United States Patent [19]

Crowe

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[45] **Oct. 14, 1975**

[54] **SUBSURFACE WELL BORE SHIFTING TOOL**

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

[22] Filed: **June 3, 1974**

[21] Appl. No.: **475,587**

Related U.S. Application Data

[62] Division of Ser. No. 275,910, July 28, 1972, abandoned, which is a division of Ser. No. 243,806, April 13, 1972, Pat. No. 3,771,603.

[52] **U.S. Cl.** **166/212;** 166/217; 166/237

[51] **Int. Cl.** **E21b 23/00**

[58] **Field of Search** 166/123, 124, 125, 181, 166/182, 212, 237, 189, 217

[56] **References Cited**

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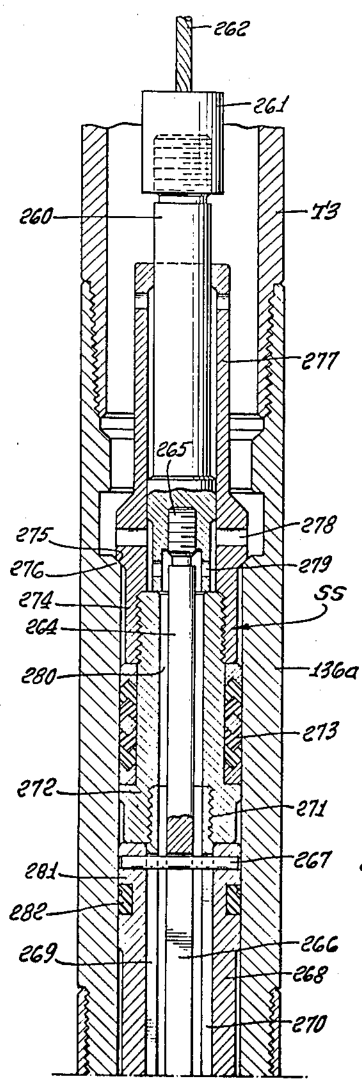
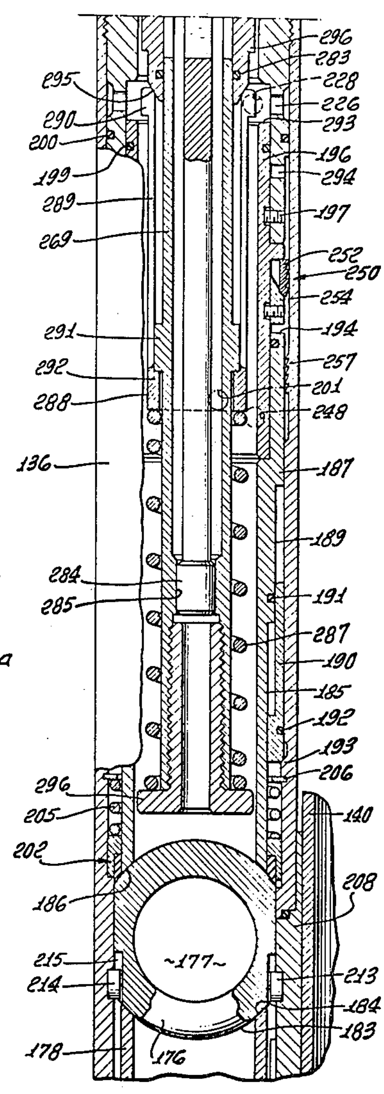
Primary Examiner—James A. Leppink
Attorney, Agent, or Firm—Bernard Kriegel

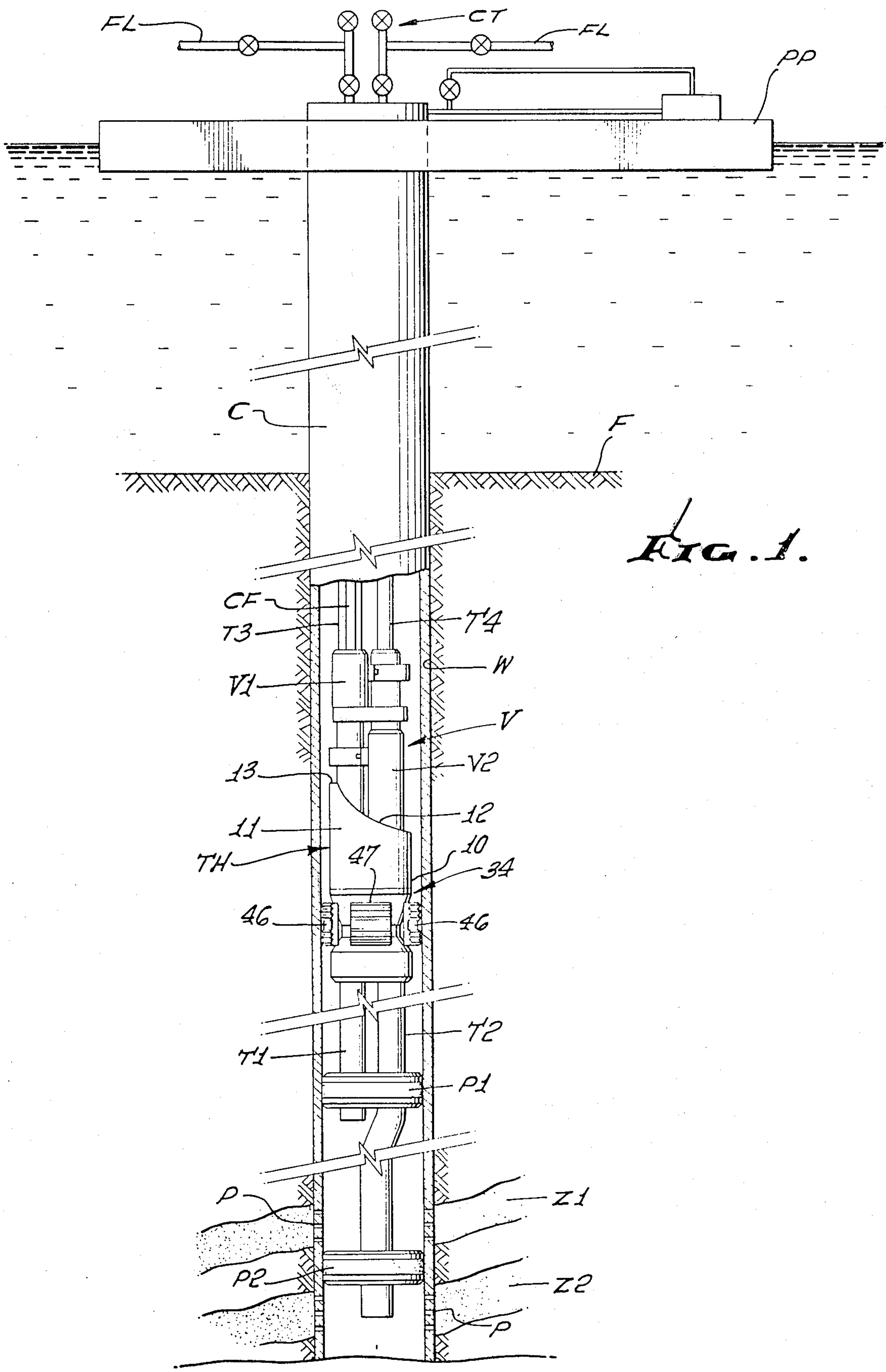
[57] **ABSTRACT**

A subsurface well bore tool for shifting a member, such as a sleeve structure for actuating safety valve, the tool includes a mandrel carrying normally retracted latch means expandable laterally by a fluid pressure operated actuator shiftable along the mandrel into latching engagement with the member or sleeve structure, enabling the actuator to then shift the member or safety valve sleeve structure longitudinally in one direction, the actuator being shiftable longitudinally in the opposite direction to permit retraction of the latch means and withdrawal of the shifting tool from the well bore.

11 Claims, 30 Drawing Figures



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P2
Z2
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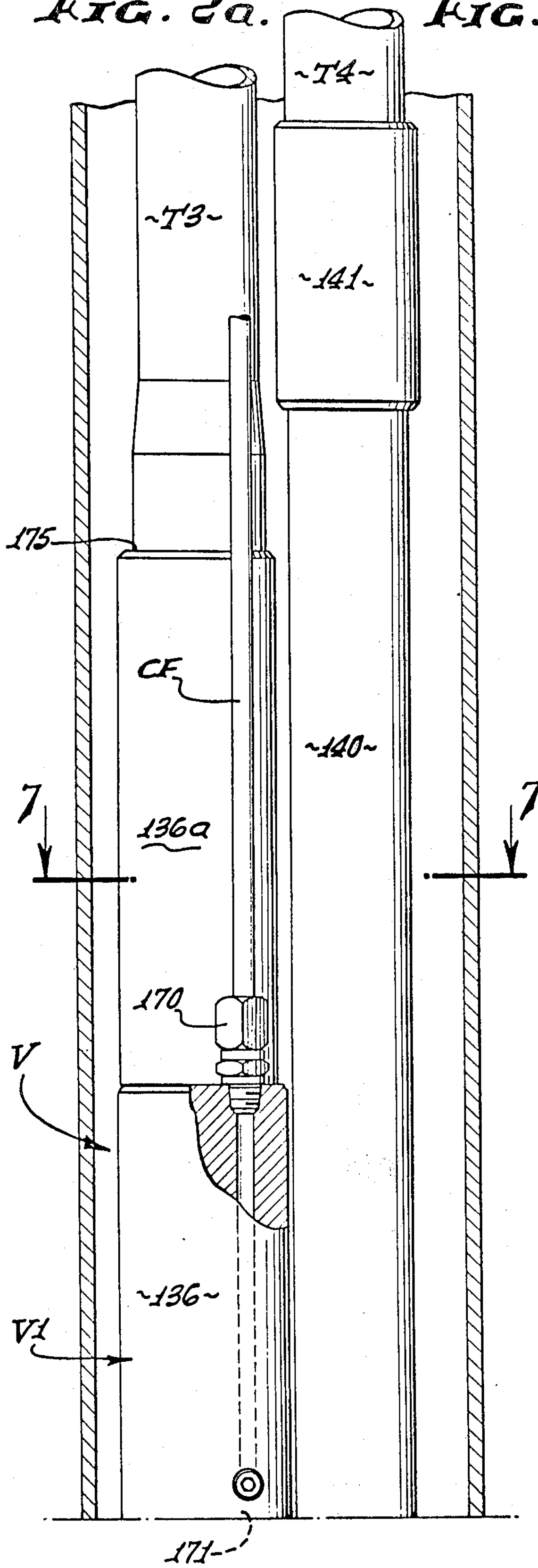
FIG. 1.

FIG. 2a.


T3
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V
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FIG. 2b.

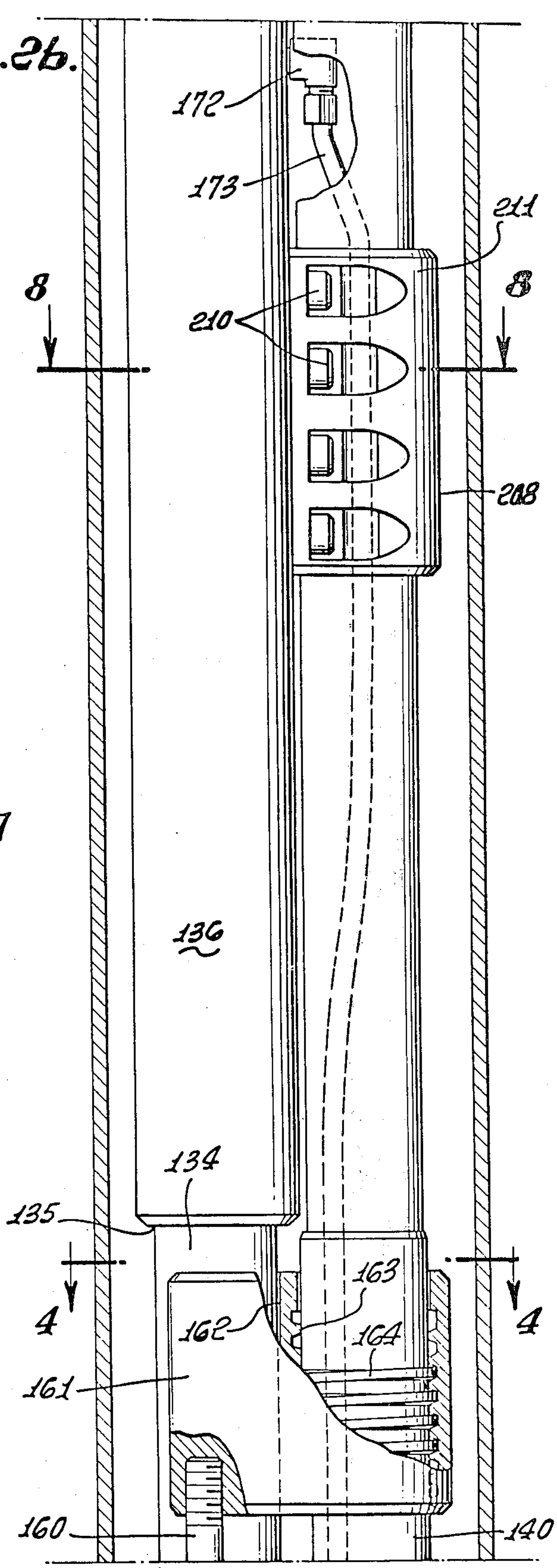
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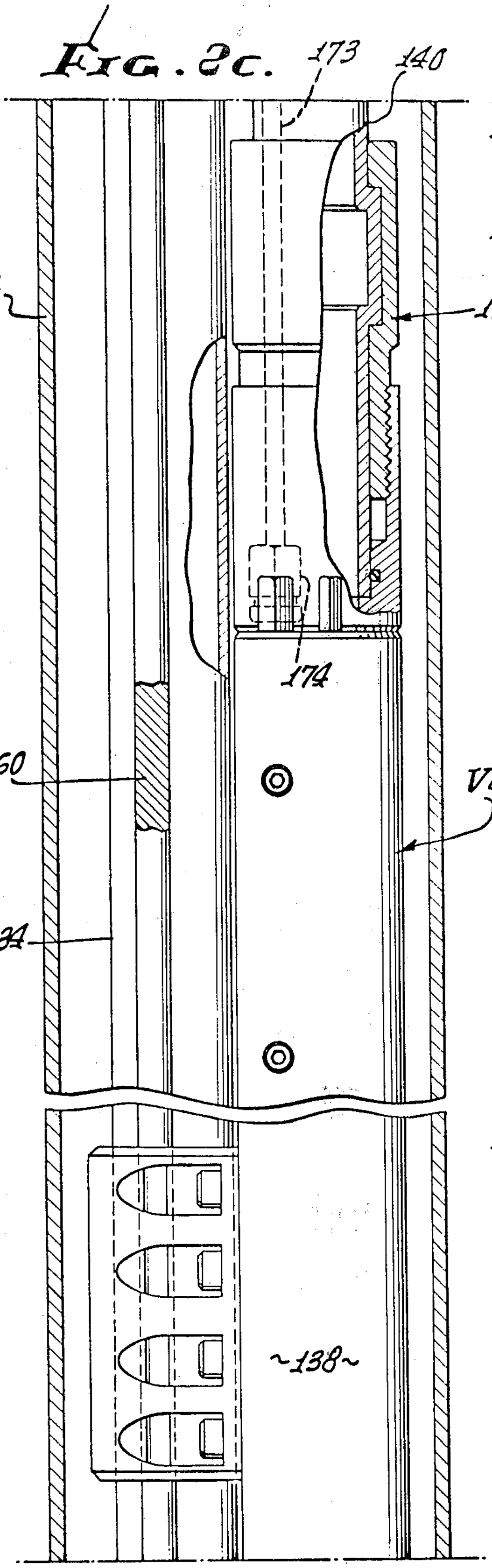
FIG. 2c.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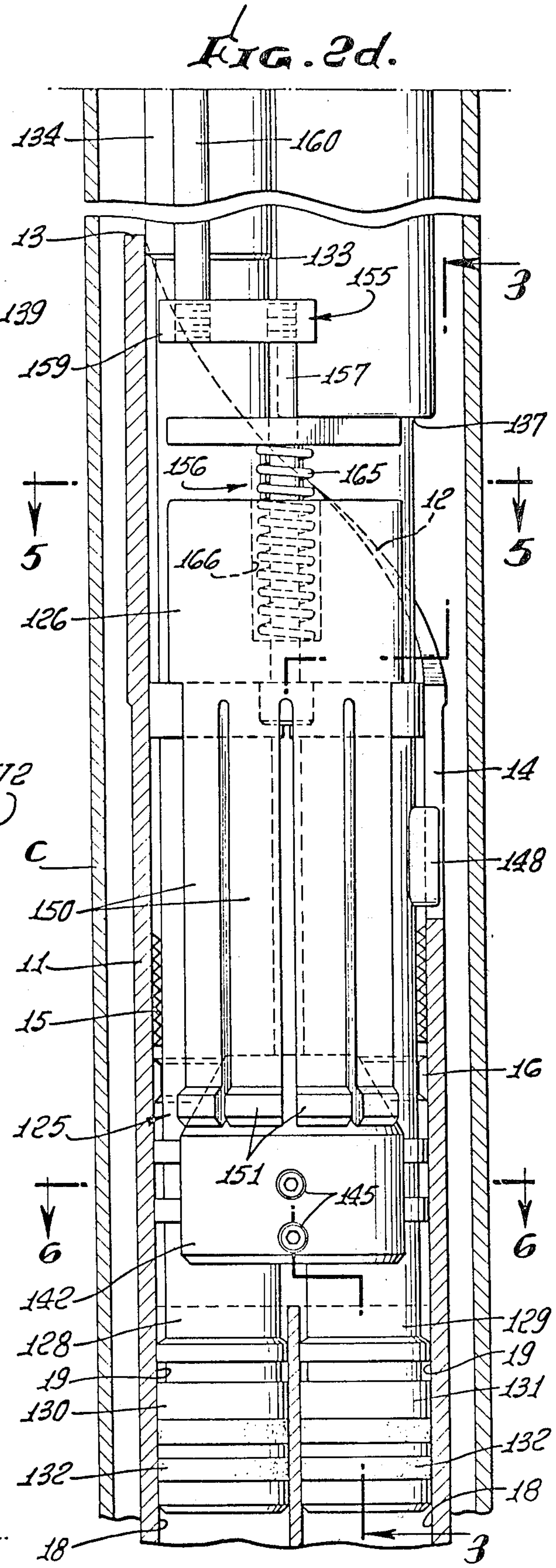
~138~

FIG. 2d.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15
16
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3

FIG. 3.

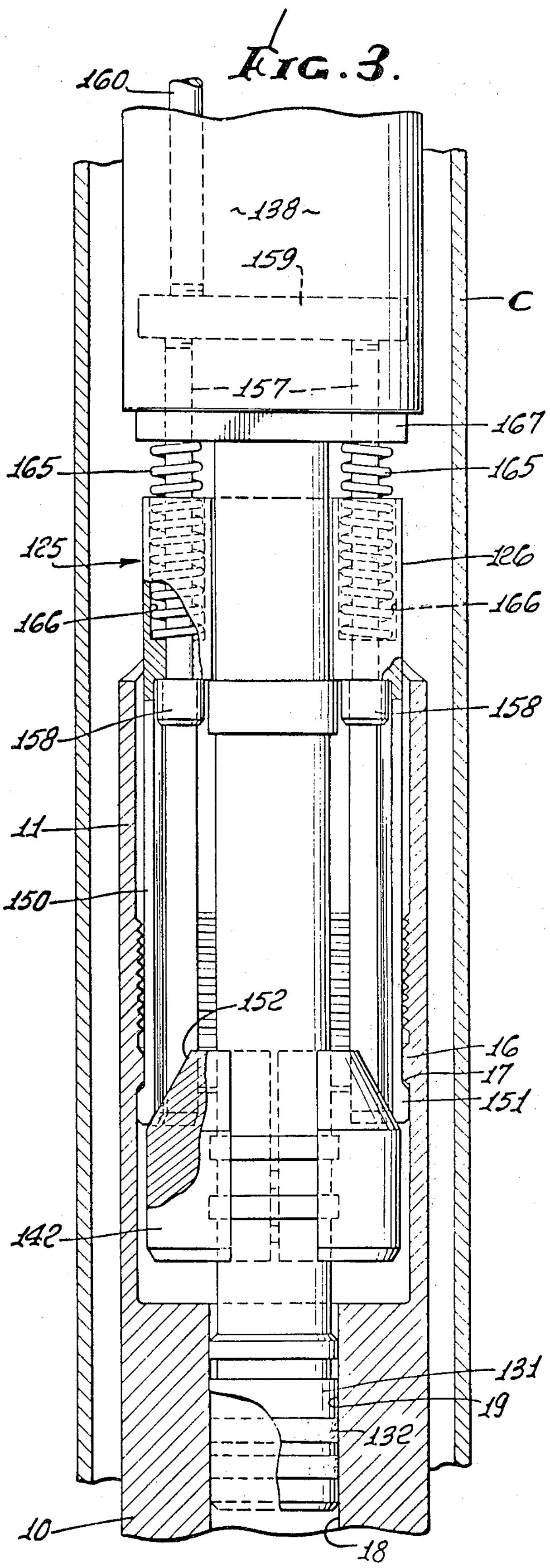

FIG. 4.

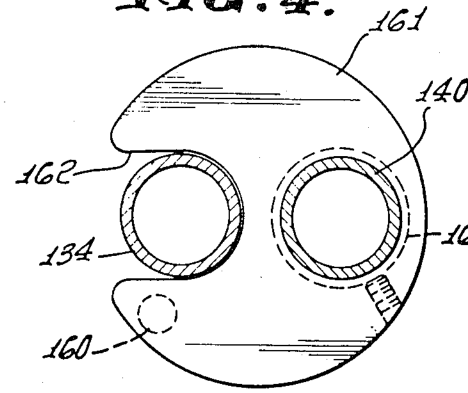

FIG. 5.

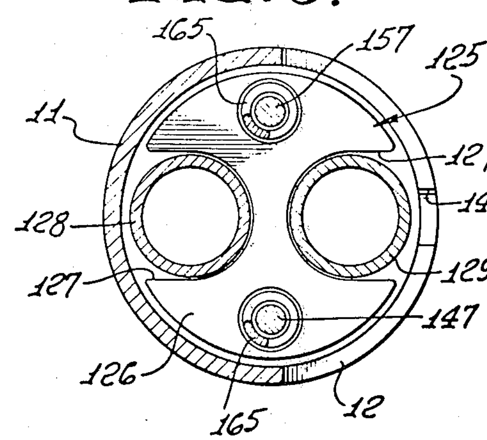

FIG. 6.

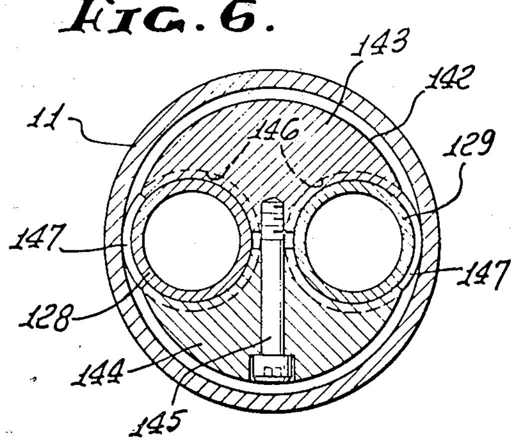

FIG. 7.

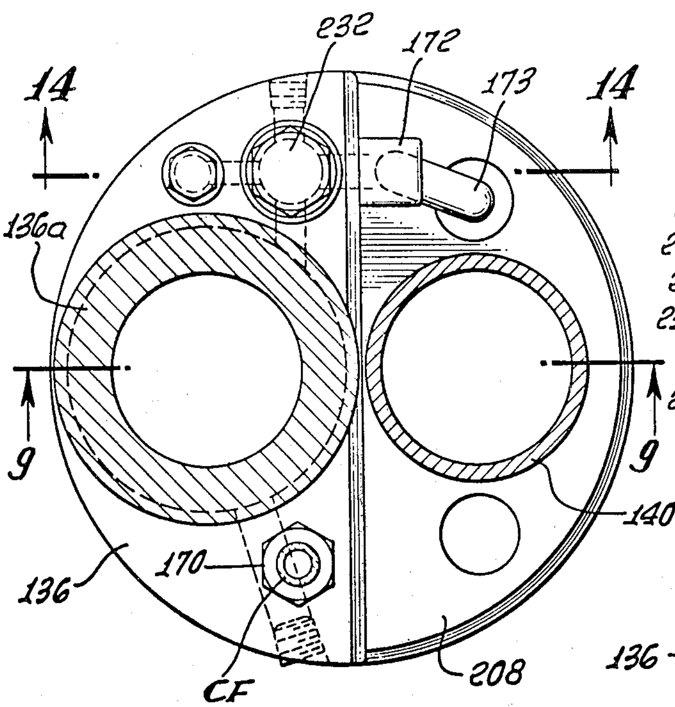

FIG. 8.

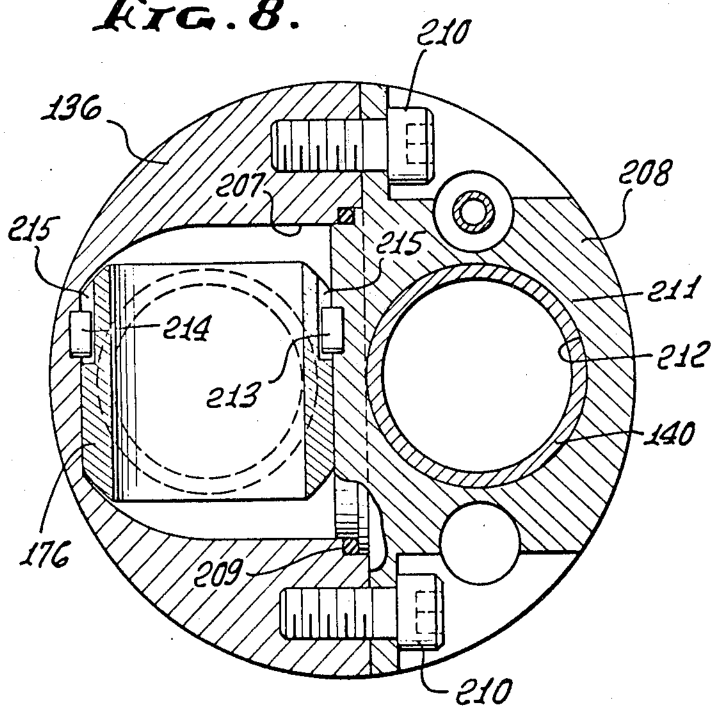

FIG. 14.

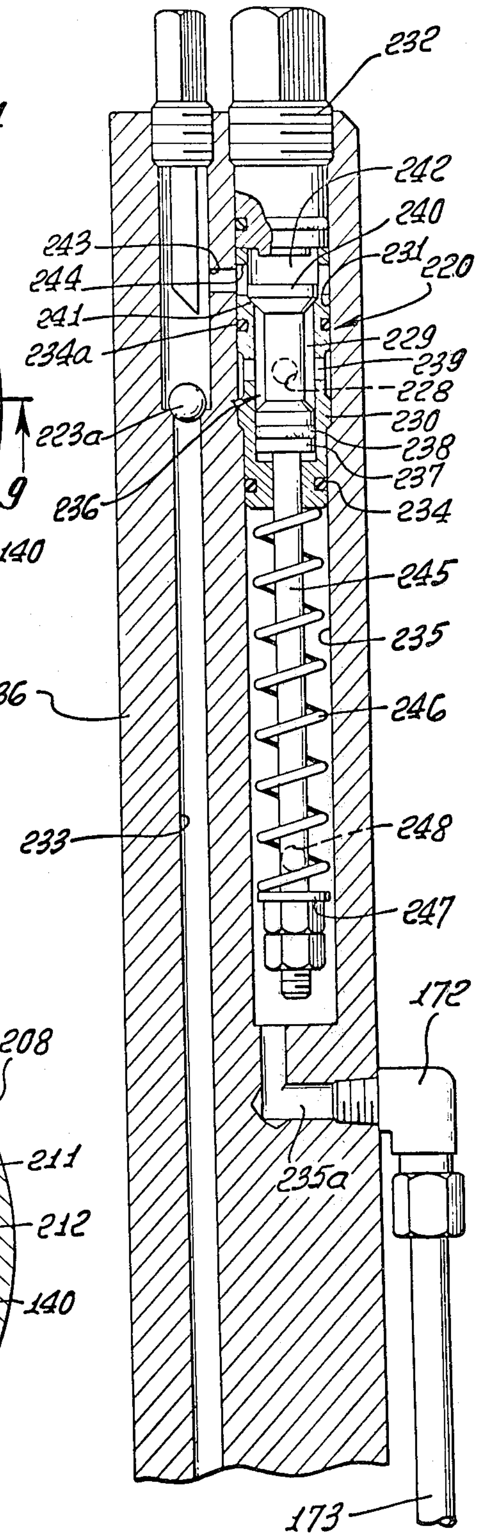

FIG. 9a.

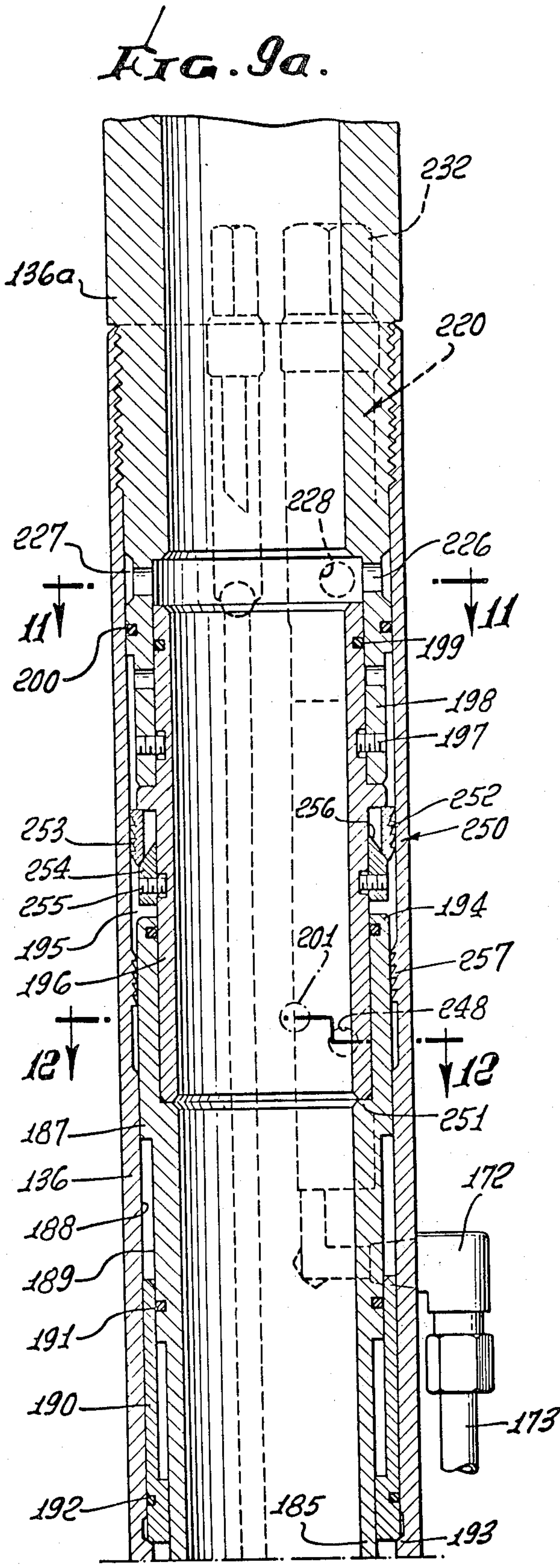
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FIG. 9b.

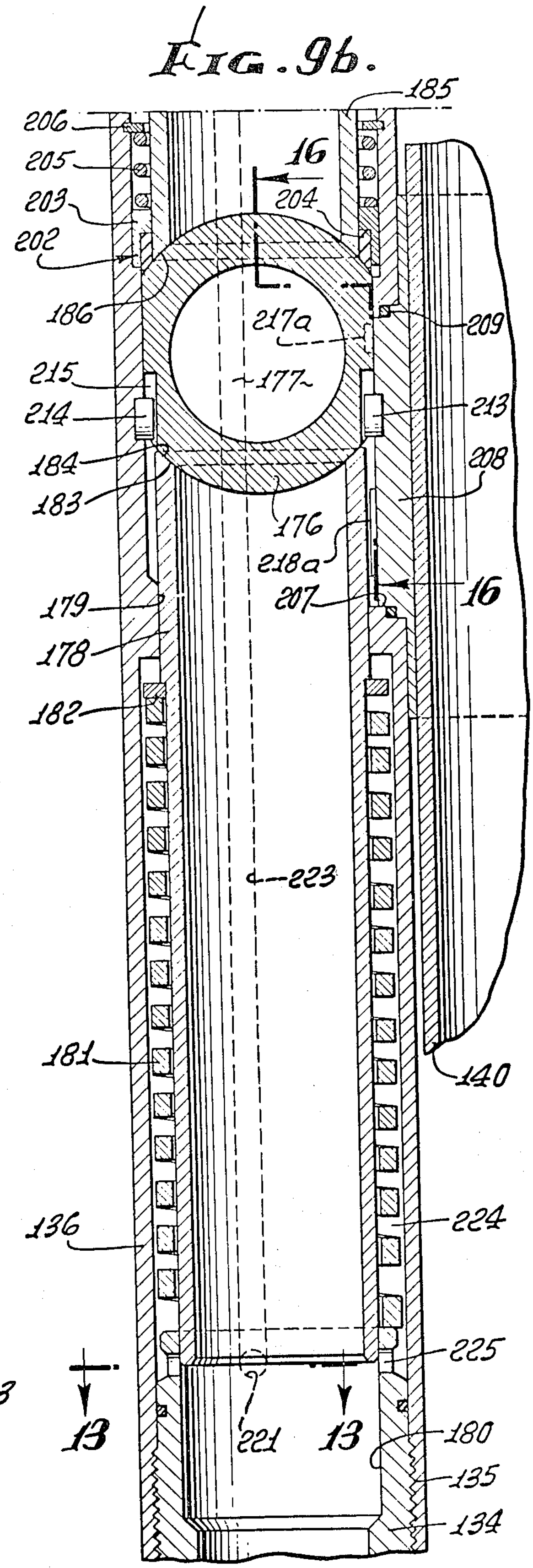
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FIG. 10a.

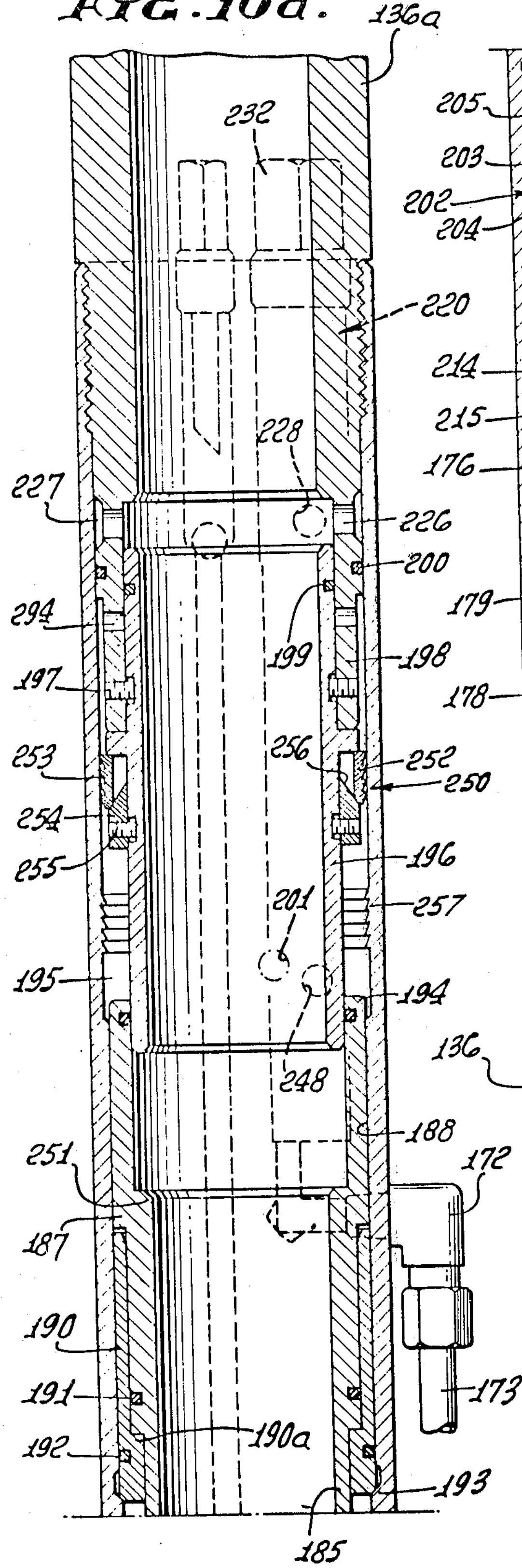


FIG. 10b.

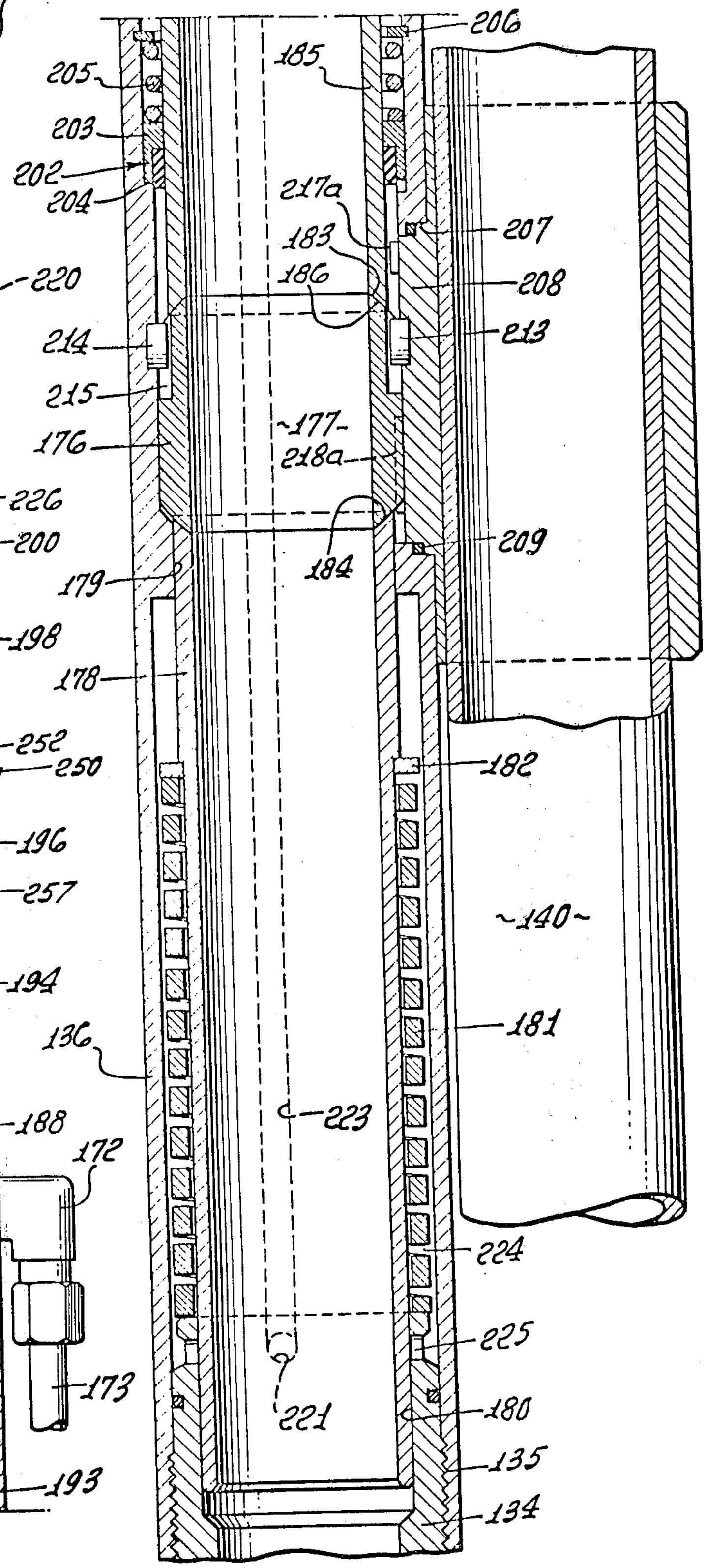


FIG. 11.

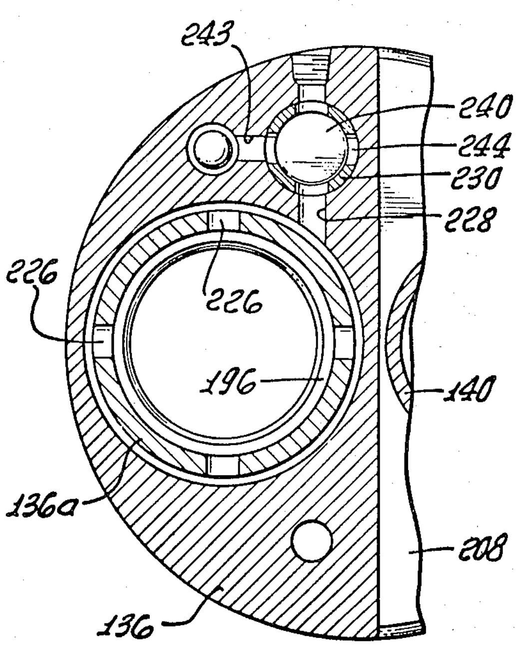


FIG. 12.

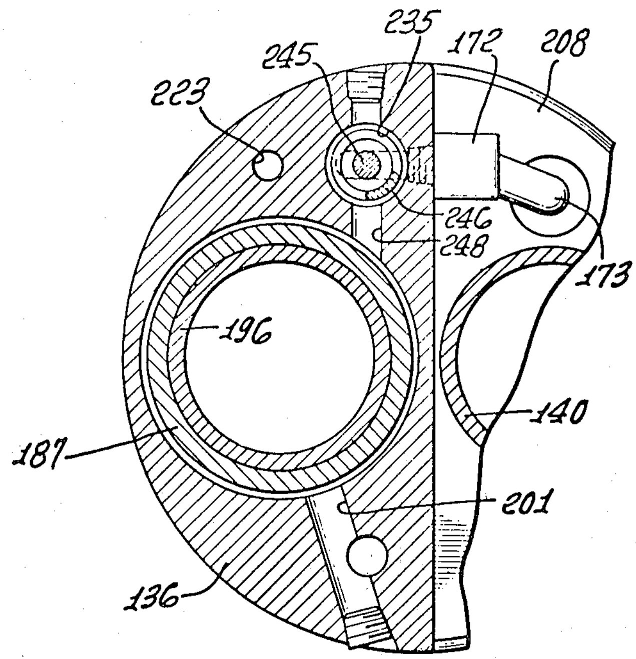
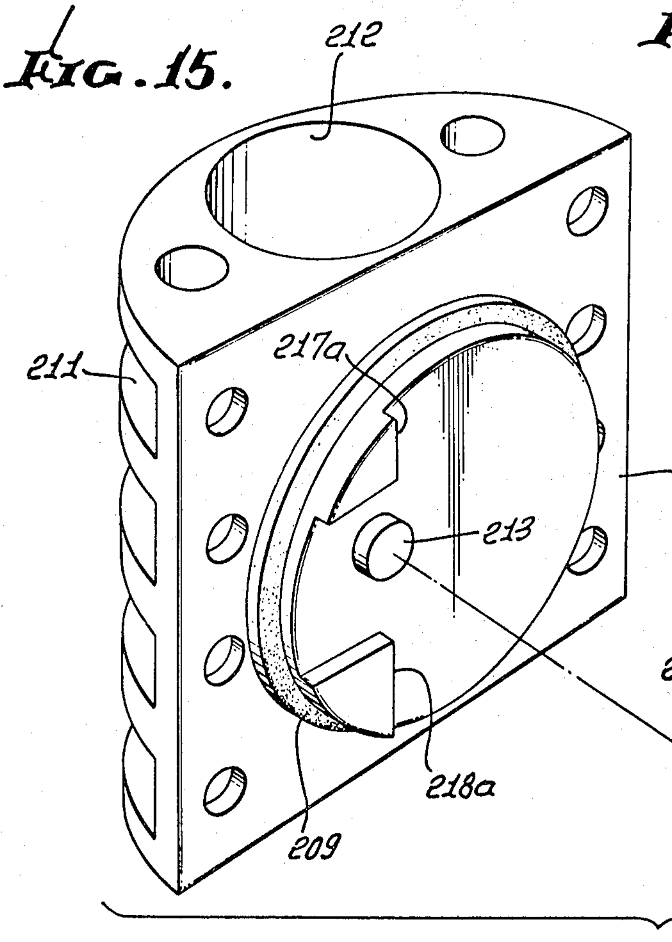


FIG. 15.



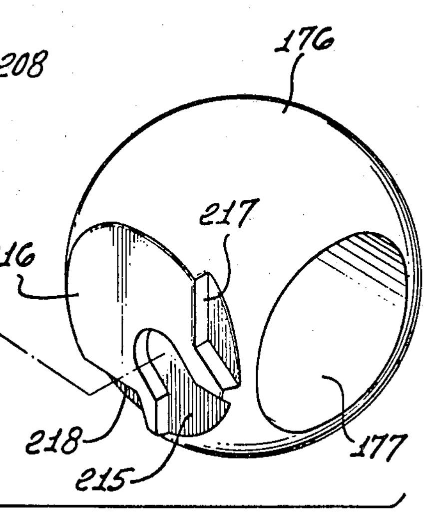
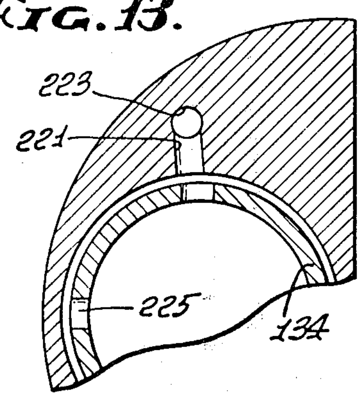


FIG. 13.



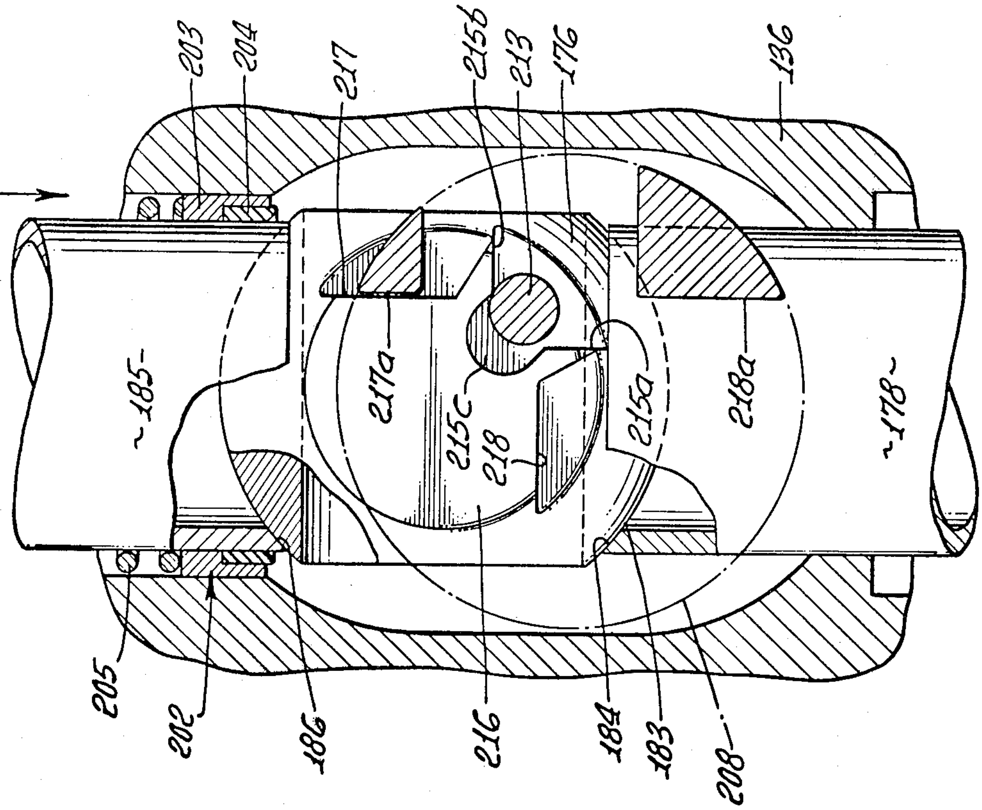

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FIG. 17.

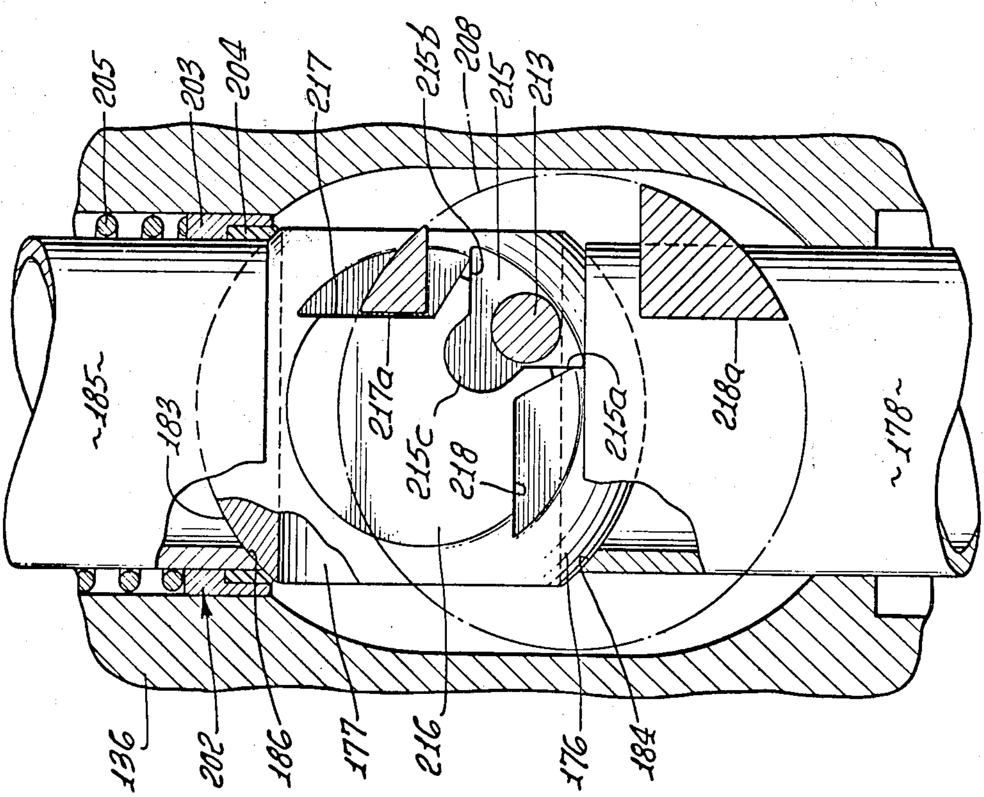
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FIG. 16.

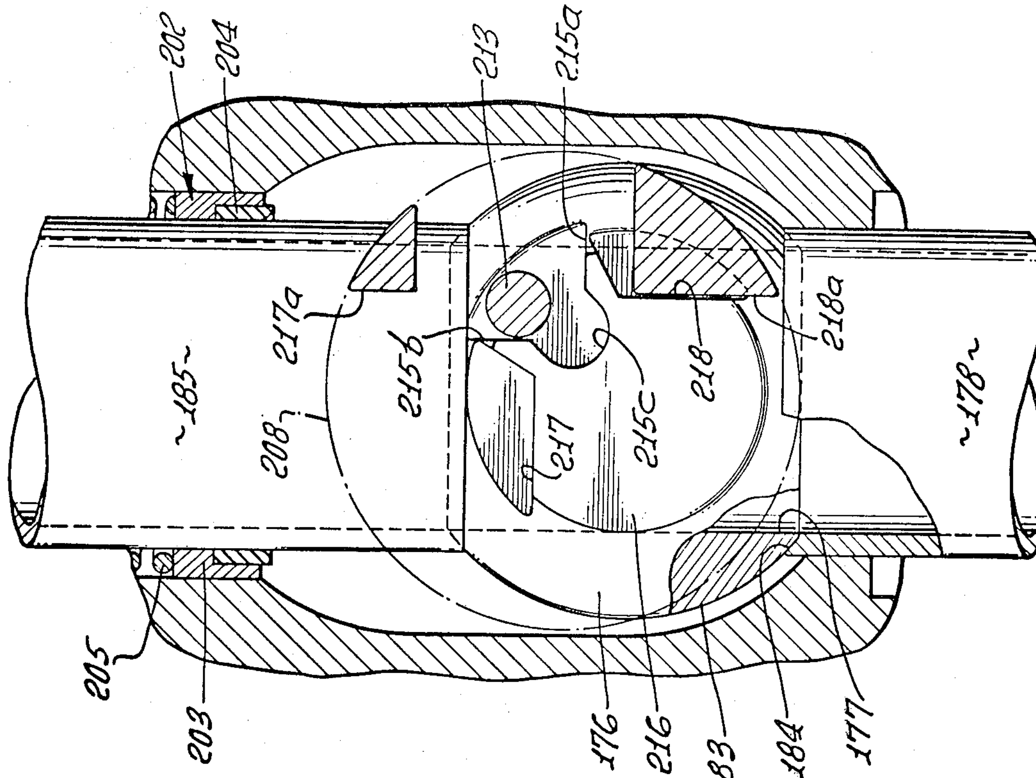
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FIG. 19.

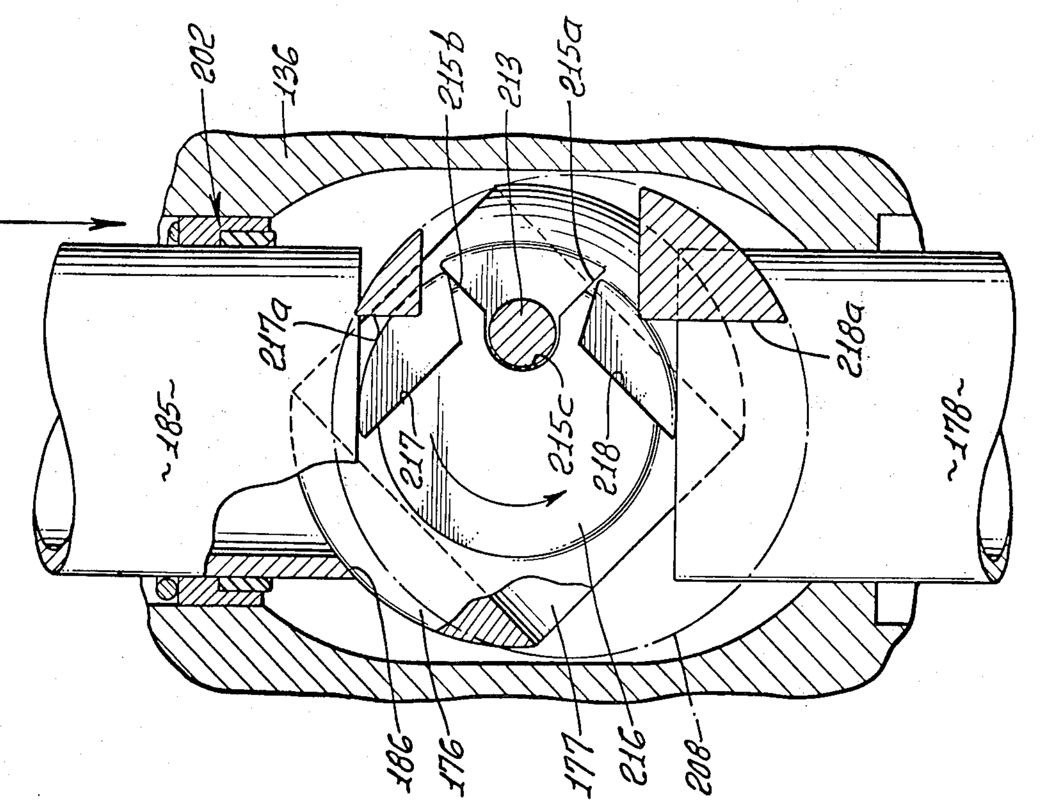
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FIG. 18.

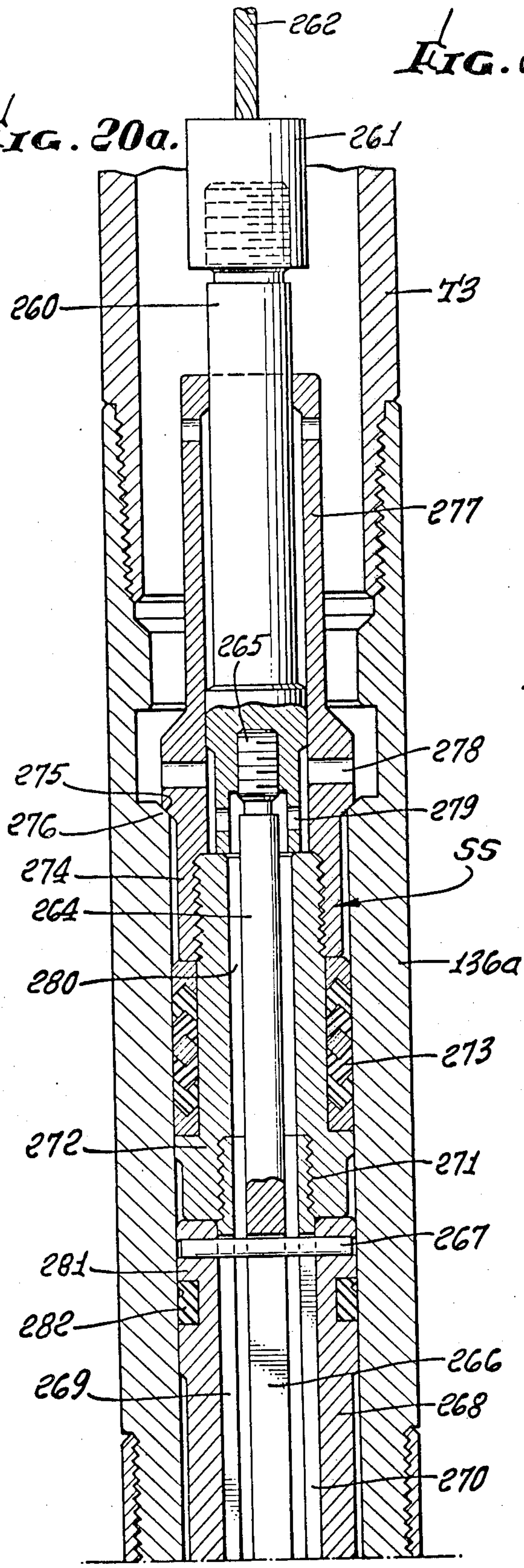


FIG. 20a.

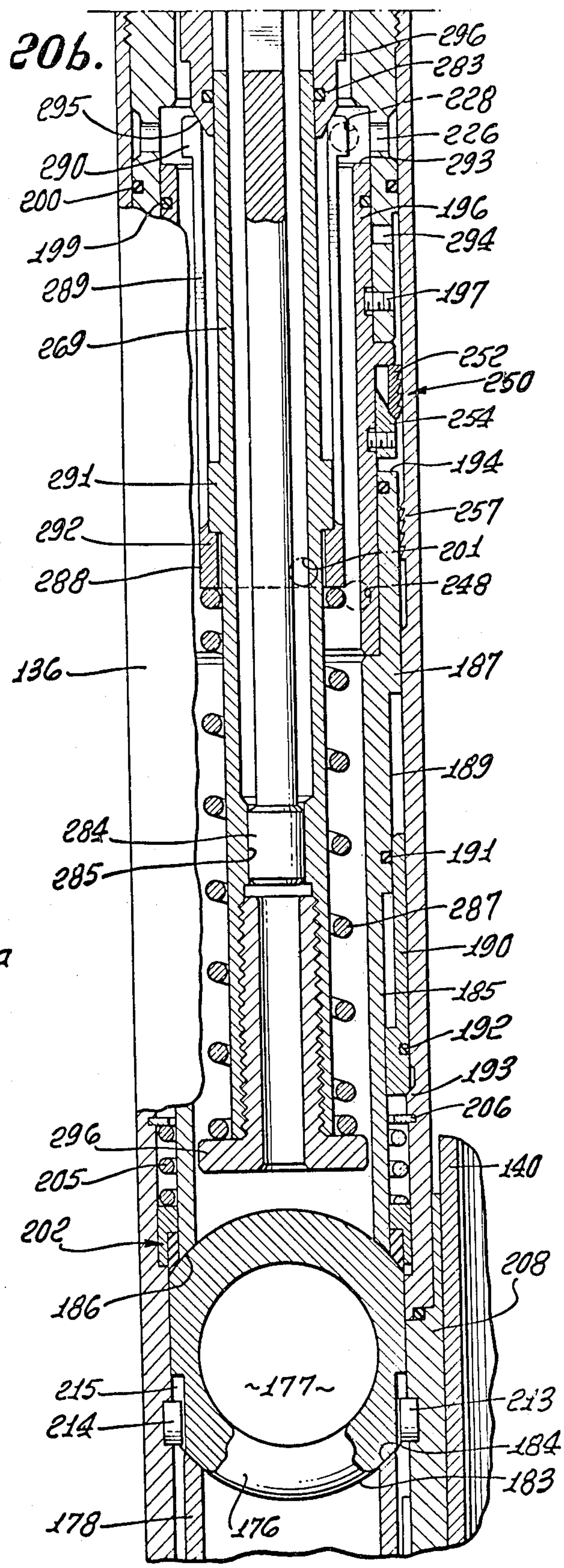


FIG. 20b.

FIG. 21a.

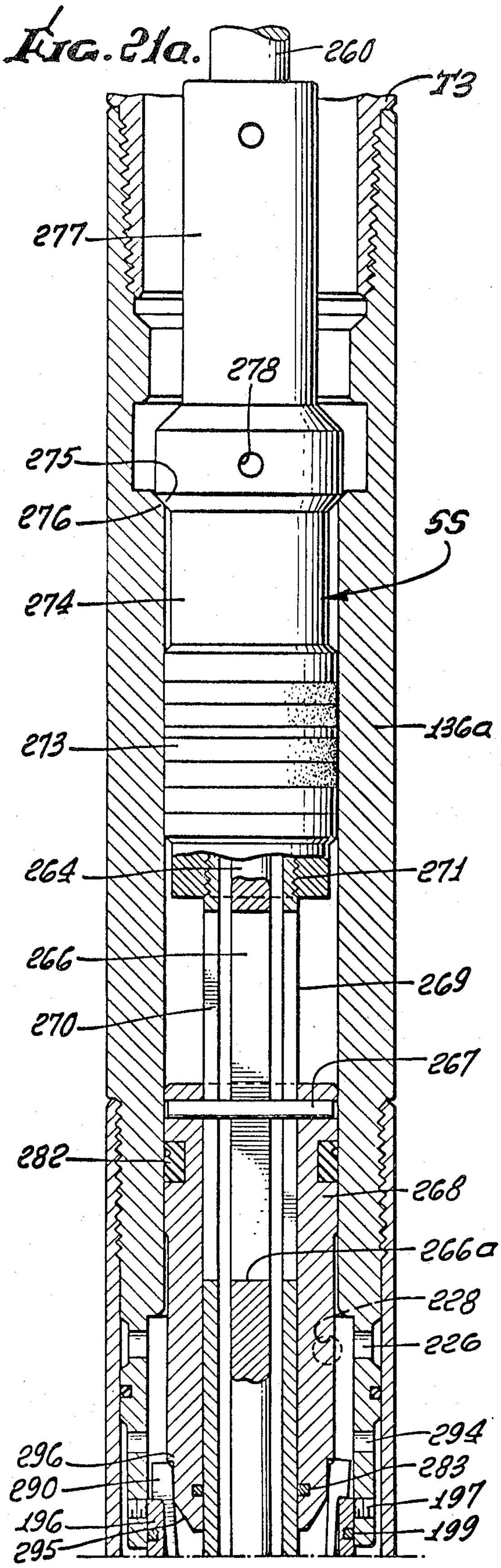


FIG. 21b.

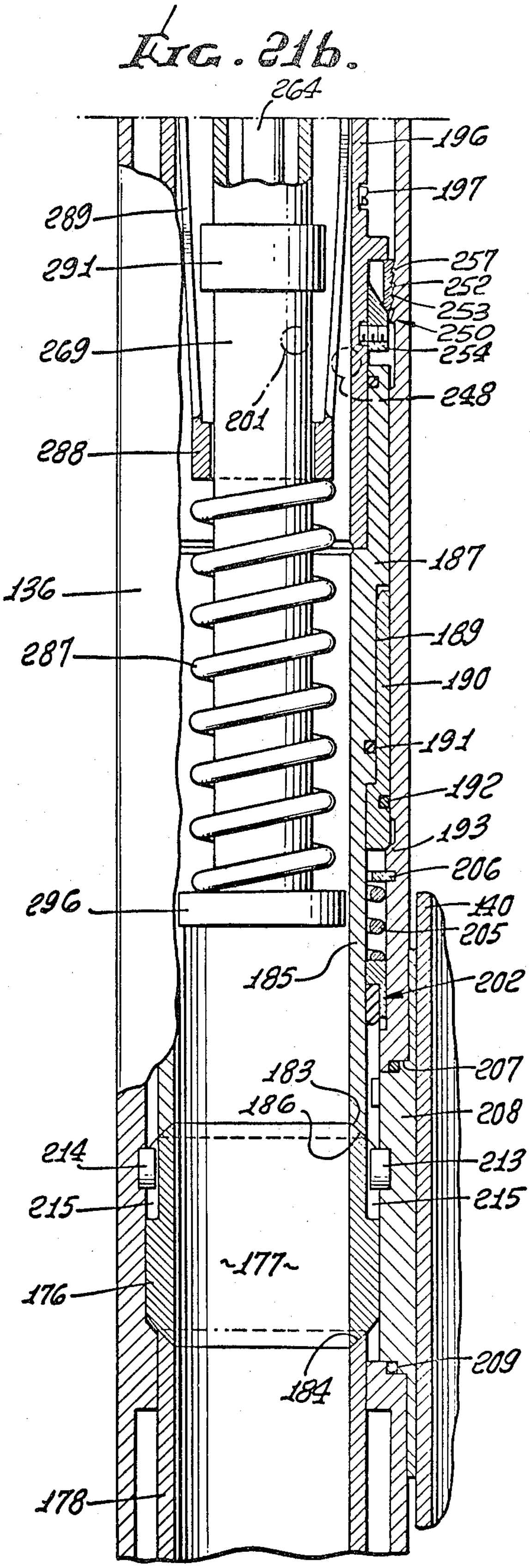


FIG. 22a.

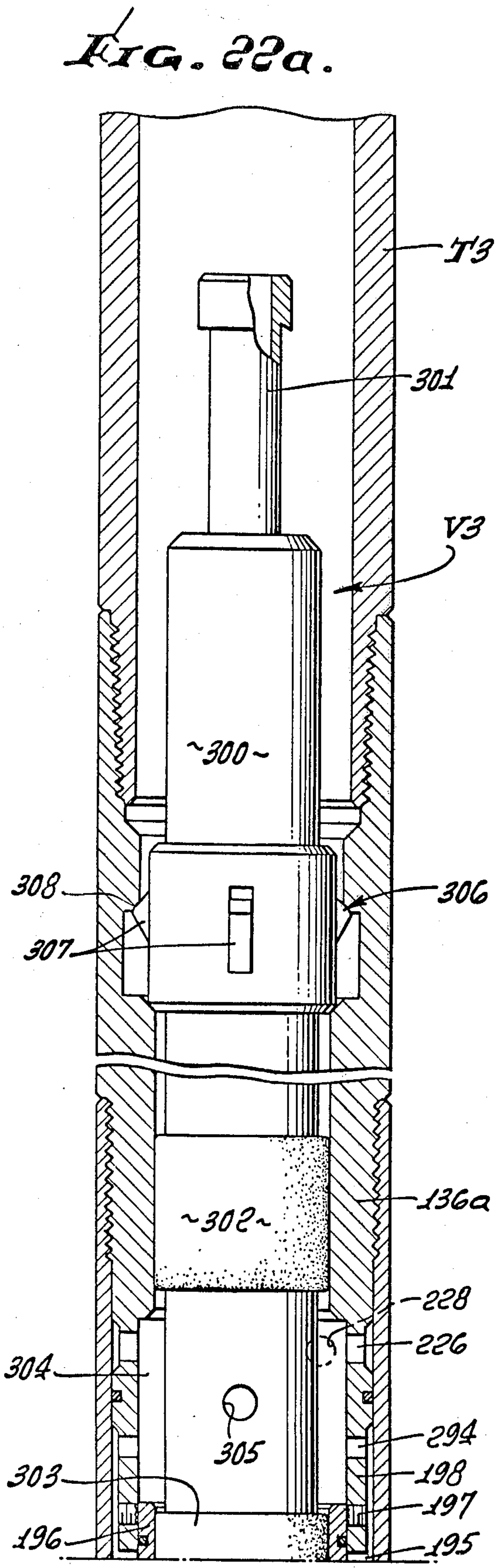
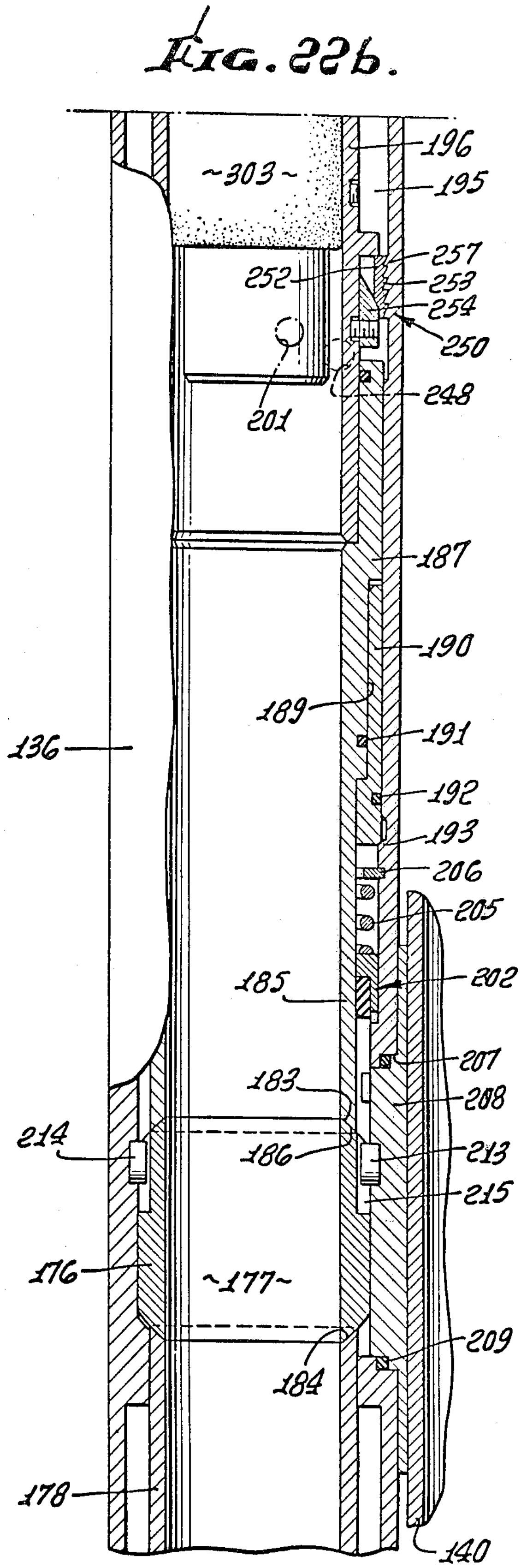


FIG. 22b.



SUBSURFACE WELL BORE SHIFTING TOOL

This application is a division of application Ser. No. 275,910, filed July 28, 1972, now abandoned, which is a division of application Ser. No. 243,806, filed Apr. 13, 1972, now U.S. Pat. No. 3,771,603.

In the production of well fluids, such as oil and/or gas, from wells, it has been the practice to provide automatically closable 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 regulations, 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, 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 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 lease 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.

In the above-identified applications of which this application is a division, there is disclosed a plural zone, subsurface safety valve system which is conveniently useful in the control of a multiple zone well. The subsurface valve assembly is run into the well on upper tubing strings and is landed in a receptacle provided in a tubing hanger which is anchored in the well casing, say, below the mudline of an offshore well, and supports the major production tubing weight suspended below the tubing hanger. The plural safety valve can readily be retrieved from the tubing hanger without requiring that the entire production tubing string be pulled from the well, and without requiring that the well be killed. However, even though the pulling of the upper tubing strings and the subsurface valve assembly from the tubing hanger may be a comparatively simple task, there is a resultant loss of well production time from the several well zones.

The present invention provides a shifting tool for shifting a safety valve member, which has been closed by well fluid pressure, to an open position, in the event that a control fluid pressure responsive operating device should fail, which normally can hold the valve member open. Such shifting of the valve member to open position enables an auxiliary wireline retrievable safety shutoff valve to be installed, which is also operable by the same control fluid pressure that was holding the valve member open, whereby the safety function of the subsurface valve means is maintained until the entire subsurface tubing valve is pulled. The shifting tool is adapted to be removably seated in the tubing valve and operated by fluid pressure supplied to the tubing string to actuate a sealing sleeve which bears against the safety valve member, to move the safety valve member to its opened position, at which position it is retained.

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 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.

REFERRING TO THE DRAWINGS

FIG. **1** is a digrammatic 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 **9***b* 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;

FIGS. 20*a* and 20*b* together constitute a vertical section, with certain parts shown in elevation, showing a shifting tool disposed in a valve assembly with the valve in the closed position prior to movement of the valve to the open position by the shifting tool, FIG. 20*b* constituting a downward continuation of FIG. 20*a;*

FIGS. 21*a* and 21*b* together constitute a view generally corresponding to FIGS. 20*a* and 20*b*, but showing the valve shifted to the open position by the shifting tool, and the valve being locked open; and

FIGS. 22*a* and 22*b* together constitute a vertical section with certain parts shown in elevation, and showing a wireline retrievable shutoff valve seated and locked in the bore of the locked open main shutoff valve.

As seen in the drawings, the invention is shown in a plural safety valve for an offshore well. 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 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 mudline 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 shut off. 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 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, 2*d* 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 is connectable, as disclosed and claimed in the companion application Ser. No. 275,911, filed July 28, 1972, for "Tubing Hanger

Apparatus", now U.S. Pat. No. 3,830,295. 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 valve assemblies used in the production of more or less than two well zones.

At its lower end, as seen in FIGS. 2*d* 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 into 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 retracted 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 expansible outwardly by a wedge surface **152** on the split body **142** when the cross-head **126** is moved downwardly relative to the body **142,** from the position of FIG. 2*d* to the position of FIG. **3.** Means **155** are provided for normally holding the latch fingers **150** in the retracted positions, and spring means **156** are provided for actuating the cross-head **126** downwardly to cam the fingers **150** outwardly.

More particularly, a pair of bolts **157** extend through the cross-head **126** and have their heads **158** engageable beneath the cross-head **126** to hold the latter in an upper position, as seen in FIG. 2*d*. These bolts **157** are threaded into a plate **159** which is connected to a pull rod **160,** the pull rod extending upwardly alongside the length of tubing **134** and being connected, as seen in FIG. 2*b*, 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*b*, to allow downward movement of the plate **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 cammed by the cam surface **152,** outwardly for engagement beneath the latch shoulder **17** of the tubing hanger body section **11.**

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 made according to the invention and 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***b*, and a lower position, as seen in FIG. **10***b*. The sleeve **178** is piloted in a reduced bore **179** in the body **136,** and the lower end of the sleeve 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** 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 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 releasably connected by suitable means such as 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.** This sleeve **196** will be more particularly described hereinafter.

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 valve actuating and sealing 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.**

The respective valve assemblies **V1** and **V2** and full opening valve assemblies through which remedial operations can be performed when the ball valve is opened. The valve assembly, as shown, is more particularly the subject matter of the companion application Ser. No. 286,151, filed Sept. 5, 1972, now U.S. Pat. No. 3,797,573.

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 closure 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 alligned 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-rotative 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. **16,** 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. **19** 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 **19.** 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. **9***b*) 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 **234** and **234***a* 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** engaged the insert **203** 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 spring **246** cause a net 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 accordance with the present invention, however, 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 invention 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, 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**. The sleeve shifting tool SS of FIGS. **20***a*, 20*b*, and FIGS. **21***a*, 21*b* provides means for shifting the sleeve **196** downwardly.

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**.

The sleeve shifting tool SS, as seen in FIGS. **20***a* and 20*b*, comprises an inner mandrel **260** connected by a rope socket **261** to a wireline **262**, and having an inner rod **264** connected thereto at **265** and extending downwardly therefrom. The inner rod **264** has an elongated slot **266** through which a pin **267** extends. This pin **267** is carried by an actuator sleeve **268** which is slidably disposed upon an elongated support sleeve **269** of the mandrel, also having an elongated slot **270** through which the pin **267** extends. The support sleeve **269** is threadedly connected at **271** to a tubular body **272** of the mandrel about which is a suitable packing means **273** sealingly engageable within the upper body section **136***a* of the shutoff valve body **136**. Above the packing **273** is a nut **274** having a downwardly facing shoulder **275** adapted to abut with the upwardly facing shoulder **276** in the body section **136***a*. The mandrel **260** is slidably disposed within an upward extension **277** of the nut **274** communicating via ports **278** in the nut **274** and ports **279** in the lower end of the mandrel **260** with an inner annular space **280**, so that fluid pressure in the tubing string T3 is applicable to the piston section **281** of the actuator sleeve **268**, the piston section **281** having a seal ring **282** slidable within the valve body section **136***a*.

At its lower end, the actuator sleeve **268** slidably engages the support sleeve **269** below the slot **270** and has a seal ring **283** sealingly engaged with the support sleeve **269**. At its lower end, the middle rod **264** has an enlarged end **284** initially sealingly engaged within a cylindrical wall **285** of the support sleeve **269**, above a longitudinally ported spring seat **286**. A coiled compression spring **287** engages the spring seat **286** and acts upwardly on a latch sleeve **288** having a plurality of normally retracted resiliently outwardly expansible fingers **289** on which are upper end lugs **290**. Upward movement of the latch sleeve **288** is limited by a collar **291** on the support sleeve **269** and engaged by a solid ring section **292** on the latch sleeve **288**. The lugs **290** on the fingers **289**, when the shoulders **275** and **276** limit downward movement of the sleeve shifting tool SS in the valve body section **136***a*, are located above the upper end **293** of the sleeve **196** which, as previously indicated, is initially held in its upper position by the shear screws **197**, so that the seal ring **199** on the sleeve **196** is initially disposed above a number of radial ports **294** in the skirt portion **198** of the upper body section **136***a* of the valve assembly V1 or V2.

In order to shift the sleeve **196** downwardly, the actuator sleeve **268**, to which fluid pressure is applicable to move the latter downwardly, initially engages the upper ends of the fingers **289** with a lower cam surface **295** of the actuator sleeve **268** and flexes the fingers outwardly so that the lugs **290** thereon are engageable with the upper end **293** of the valve sleeve **196**. Above the cam surface **295** on the actuator sleeve **268** is a downwardly facing shoulder **295**, which, upon further downward movement of the actuator sleeve **268**, engages the upper ends of the fingers **289** to transmit thereto a downward force, whereby, as seen in FIGS. **21***a* and **21***b*, the sleeve **196** shears the shear screws **197** and moves downwardly. Since the sleeve **196** engages the shoulder **251**, as previously described, on the upper valve actuator sleeve **185**, the latter is also moved downwardly, thereby opening the ball valve **176**, as also previously described.

Such downward movement of the sleeve **196** causes the latch means **250** to be engaged, that is, the lock ring **252** engages the internal teeth **257** within the valve body **136**, thereby holding the valve actuating sleeve **185** in its lower position.

Thereafter, the sleeve shifting tool SS may be removed from the valve body section **136***a* by simply lifting the mandrel **260** with the wireline **262**, thereby lifting the middle rod **264** until the bottom **266***a* of the slot **266** contacts the pin **267**, thereby lifting the actuator sleeve **268** until it again engages the tubular body **272**, at which time, the resilient fingers **289** will again flex inwardly, retracting the lugs **290** to their original positions.

When the sleeve **196** is locked by the locking means **250** in the lower position, holding the shutoff valve **176** open, the sleeve **196** and the valve body section **136***a* are adapted to receive a conventional wireline retrievable auxiliary shutoff valve assembly **V3**, as seen in FIGS. **22***a* and **22***b*. In the illustrated arrangement, the wireline retrievable valve assembly V3 comprises a valve body **300**, at the upper end of which is a typical running and retrieving neck **301**. Spaced axially along the body **300** is an upper packing means **302** sealing engageable within the valve body section **136***a* of the main shutoff valve assembly V1 or V2 and a lower packing means **303** sealingly engaged within the sleeve **196**, and straddling the ports **226** and the ports **294** in the skirt **198** of the upper body section **136***a* which are both in communication with an annular space **304** defined between the skirt **198** and the valve body **300**, this annular space **304** being in communication, via the ports **294**, with the annular space or control pressure chamber **195** of the valve assembly V1 or V2. Thus, control fluid pressure supplied to the annular space **195** via the inlet port **201** is admitted through a valve port

305 in the valve body 300 to operate the wireline retrieveable valve V3 in the well known manner to open the same.

Suitable releaseable latch means 306 including a number of retractable latch elements 307 engageable beneath a shoulder 308 in the valve body section 136*a* are adapted to retain the valve assembly V3 seated in the valve assembly V1 or V2 until it is desired that the valve assembly V3 be removed. Thus, without requiring recovery of the entire valve assembly V in order to effect service or repair of one of the valve assemblies V1 or V2, the utilization of the auxiliary valve assembly V3 enables the continued production of both well zones while maintaining control of the production by the auxiliary shutoff valve V3 in the otherwise inoperative shutoff valve V1 or V2.

I claim:

1. A shifting tool for moving an element longitudinally with respect to the tubular body of a well tool connected in a well pipe and having a bore in which said element is disposed, said shifting tool comprising: a mandrel adapted to be lowered through said pipe into said body, normally retracted latch means carried by said mandrel and expansible into engagement with said element, actuator means movable downwardly along said mandrel and said latch means to engage and expand said latch means outwardly to a position of engagement with the element, enabling joint downward movement of said actuator means and latch means to shift said element downwardly with respect to said body, and means carried by said mandrel and engageable with said actuator means to move said actuator means upwardly of said latch means to a position enabling said latch means to retract from said expanded position.

2. In a shifting tool for moving an element longitudinally with respect to the tubular body of a well tool connected in a well pipe and having a bore in which said element is disposed, said shifting tool comprising: a mandrel adapted to be lowered through said pipe into said body, normally retracted latch means carried by said mandrel and expansible into engagement with said element, actuator means for shifting said latch means longitudinally in one direction with respect to said mandrel to move said element longitudinally with respect to said body, and means carried by said mandrel for moving said actuator means in the other direction following movement of said element, said mandrel having seal means sealingly engageable in said body, and said actuator means comprising a piston shiftable on said mandrel, said mandrel having fluid passage means for exposing said piston to the pressure of fluid in said well pipe above said seal means.

3. In a shifting tool as defined in claim 2, said piston having means for initially expanding said latch means into engagement with said element and means for then shifting said latch means and said element.

4. In a shifting tool as defined in claim 2, said piston having means for initially expanding said latch means into engagement with said element and means for then shifting said latch means and said element, said mandrel and said piston having means for effecting opposite movement of said piston and release of said latch means upon movement of said mandrel with respect to said element.

5. In a shifting tool as defined in claim 2, said piston having means for initially expanding said latch means into engagement with said element and means for then shifting said latch means and said element, said mandrel having means for venting said fluid passage means upon movement of said mandrel with respect to said element, and said mandrel and said piston having means for effecting opposite movement of said piston and release of said latch means upon movement of said mandrel with respect to said element.

6. In a shifting tool as defined in claim 2, said mandrel and said piston having pin and slot means enabling movement of said piston in a direction to actuate said latch means and shift said element and for shifting said piston in the opposite direction upon movement of said mandrel to release said latch means.

7. In a shifting tool as defined in claim 2, said mandrel and said piston having pin and slot means enabling movement of said piston in a direction to actuate said latch means and shift said element and for shifting said piston in the opposite direction upon movement of said mandrel to release said latch means, and including spring means acting on said latch in said opposite direction.

8. In a shifting tool for moving an element longitudinally with respect to the tubular body of a well tool connected in a well pipe and having a bore in which said element is disposed, said shifting tool comprising: a mandrel adapted to be lowered through said pipe into said body, normally retracted latch means carried by said mandrel and expansible into engagement with said element, actuator means for shifting said latch means longitudinally in one direction with respect to said mandrel to move said element longitudinally with respect to said body, and means carried by said mandrel for moving said actuator means in the other direction following movement of said element, said mandrel having seal means sealingly engageable in said body, said mandrel extending reciprocably through said seal means, said seal means and said mandrel having passage means extending through said seal means, said actuator means including a piston exposed to fluid pressure applied through said passage means, said mandrel having a tubular member on which said piston is shiftable and a rod extending into said tubular member, said rod and said tubular member having elongated slots and said piston having a pin extending through said slots whereby said piston is shiftable along said tubular member in one direction and said piston is shiftable in the other direction upon longitudinal movement of said rod in said tubular member.

9. In a shifting tool as defined in claim 8, said piston and said tubular member having sealing means closing said slots.

10. In a shifting tool as defined in claim 8, said piston and said tubular member having sealing means closing said slots, and normally closed valve means operable upon said longitudinal movement of said rod to open said tubular member.

11. In a shifting tool as defined in claim 8, said piston and said tubular member having sealing means closing said slots, and said rod and said tubular member having normally closed valve means operable upon said longitudinal movement of said rod to open said tubular member.

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