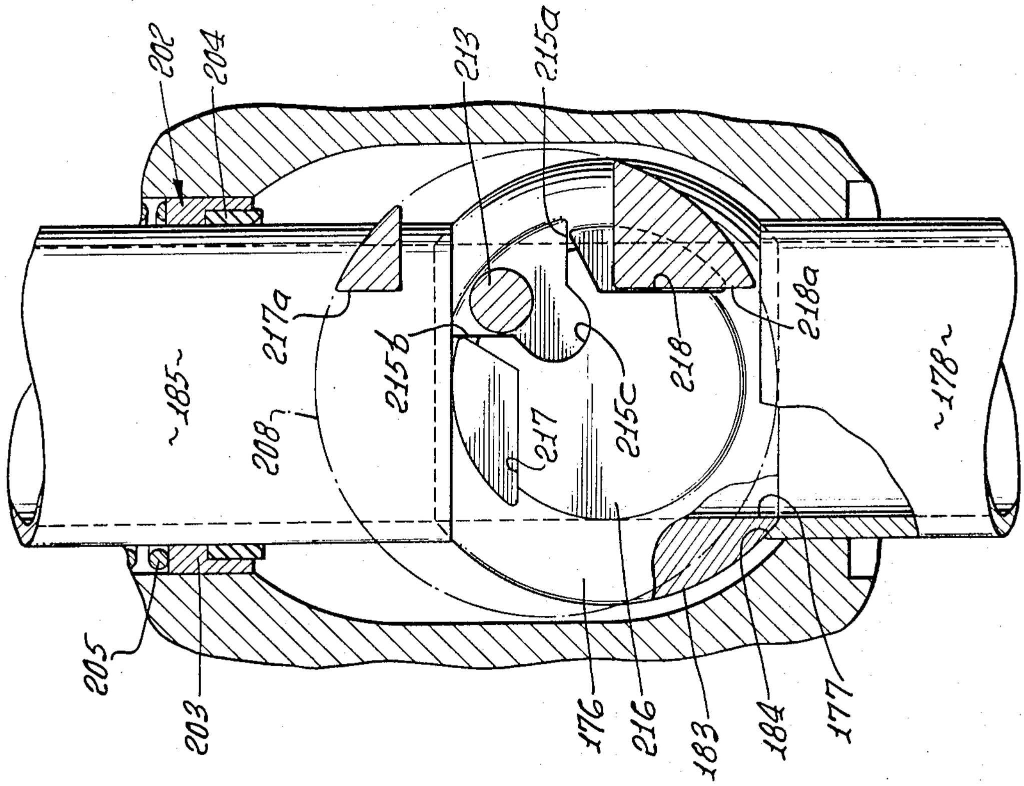
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FIG. 19.

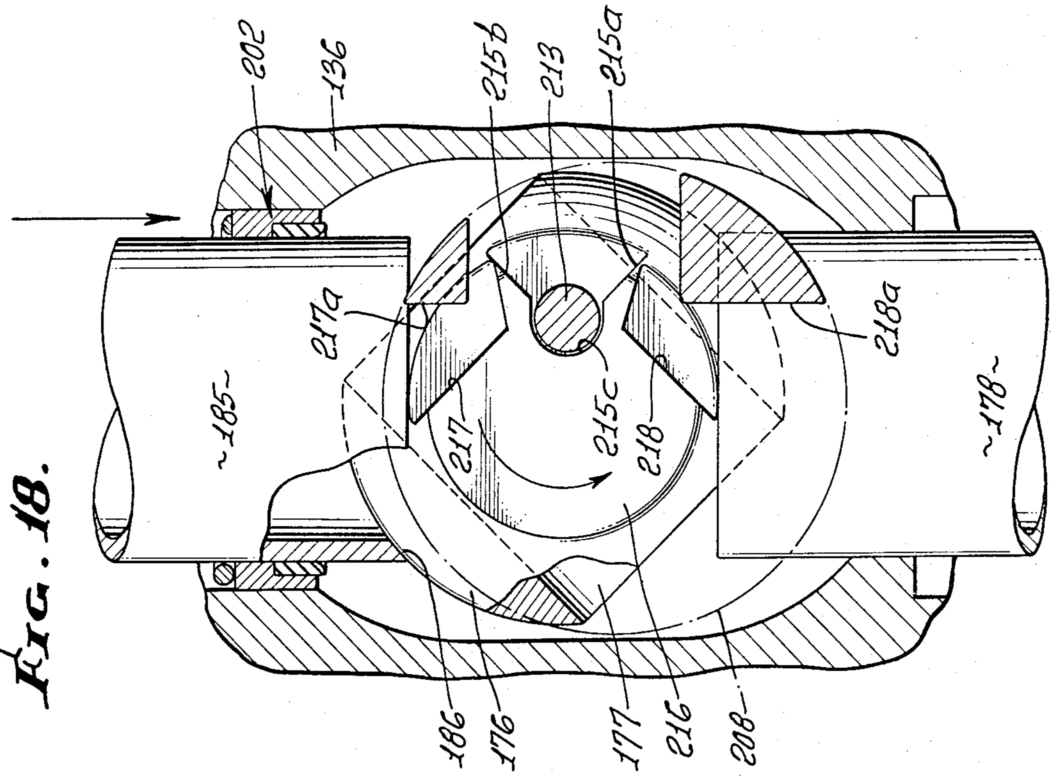
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FIG. 18.

FULL OPENING SAFETY VALVE

This application is a division of application Ser. No. 243,806, filed Apr. 13, 1972.

In the production of well fluids, such as oil and/or gas, from wells, it has been the practice to provide automatically closeable shutoff or safety valves which are located downhole in the well and are held open by control fluid pressure, the valves closing automatically when control fluid pressure is purposely reduced to allow the valves to close or damage occurs to the control fluid system at the well head or on an offshore platform.

Such valves are employed below the well head and in the case of offshore wells, the valves are installed below the mudline at such depth as may be desired or established by regulation, so that in the event of damage to the well caused by shifting earth or subsidence, the wells can be shut in to avoid loss of valuable well fluids into the water and, and also, to avoid contamination of the water and the shore.

Many offshore wells are produced from spaced well zones through separate strings of production tubing, and a safety or shutoff valve is required for each zone. Since, from time to time, it is necessary to perform various remedial operations through the tubing strings, it is preferred that the safety valves have a full bore opening which will allow wireline tools to pass through the safety valves. On the other hand, it is also preferred that the safety valves be easily removed from the well for service or repair. While safety valves adapted to be run into the well and landed in a seat on a wireline and retrieved on wireline are relatively simple to run and retrieve without requiring that the tubing string be pulled from the well, such wireline valves, in general, do not have a full bore opening through which remedial operations can be performed through the production tubing, particularly if the well is cased with comparatively small casing so that the valves must be small in diameter.

Full opening valves have, before the present invention, been made up in the tubing strings and run into the well in the tubing string. Accordingly, repair or service of such tubing string safety valves has required that the entire tubing string be hoisted, at least until the valve is accessible. Such operations have generally involved killing the well, with prospective damage to the productive formation, as well as the use of heavy hoisting equipment capable of lifting an entire tubing string which may be many thousands of feet in length.

In addition, when an offshore well is cased with comparatively small diameter casing, a limitation is inherently imposed on the size of the tubing valves that can be run into the well on tubing, as well as on wireline.

The present invention involves novel safety valve apparatus, whereby a dual safety or shutoff valve for dual or multiple tubing strings may be conveniently employed in a well which is being produced from multiple zones.

More particularly, the present invention involves the provision of dual safety or shutoff valves which are run into the well casing on production tubing and landed in a tubing hanger which supports the greater weight of the downwardly extended production tubing strings, in a plural zone well, and which provides a seat for removable plural safety valves. Thus, a comparatively light hoist apparatus may be employed to run and retrieve the valve assembly, and costly work-over or pulling rigs need not be utilized.

In accomplishing the foregoing, the tubing hanger, with the production tubing for a plurality of well zones depending therefrom is run into the well casing on a setting tool to a desired location, say to a prescribed depth below the mudline in the case of an offshore well. The tubing hanger is anchored in the well casing and the setting tool is released from the tubing hanger and removed from the well. The tubing hanger provides a seat for a plural safety or shutoff valve assembly which is run into the well on an upward extension of the production tubing and landed in the tubing hanger, with the tubing in the well below the tubing hanger in communication with the tubing above the tubing hanger. Control fluid is supplied to open the respective safety valves, but in the event of a sufficient decrease in the control fluid pressure, the safety valves will automatically close to shut off the flow of production fluid.

When, from time to time, the production tubing below the hanger must be pulled from the well to enable various operations, such as further drilling, recementing, or the like, the tubing hanger is retrievable from the well, following removal of the subsurface safety valve assembly. To accomplish this, the plural valve assembly has anchor means engageable in and releasable from the tubing hanger and operable by rotation of one of the tubing strings, as more particularly disclosed in the aforementioned application of which this is a division. The tubing hanger is adapted to receive a retrieving tool which can be run into the well and into the tubing hanger to engage the same and pull it from the well, along with the production tubing below the tubing hanger.

The overall diameter or size of the respective valve bodies of safety valves of the type here involved is limited by the available space within the well casing. Thus, full opening plural safety valves of the ball type have not been available for use in certain wells wherein the casing is comparatively small. Limitations on the overall size of the opening through the ball valve, so that the performance of subsurface work in the well through the safety valve has been a problem.

However, the present safety valve is so constructed that the opening through the ball valve is larger and subsurface operations can be performed through the open ball valve. This is accomplished by providing a lateral opening in the valve body into which the ball valve can be inserted and held in place by a closure. The ball valves are staggered longitudinally to space the closure members, and the closure members provide a support or guide for the respective tubings which lead to the top of the well.

The ball valve of the present invention is actuated to an open position by a control fluid pressure responsive tubular member or sleeve. The effective control fluid responsive area of which is reduced by a second sleeve which affords an increased well fluid responsive area to enable closing of the ball valve. Thus, the valve assembly can be located at a substantial depth beneath the top of the well and the hydrostatic pressure of control fluid will not open the ball valve in the absence of substantial well fluid pressure acting to close the ball valve.

When the valve is closed by well fluid pressure and there is, therefore, substantial differential pressure across the ball valve holding it closed, the shifting force to open the valve would ordinarily be quite high due to high friction, and damage to the valve operating means or sealing means could occur. However, the present valve provides a lost motion connection between the ball valve support and rotating means and the ball valve, whereby the sealing means are protected. In addition, the valve assembly includes by-pass valve means, whereby the differential pressure across the ball valve is equalized before the valve is opened. When the equalizing valve and the ball valve are held open during fluid circulating operations, no fluid can flow through the by-pass passage from the well which might have foreign materials tending to interfere with the operation of the by-pass valve.

This invention possesses many other advantages, and has other purposes which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It and its method of use 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 description is 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 illustration showing dual safety valve apparatus installed in a tubing hanger anchored in a well casing extending through vertically spaced productive well zones which are isolated from one another by packers, and from which well fluid are produced through a pair of production tubing strings;

FIGS. 2*a*, 2*b*, 2*c* and 2*d* together constitute a view generally in elevation, but with certain parts broken away, showing the subsurface valve assembly landed in the tubing hanger, FIGS. 2*b* through 2*d*, respectively, constituting successive downward continuations of FIG. 2*a;*

FIG. 3 is a view partly in elevation and partly in section as taken on the line 3—3 of FIG. 2*d;*

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

FIG. 5 is a horizontal section as taken on the line 5—5 of FIG. 2*d;*

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

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

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

FIGS. 9*a* and 9b together constitute a vertical section through one of the subsurface valve assemblies, as taken on the line 9—9 of FIG. 7, FIG. 9*b* constituting a downward continuation of FIG. 9*a*, and the valve being shown in the normally closed condition;

FIGS. 10*a* and 10*b* together constitute a view generally corresponding to FIGS. 9*a* and 9*b*, but showing the valve assembly in the open condition;

FIG. 11 is a horizontal section as taken on the line 11—11 of FIG. 9*a;*

FIG. 12 is a horizontal section as taken on the line 12—12 of FIG. 9*a;*

FIG. 13 is a fragmentary horizontal section as taken on the line 13—13 of FIG. 9*b;*

FIG. 14 is a fragmentary vertical section as taken on the line 14—14 of FIG. 7;

FIG. 15 is an exploded detail view in perspective, showing a typical ball valve and a removable side closure and valve supporting member;

FIG. 16 is a fragmentary detailed view partly in elevation and partly in section showing the ball valve in a closed position;

FIG. 17 is a view generally corresponding to FIG. 16, but showing the ball valve shifted longitudinally downwardly from engagement with the resilient seal but prior to rotation towards the open position;

FIG. 18 is a view corresponding to FIGS. 16 and 17, showing the ball valve rotated towards an open position;

FIG. 19 is a view corresponding to FIGS. 16 through 18, but showing the ball valve in the full open position.

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 open 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 comprise 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 mudline of a body of water, at a desired or required depth of say 500 to 1,000 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 tree 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 well 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 the application of which this is a division, and the valve assembly V is thereafter adapted 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 repair or service of the subsurface valve assembly V, it is not necessary to pull the entire dual tubing strings T1 and T2, as has heretofore been the practice. Since only the comparatively short upper tubing strings T3 and T4 need be pulled from the well to remove the valve assembly V, and the substantially longer tubing strings T1 and T2 remain in the well, the platform PP need not be equipped with or supplied with high-powered hoisting apparatus. Instead, the platform PP may simply be provided with a small low-powered hoist mechanism or a gin pole hoist. In addition, the tubing strings T1 and T2 can be plugged off at or below the tubing hanger TH to enable the service or repair of the valves V1 and V2 without requiring that the well be killed.

As seen in FIGS. 1, 2d and 5, the tubing hanger TH comprises a body section 10 having an upwardly extended tubular guide section 11, the upper end edge 12 of which is arched downwardly from a peak 13, in opposite directions, to a vertically extended slot 14 at the side of the guide section 11 diametrically opposite the peak 13. Internally of the guide section 11, between the lower end of the slot 14 and the body section 10, is a thread 15 to which a setting tool may be connected. Below the internal thread 15, is an internal flange 16 which provides a downwardly facing shoulder 17, for anchoring the valve means V in the hanger TH, as will be later described.

Extending downwardly into the body section 10 from the guide section 11, are a pair of diametrically spaced fluid passages 18, 18 at the upper end of each of which, is a cylindrical receptacle or socket 19. At the lower end of the body section 10, the tubing strings T1 and T2 are connected thereto in communication with the respective passages 18, 18.

Anchor means 34 for the tubing hanger may be as described and shown in the aforementioned application of which this is a division, and comprise suitable slip elements 46 and 47 which are expansible into anchoring engagement with the casing C.

When the setting tool has been removed from the well casing, the tubing hanger assembly is then in condition to receive the dual valve assembly V, as seen in FIGS. 2*a* through 2*d*.

The dual valve assembly V, as previously indicated, comprises, in the illustrated embodiment, a pair of valves V1 and V2, since the apparatus is shown as applied to producing from a pair of well zones Z1 and Z2, but it will be understood that the invention is applicable, also, to the production from more than two well zones.

At its lower end, as seen in FIGS. 2d and 3, the valve assembly V is adapted to be received in the upper tubing hanger body section 11 and to be latched in place by releasable latch means 125 beneath the internal flange 16 in the hanger body section. At diametrically spaced locations in a cross-head 126 of the latch means 125, the latch means 125 has elongated laterally opening spaces 127, 127 accommodating flow tubes 128 and 129 which are respectively adapted to establish communication between the tubing strings T1 and T2 and the valve assemblies V1 and V2, respectively.

At their lower ends, the flow tubes 128 and 129 have sealing end portions 130 and 131, respectively, each having sealing ring means 132 engageable within the bores or receptacles 19 in the tubing hanger body 10. The flow tube 128 extends upwardly from the cross-head 126 and is connected at 133 to a length of tubing 134 which extends further upwardly a suitable distance, and is connected at 135 to the housing 136 of the upper valve assembly V1, which will be hereinafter described. The flow tube 129 also extends upwardly from the cross-head 126 and is connected at 137 to the valve assembly V2, which is spaced vertically downwardly from the valve assembly V1 to enable utilization of valve assemblies V1 and V2 having full bore flow passages, as will also be later described. Extending upwardly from the valve housing 138 through swivel means 139 is a rotatable tubular member 140 which is connected at its upper end by a coupling 141 to the tubing string T4 above the connection of the tubing string T3 to the valve assembly V1, as seen in FIG. 2*a*. Rotation of the tubing string T4 and, thus, the tubular member 140 is utilized to engage and release the latch means 126 when the valve assembly V is run into the tubing hanger TH.

The flow tubes are retained in parallel, assembled relation by a vertically split body 142 comprising opposed half sections 143 and 144, as seen in FIG. 6, clamped together by fasteners 145. The body sections 143, 144 have internal grooves 146 which receive annular ribs 147 on the flow tubes 128, 129 to hold the latter against relative axial movement.

When the valve assembly V is being lowered in the tubing hanger TH, a key 148 on one side of the assembly, shown on the flow tube 129, and engageable with the peak 13 of the hanger body section 11 will cause rotation of the valve assembly V, as the key 148 rides downwardly on the inclined surface 12 and is guided into the vertical slot 14, whereby the lower ends 130, 131 of the flow tubes 128, 129 will be properly positioned or oriented so as to be stabbed into the bores or receptacles 19 in the hanger body 11.

The latch means 125 referred to above, comprises a plurality of resilient, normally collett fingers 150 depending from the cross-head 126 and having outwardly projecting latch lugs 151 at their lower ends. The lower ends of the latch fingers 150 are inwardly flexible to enable them to pass through the internal flange 16 in the hanger body 11, so that the latch lugs 151 may engage beneath the downwardly facing shoulder 17. The fingers 150 can then be held against inward deflection by a wedge surface 152 on the split body 142. Means 155 are provided for holding the latch fingers 150 in the positions upwardly spaced from the wedge 152 so that they may flex inwardly as described above, and spring means 156 are provided for actuating the cross-head 126 downwardly to assure engagement of the fingers 150 with the wedge 152 after the fingers pass through the flange 16.

More particularly, a pair of bolts 157 extend through the cross-head 126 and have their heads 158 engageable beneath the cross-head 126 as seen in FIG. 2*d*. These bolts 157 are threaded into a pair of horizontally spaced bars or plates 159 which are connected to pull rods 160, the pull rods extending upwardly alongside the length of tubing 134 and being connected, as seen in FIG. 2*d* and FIG. 4, to a non-rotatable nut 161, having a notch 162 for straddling the tubing 134 to prevent rotation of the nut. The nut 161 has a threaded bore 163, in which a complemental thread 164 on the rotatable tubing section 140 is engaged. Accordingly, when the tubing string T4, which, as previously indicated, is connected to the tubing section 140, is rotated, the nut 161 is moved axially on the tubing section 140, downwardly, from the position of FIG. 2*d*, to allow downward movement of the plates 159 and the bolts 157.

The spring means 156 are operable to force the cross-head 126 downwardly and comprises a pair of coiled compression springs 165 disposed about the bolts 157 and seating at their lower ends in bores 166 in the cross-head 126 and at their upper ends against a spring seating plate 167 which abuts beneath the lower valve housing 138. When the cross-head 126 is moved downwardly by the springs 166, the lugs 151 on the latch fingers 150 are engaged with the wedge surface 152, and are held outwardly for locking engagement beneath the latch shoulder 17 of the tubing hanger body section 11. The springs 165 are not relied upon, necessarily, to provide sufficient downward force on the cross-head 126 to assure inward deflection of the fingers 150 as the lugs 151 pass through the flange 16, since the cross-head may be forced upwardly into abutting engagement with the plate 167.

As seen in FIGS. 2*a* through 2*c*, the control fluid conduit CF is connected by a fitting 170 to the upper valve housing 136 of the valve V1 and passage means 171 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 fluid pressure responsive shutoff valve V1 is representative of the two valves V1 and V2 and will now be described.

In this form, as seen in FIGS. 9*a*, 9*b* and 10*a*, 10*b*, the valve assembly 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, as previously described, is threadedly connected at 135 to the flow tube 134 which seats in one of the bores or receptacles 19 in the tubing hanger body 10.

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 178 which is reciprocable in the valve body 136 between an upper position, as seen in FIG. 9*a*, and a lower position, as seen in FIG. 10*a*. The sleeve 178 is piloted in a reduced bore 179 in the body 136, and the lower end of the sleeve extends into 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 on the sleeve 178, and biases the sleeve 178 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.

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 ring 191 on the cylindrical section 189 and having 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 sleeve 190 and the annular cross-sectional area end 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 171, 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. 9*b* to the position of FIG. 10*b*, as the upper sleeve 185 is forced downwardly. When the over-riding control fluid pressure is relieved, the pressure of production fluid acts to close the ball valve 176 across the combined areas of the upper sleeve or piston section 187 and the secondary sleeve 190 when the latter shoulders at 190*a*, as seen in FIG. 10*a*.

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.

In accordance with the invention, 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 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 valve supporting closure member 208 which fits within the opening 207, and is sealed therein by a suitable seal ring 209. Referring again to FIG. 2*b*, it will be noted that the enclosure and valve support member 208 is adapted to be secured to the valve body 136 by a suitable number of fasteners 210, and as best seen in FIG. 8, the closure member 208 includes a guide section 211 having a bore 212 through which the tubular member 140 rotatably extends.

In order to support the ball valve 176 and cause rotation thereof in response to movement of the ball longitudinally between the sleeves 185 and 178, the valve supporting member 208 has a pin or lug 213 projecting therefrom in aligned opposition to a corresponding pin or lug 214 carried within the valve body 136, and the ball valve 176 has at its opposite sides corresponding slots 215 in which the respective pins or lugs 213 and 214 are engageable for rotating the ball valve 176 between the opened and closed positions, as best illustrated in FIGS. 16 through 19. In these views, the side of the ball valve 176 supported by the closure 208 is illustrated, but similar structure will be understood to be located at the other side of the ball valve, also. In FIG. 16, the valve is shown fully closed and sealed by the sleeves 178 and 185 as well as by the resilient sealing means 202. In FIG. 17, 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. 18, the ball valve 176 is in the partially opened position. In FIG. 19, the ball valve 176 is in the fully opened position.

More particularly, the ball valve member 176 on each of its opposite sides has a chordal flat surface 216 adjacent to the diametrically opposite portions of the body 136 and the support 208. The slot 215 extends radially with respect to the axis of rotation to the ball valve member 176, and at right-angularly spaced locations, the ball face 190 is recessed to form a stop surface 217 and a stop surface 218 cooperable with fixed stop lug surfaces 217*a* and 218*a* on the closure 208 to limit rotation of the ball 176 between the extremes of FIG. 16 and FIG. 19. When the ball valve member 176 is in the position of FIG. 25, 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 open. The stop surface 218 engages the stop surface 218*a*, as shown in FIG. 28 to limit rotation of the valve member 176 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 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, as indicated by the arrows in FIGS. 17 and 18. The slot 215 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, as seen in FIG. 16, 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*a* and 217*b*. 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. 16 to the position of FIG. 19 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. 19 to the position of FIG. 16 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. 19, the pin 213 clears the flat wall 215*a* 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 open, as seen in FIG. 16, 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 rotating pin 213 relieves the connection of damaging forces when the ball valve is in either of its closed or opened 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 order to equalize the pressure across the valve, equalizing valve means 220 are provided, as best seen in FIG. 14, for establishing communication between a port 221 below the ball valve 176 (FIG. 9b) and a port 228 above the valve 176 (FIG. 9*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 tubular member 134 through radial ports 225 in the upper end of the member 134, when the valve 176 is closed, as seen in FIG. 9*b*. Above the ball valve 176, the skirt 198 of the upper valve body section 136*a* has a number of radial ports 226 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. The 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 a reduced bore 235. A valve member 236 is reciprocable in the insert 230 and has its lower end 237 provided with a seal 238 slidably 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 223 and via a radial port 243 in the body 136 and ports 244 in the insert 230. A rod 245 slidably 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 176 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 disclosed in my companion application Ser. No. 243,806 filed 4/13/72, for Subsurface Tubing Safety Valve With Auxiliary Operating Means, 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. 9*a*, 9*b*, and in FIGS. 10*a*, 10*b*, the sleeve 196 is held by the shear screws 197 in an initial upper position, and the sleeve 196 cooperates with the body 136 to form the control fluid pressure chamber or annular spacc 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 will engage a shoulder 251 on the sleeve 185 and shift the latter downwardly to open the the ball valve 176. More particularly, 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. A sleeve shifting tool is disclosed and claimed in the aforementioned companion application Ser. No. 243,806.

I claim:

1. In a subsurface safety valve for wells: an elongated valve body having a flow passage therethrough, said body having means at its upper end for connection to an upwardly extending tubing string, said body having means at its lower end for connection to a downwardly extending tubing string, valve means in said body including a valve member shiftable between a first position closing said flow passage and a second position at which said flow passage is open, fluid pressure responsive operating means within said body for moving said valve member between said positions, said body having a lateral opening leading into said flow passage, a closure for said lateral opening, and means within said body and on said closure for shiftably supporting said valve member for movement between said positions.

2. In a subsurface safety valve as defined in claim 1, said valve member being a ball valve having a port therethrough, said ball valve being smaller than said lateral opening, said supporting means mounting said ball valve for rotative movement between said positions to interrupt and establish communication between said flow passage and said port.

3. In a subsurface safety valve as defined in claim 1, said valve member being a ball valve having a port therethrough, said ball valve being smaller than said lateral opening, said supporting means including cooperative pin and slot means mounting said ball valve for rotative movement between said positions to interrupt and establish communication between said flow passage and said port.

4. In a subsurface safety valve for wells: an elongated valve body having a flow passage therethrough, said body means having means at its upper end for connection to an upwardly extending tubing string, said body having means at its lower end for connection to a downwardly extending tubing string, valve means in said body including a valve member shiftable between a first position closing said flow passage and a second position at which said flow passage is open, operating means for moving said valve member between said position, said body having a lateral opening leading into said flow passage, a closure for said lateral opening, and means within said body and on said closure for shiftably supporting said valve member for movement between said positions, said valve member being a ball valve having a port therethrough, said ball valve being smaller than said lateral opening, said supporting means including cooperative pin and slot means mounting said ball valve for rotative movement between said positions to interrupt and establish communication between said flow passage and said port re-

sponsive to longitudinal movement of said ball valve in said body, said operating means including sleeve means reciprocable in said flow passage for moving said ball valve longitudinally, means for shifting said sleeve means in one direction to move said ball valve to said first position responsive to the pressure of fluid flowing through said passage to close the latter, and means sealingly engaged with said ball valve in said first position.

5. In a subsurface safety valve as defined in claim **4**, said means for shifting said sleeve means in one direction to move said ball valve to said first position including a spring acting on said sleeve means.

6. In a subsurface safety valve as defined in claim **4**, said means for shifting said sleeve means in one direction including a spring acting on said sleeve means in said one direction.

7. In a subsurface safety valve as defined in claim **4**, including means responsive to applied control fluid pressure for shifting said sleeve means in the other direction to move said ball valve to said second position.

8. In a subsurface safety valve as defined in claim **4**, including means responsive to applied control fluid pressure for shifting said sleeve means in the other direction to move said ball valve to said second position, said body having a bypass passage and normally closed bypass valve means responsive to said control fluid pressure to open said bypass passage and equalize pressure across said ball valve when in said first position prior to movement of said ball valve to said second position.

9. In a subsurface safety valve as defined in claim **4**, releasable anchor means associated with said body for releasably retaining said body in a hanger for said downwardly extended tubing.

10. In a plural subsurface safety valve assembly for wells; a pair of elongated valve bodies having flow passages therethrough each of said bodies having means at its upper end for connection to an upwardly extending tubing string, each of said bodies having means at its lower end for connection to a downwardly extending tubing string, valve means in each of said bodies including a valve member shiftable between a first position closing said flow passage and a second position at which said flow passage is open, fluid pressure responsive operating means within said body for moving said valve member between said positions, said bodies each having a lateral opening leading into said flow passage, a closure for said lateral opening, and means within the respective bodies and on the respective closures for shiftably supporting said valve member for movement between said positions.

11. In a plural subsurface safety valve assembly as defined in claim **10**, said valve member being a ball valve having a port therethrough, said ball valve being smaller than said lateral opening, said supporting means mounting said ball valve for rotative movement between said positions to interrupt and establish communication between said flow passage and said port.

12. In a plural subsurface safety valve assembly as defined in claim **10**, said valve member being a ball valve having a port therethrough, said ball valve being smaller than said lateral opening, said supporting means including cooperative pin and slot means mounting said ball valve for rotative movement between said positions to interrupt and establish communication between said flow passage and said port.

13. In a plural subsurface safety valve as defined in claim **10**, said bodies being spaced longitudinally with respect to one another, said means at the upper end of the lower valve body for connecting it to an upwardly extending tubing string comprising tubular member extending longitudinally alongside of the upper valve body, and said means at the lower end of the upper valve body for connecting it to a downwardly extending tubing string comprising a tubular member extending alongside of the lower valve body.

14. In a plural subsurface safety valve assembly for wells: a pair of elongated valve bodies having flow passages therethrough each of said bodies having means at its upper end for connection to an upwardly extending tubing string, each of said bodies having means at its lower end for connection to a downwardly extending tubing string, valve means in each of said bodies including a valve member shiftable between a first position closing said flow passage and a second position at which said flow passage is open, operating means for moving said valve member between said position, said bodies each having a lateral opening leading into said flow passage, a closure for said lateral opening, and means with the respective bodies and on the respective closures for shiftably supporting said valve member for movement between said positions, said bodies being spaced longitudinally with respect to one another, said means at the upper end of the lower valve body for connecting it to an upwardy extending tubing string comprising tubular member extending longitudinally alongside of the upper valve body, and said means at the lower end of the upper valve body for connecting it to a downwardly extending tubing string comprising a tubular member extending alongside of the lower valve body, said closure for the lateral opening in the respective valve bodies having an opening therein through which the respective tubular members extend.

15. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well.

16. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, and spring means normally maintaining said latch means in condition retaining said assembly in the receptacle.

17. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch element in condition retaining said assembly in the receptacle.

18. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and including means responsive to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, and means for relatively shifting said latch elements and said member engageable therewith in the other direction.

19. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and including means responsive to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, and spring means for relatively shifting said latch elements and said member engageable therewith in the other direction.

20. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and including means responsive to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, and spring means for relatively shifting said latch elements and said member engageable therewith in the other direction, said tubular member extending alongside of said lower valve body and the means at lower end of the body of said lower valve each having sealing means insertable in complemental seal means in a receptacle in said well.

21. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receiptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and including means responsive to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, and spring means for relatively shifting said latch elements and said member engageable therewith in the other direction, said tubular member extending alongside of said lower valve body and the means at lower end of the body of said lower valve each having sealing means insertable in complemental seal means in a receptacle in said well and orienting means on said assembly for aligning said seal means with said complemental seal means.

22. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assemby in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and inlcuding means responsie to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, and spring means for relatively shifting said latch elements and said member engageable therewith in the other direction, said tubular member extending alongside of said lower valve body and the means at lower end of the body of said lower valve each having sealing means insertable in complemental seal means in a receptacle in said well, said member engageable with said latch elements comprising a longitudinally split body, and including means securing said split body together with said tubular member extending alongside said lower valve body and said means at the lower end of said lower valve body.

23. In a plural subsurface safety valve as defined in claim **14**, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and including means responsive to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, and means for relatively shifting said latch elements and said member engageable therewith in the other direction, said means responsive to rotation of said rotatable tubular member comprising a nut threaded on said rotatable tubular member, and rod means connected to said nut and one of said expander and said latch elements.

24. In a plural subsurface safety valve as defined in claim 14, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well, said latch means comprising resilient latch elements and means for maintaining said latch elements in condition retaining said assembly in the receptacle including a member engageable with said latch elements to prevent release thereof, said latch elements and said member engageable therewith being relatively shiftable in opposite directions to effect latching and allow release of said latch elements, and including means responsive to rotation of said rotatable tubular member for relatively shifting said latch elements and said member engageable therewith in one direction, said means responsive to rotation of said rotatable tubular member comprising a nut threaded in said rotatable tubular member, and rod means connected to said nut and to said latch elements, said expander being fixed with respect to said valve bodies.

25. In a plural subsurface safety valve assembly for wells: a pair of elongated valve bodies having flow passages therethrough each of said bodies having means at its upper end for connection to an upwardly extending tubing string, each of said bodies having means at its lower end for connection to a downwardly extending tubing string, valve means in each of said bodies including a valve member shiftable between a first position closing said flow passage and a second position at which said flow passage is open, operating means for moving said valve member between said positions, said bodies each having a lateral operning leading into said flow passage, a closure for said lateral opening, and means within the respective bodies and on the respective closures for shiftably supporting said valve member for movement between said position, said bodies being spaced longitudinally with respect to one another, said means at the upper end of the lower valve body for connecting it to an upwardly extending tubing string comprising tubular member extending longitudinally alongside of the upper valve body, and said means at the lower end of the upper valve body for connecting it to a downwardly extending tubing string comprising a tubular member extending alongside of the lower valve body, said lower valve body and its tubular member having means supporting the latter for rotation, and including latch means operable responsive to rotation of said rotatable tubular member for retaining said assembly in a receptacle in the well.

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CERTIFICATE OF CORRECTION

Patent No. 3,797,573 Dated March 19, 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 1, line 20: cancel "and" (second occurrence).

Column 4, line 19: change "w" to --W--.

Column 11, line 54: change "243,806" to --275,910--.

line 54: change "4/13/72" to --7/28/72--.

Column 12, line 15: change "243,806" to --275,910--.

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents