United States Patent [19]

Mott

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[45] Sept. 24, 1974

[54] **ALTERNATING VALVE METHOD AND APPARATUS**

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[73] Assignee: **Hydril Company,** Houston, Tex.

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[52] **U.S. Cl.**..... **166/315,** 166/224 A, 166/240, 251/62, 251/95

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

[58] **Field of Search**..... 166/53, 152, 224, 224 S, 166/240; 251/62, 95, 163; 175/61

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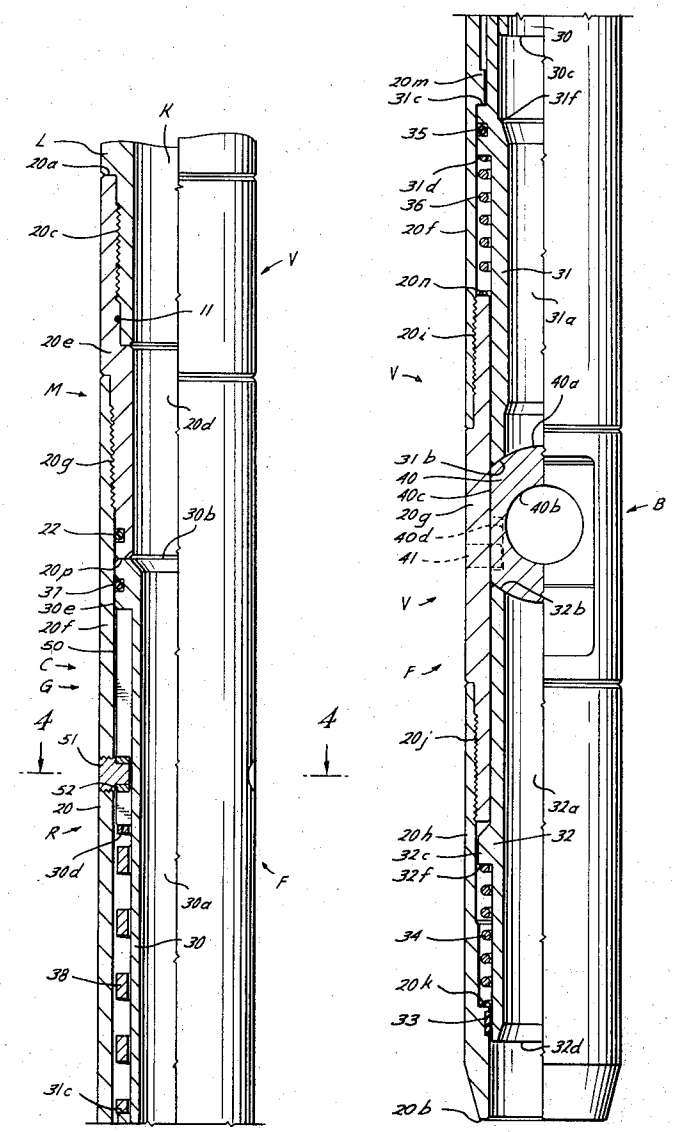
Attorney, Agent, or Firm—Pravel, Wilson & Matthews

[57] **ABSTRACT**

An alternating valve well tool and method relating thereto having a ball-type closure member which is rotatable between open and closed positions in response to the urging of a controlled sequence of preselected fluid pressure changes in the well for shutting in the well at a subsurface location when desired.

30 Claims, 14 Drawing Figures



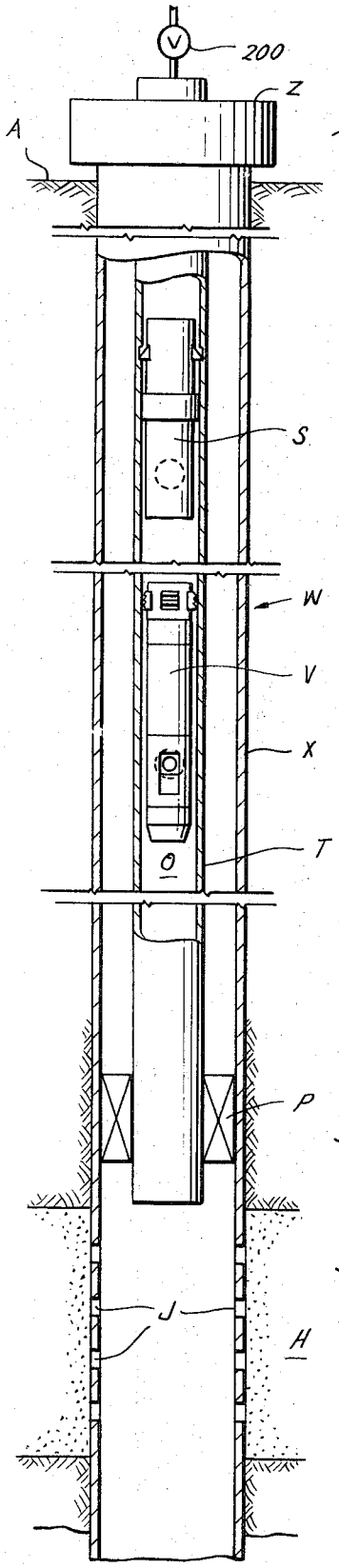


Fig. 1

Fig. 4

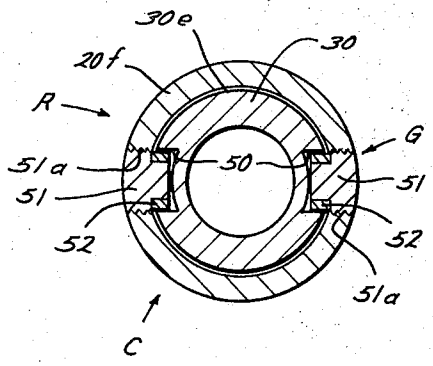


Fig. 5

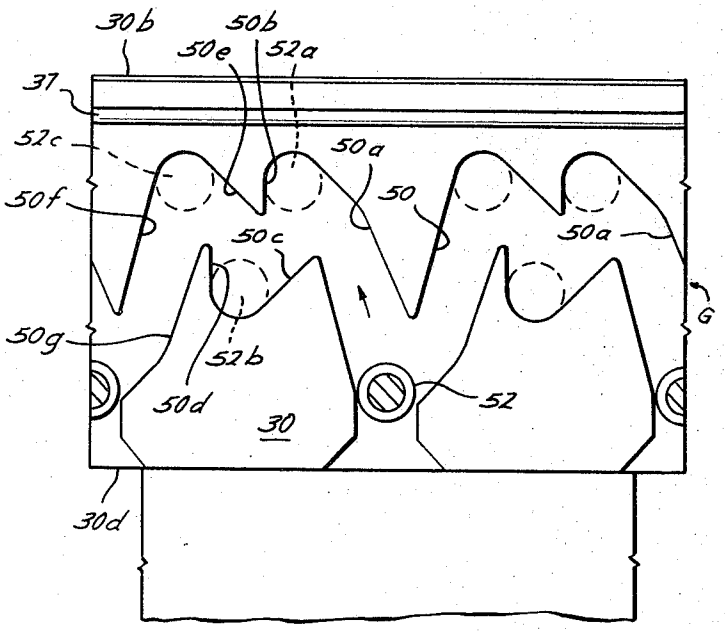
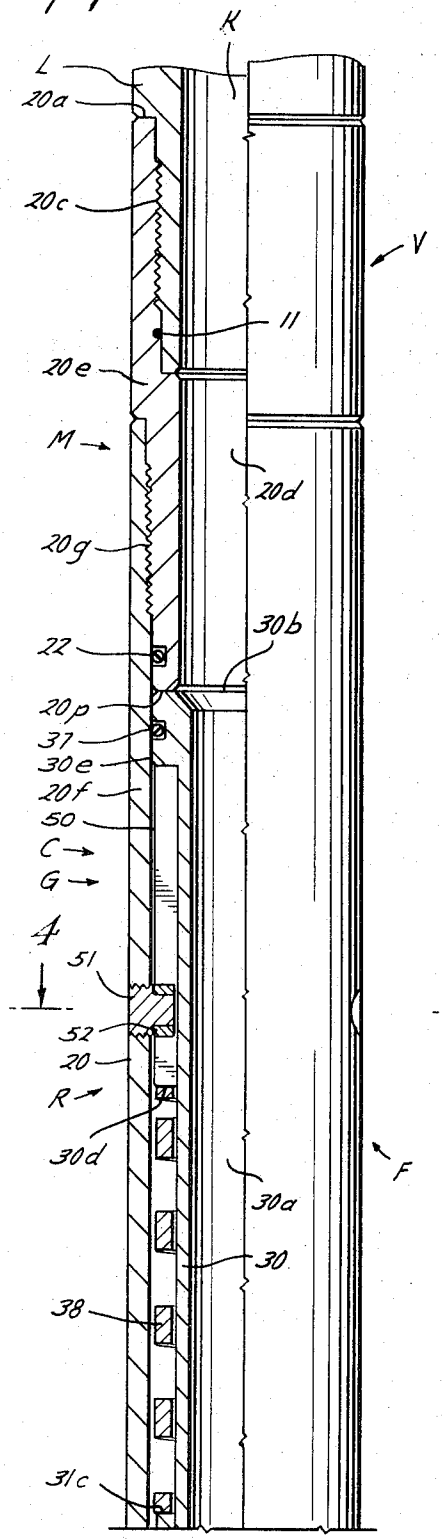


Fig. 2A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20c
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M
20d
20g
30b
22
20p
37
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20f
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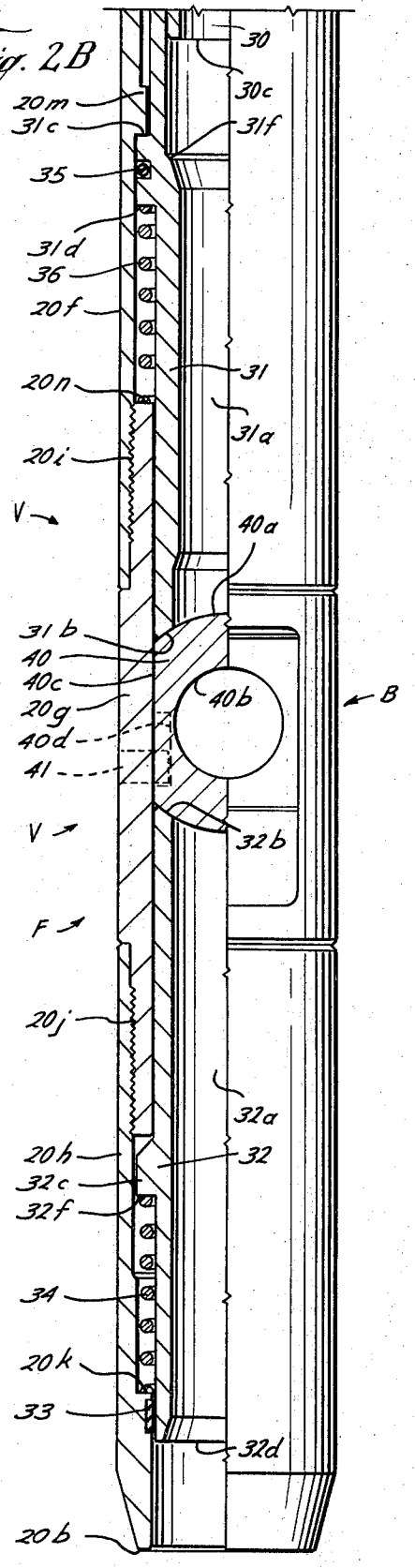
30a
30
38
31c

Fig. 2B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20g
40d
41
40b
B
V
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F
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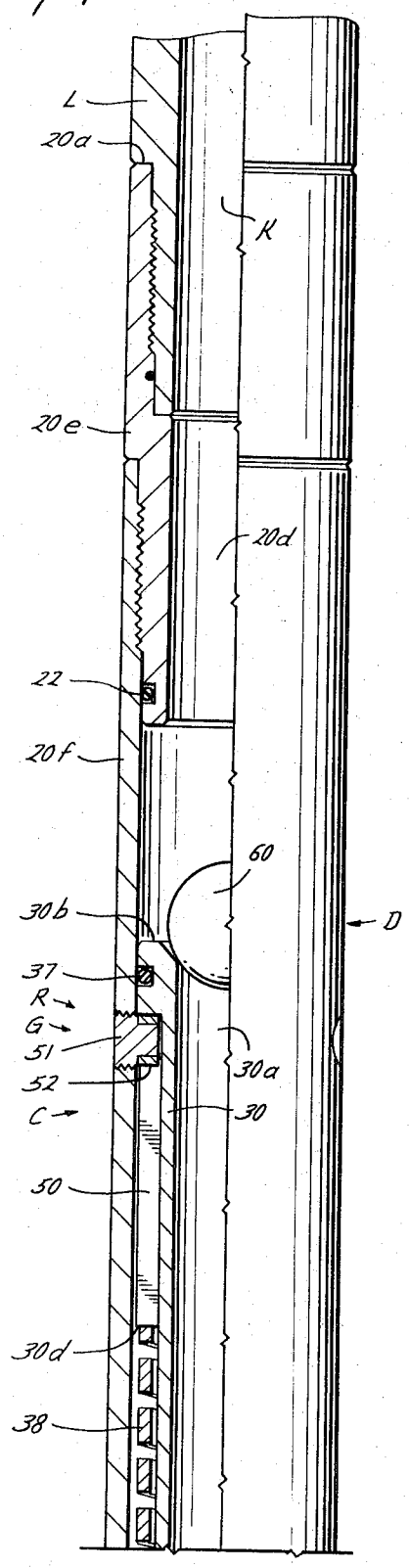
32
32c
32f
34
20k
33
32d
20b

Fig. 3A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R
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C
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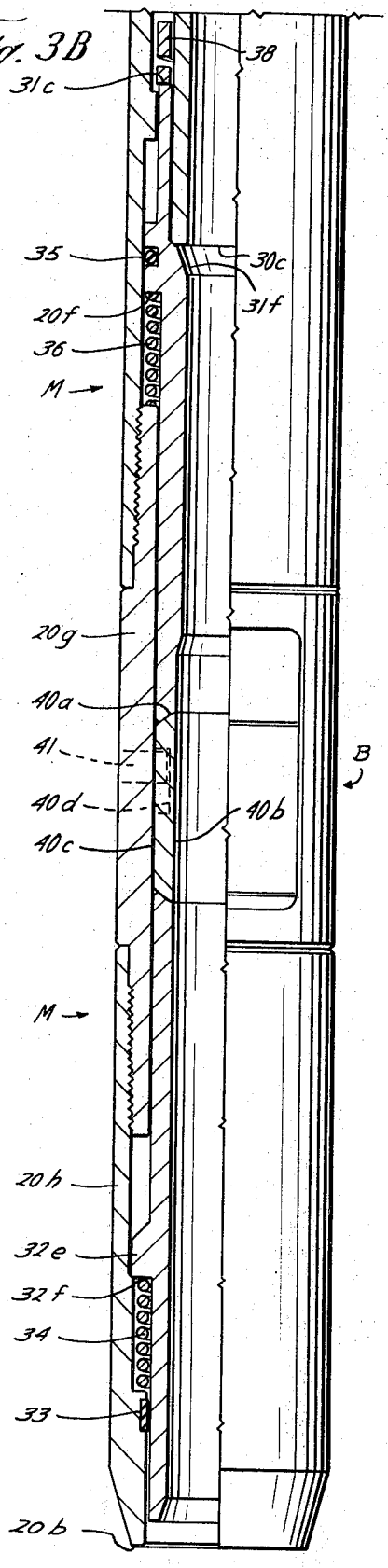
30d
38

Fig. 3B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32f
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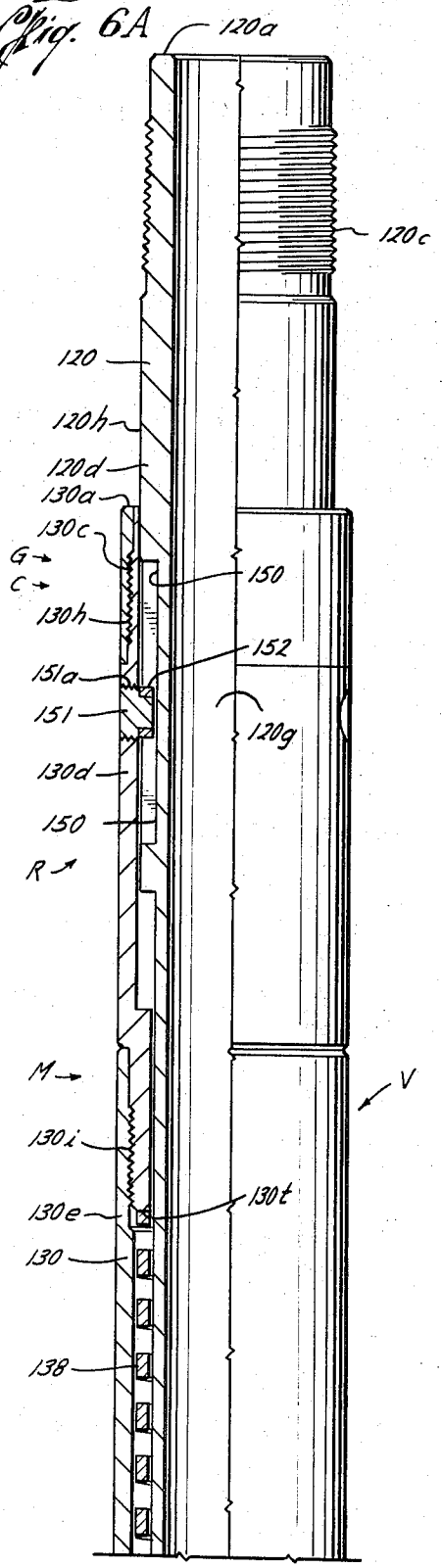
33
20b

Fig. 6A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V
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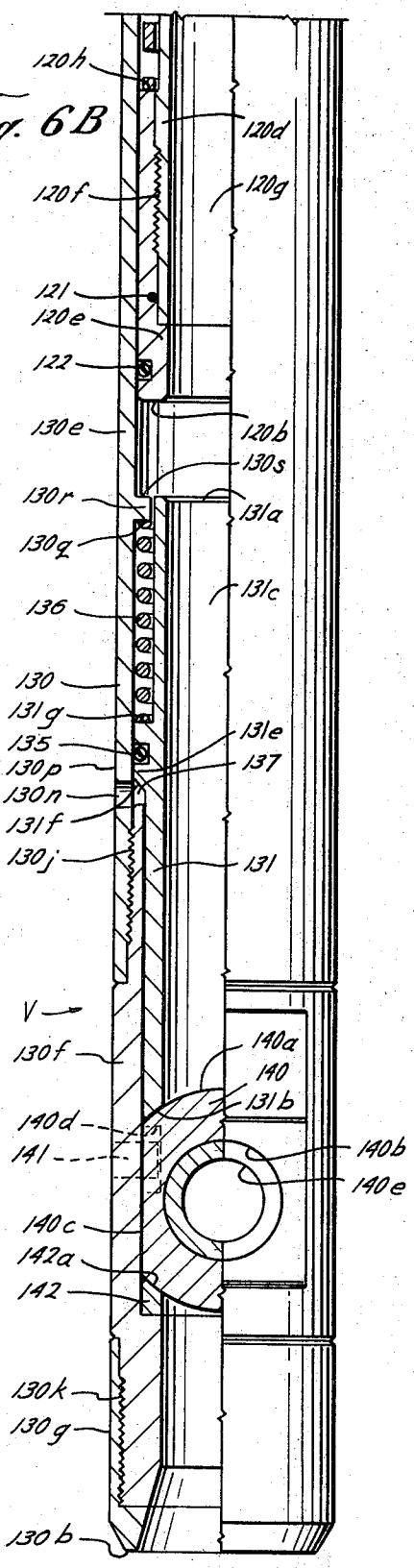
130t
130e
130
138

Fig. 6B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130p
130n
131f
130j
131
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140b
140e
140c
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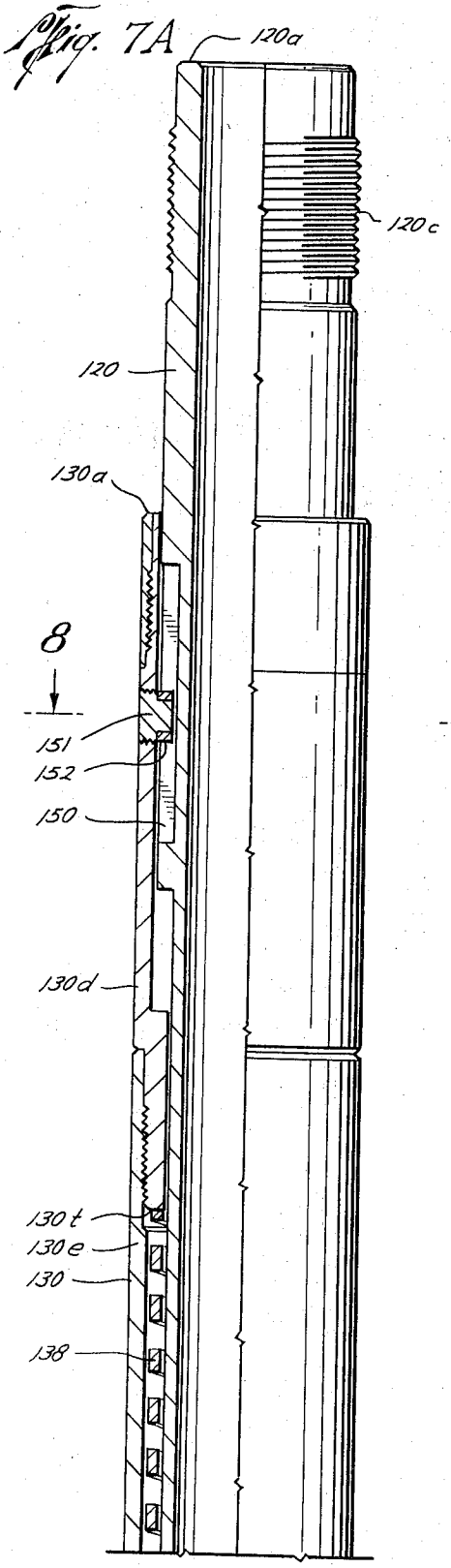
142
130k
130g
130b

Fig. 7A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130t
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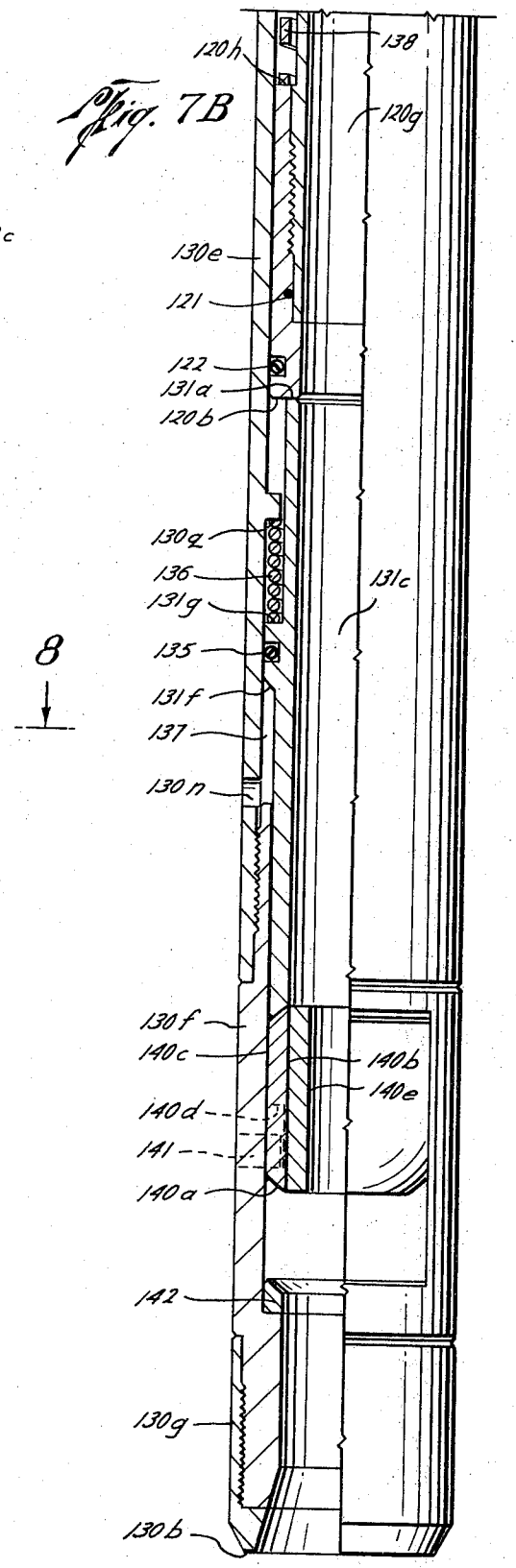
130
138

Fig. 7B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140b
140e
140d
141
140a
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130g
130b

Fig. 8

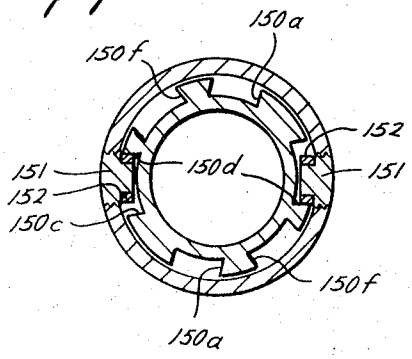


Fig. 9

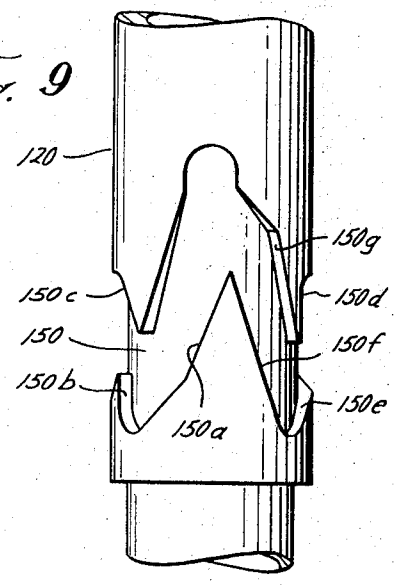
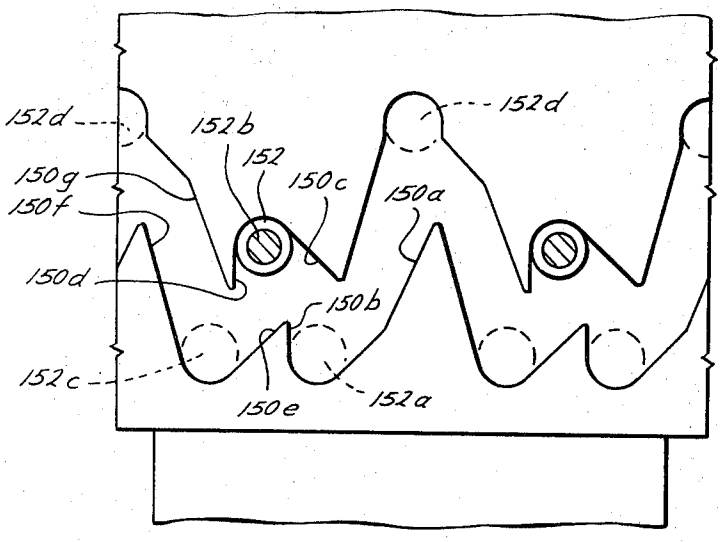


Fig. 10



ALTERNATING VALVE METHOD AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to my co-pending application Ser. No. 214,679, filed Jan. 3, 1972, entitled "WELL TOOL" now U.S. Pat. No. 3,788,594.

BACKGROUND OF THE INVENTION

This invention relates to the field of an alternating valve method and apparatus for shutting in a well at a subsurface location.

Current Federal regulations provide that all well safety valves must be frequently tested in place. This requirement has produced a serious problem when testing safety valves that close in response to either low well pressure conditions or a high flow rate from the well. Previously, this testing was performed by flowing the well wide open in order to reduce the well pressure to close the safety valve which caused many wells --for example, those on the Gulf Coast -- to "sand-up" when tested. Thus safety valve testing frequently resulted in reduced revenues to the well operator from lost production and in increasing the need for costly remedial workover operations.

Also, while it has been possible to perform downhole wireline operations with the well under pressure, such operations are not desirable because of the risk of the well pressure blowing the wireline tool up the well. Previously, devices for plugging the well below the wireline operation level to enable the operations to be performed with the well pressure shut in were somewhat unreliable and required additional trips to set and retrieve the devices.

SUMMARY OF THE INVENTION

This invention relates generally to a new and improved well tool and more particularly to a new and improved method and apparatus for an alternating valve to block in a well at a subsurface location.

The alternating valve includes a rotatable ball valve closure member moving between open and closed positions in response to the urging of a controlled sequence of preselected pressure changes in the well. One embodiment of the alternating valve requires a bridge plug to be located therein to effect operation thereof, while a second embodiment dispenses with the need for the bridge plug. Both embodiments employ a movable operator which is guided to move longitudinally and to rotate for operating the ball member. A method of controlling well pressure for effecting operation of the alternating valve and a method of employing the alternating valve in testing well safety devices are set forth.

An object of the present invention is to provide a new and improved alternating valve well tool.

Another object of the present invention is to provide a new and improved method for operating the alternating valve well tool.

Still another object of the present invention is to provide a new and improved method for testing well safety devices in conjunction with the alternating valve well tool.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view, in section, of a well bore with the alternating valve of the present invention positioned therein below a safety valve;

FIGS. **2A** and **2B** are side views, partially in section, of the alternating valve of the present invention in the closed position; and

FIGS. **3A** and **3B** are views similar to FIGS. **2A** and **2B**, respectively, with a bridge plug positioned in the alternating valve for effecting operation thereof to the open position;

FIG. **4** is a view taken along line **4—4** of the FIG. **2A**;

FIG. **5** is a projected view of an operator movement guide to effect operation of the embodiment of the alternating valve of the present invention illustrated in FIGS. **2A** and **2B**;

FIG. **6A** and **6B** are side views, partially in section, of a second embodiment of the alternating valve of the present invention in the closed position;

FIGS. **7A** and **7B** are views similar to FIGS. **6A** and **6B**, respectively, illustrating the second embodiment of the alternating valve in the open position;

FIG. **8** is a view taken along line **8—8** of FIG. **7A**;

FIG. **9** is a perspective view of the operator movement guide of the second embodiment of the alternating valve of the present invention; and

FIG. **10** is a projected view of the operator movement guide illustrated in FIG. **9**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, the character V will be used to reference the alternating valve well tool of the present invention. As will be set forth in greater detail hereinafter, the alternating valve V is preferably secured in a well bore W at a location below a subsurface safety valve S. Operation of the alternating valve V in response to the urging of a controlled sequence of preselected fluid pressure changes will shut in the well below the safety valve S for testing the valve S as well as enabling desired remedial well work to be performed downhole without having to hold well pressure.

The alternating valve V includes a flow control assembly F and a bore closure means B which is operably connected with the flow control assembly F. The flow control assembly F provides a means for effecting movement of the bore closure means B to and from an open position for enabling flow of fluid through a flow passage or bore O of a well conduit or production tubing T and to and from a closed position for blocking flow of fluid through the bore O in response to the urging of the controlled sequence of preselected fluid pressure changes in the bore O of the well conduit T.

The flow control assembly F includes a support member **20** and a movable operator mechanism M. The tubular support member **20** extends downwardly from an upwardly facing annular shoulder **20***a* (FIG. **2A**) to a lower downwardly facing annular shoulder **20***b* and includes a threaded connection **20***c* formed thereon adjacent the annular shoulder **20***a* for securing the support member **20** with a tubular landing mandrel L. The landing mandrel L which may be of any of the many well-known tools for releasably securing another well tool in the bore O of a production tubing T, and the alternating valve V are properly dimensioned to move through the bore O to the desired location for securing with the production tubing T. The mandrel L carries a sealing

means (not illustrated) on its outer surface for effecting a seal with the production tubing T when the mandrel L is secured in the bore O of the production tubing T, while the support member **20** carries an **0**-ring **21** adjacent the threads **20***c* for blocking leakage of fluid between the tubular member **20** and the mandrel L. The seals so effected block passage of fluid about the exterior of the mandrel L and thus directs flow of fluid through the communicating bore O of the production tubing T, a londitudinally extending bore **20***d* of the support member **20** and the bore K of the mandrel L.

Preferably, for ease of assembly, the support member **20** is formed of four connected sleeve members **20***e*, **20***f*, **20***g* and **20***h* secured together by a suitable fastening means. The sleeve **20***e* is secured to the sleeve **20***f* by threaded engagements at **20***g*, while the sleeve **20***g* is secured to the sleeve **20***f* and the sleeve **20***h* by threaded engagements at **20***h* and **20***i* respectively. Suitable anti-rotation pins (not illustrated) may be employed to block inadvertent disengagement of the threads **20***g*, **20***h*, or **20***i*. The sleeve **20***e* carries an O-ring **22** for effecing a seal to block passage of fluid between the sleeves **20***e* and **20***f*.

The movable operator mechanism M is concentrically mounted with the support member **20** in the bore **20***d* thereof and includes a slide member **30** (FIGS. 2A and 2B), a plunger member **31** (FIG. 2B) and a wash pipe **32**, which is positioned below the bore closure means B. The slide **30**, the plunger **31** and the wash pipe **32** co-act with the operably engaged bore closure means B as will be described in greater detail hereinafter, to move the bore closure means B to and from the open and closed position in response to the pressure changes in the bore O of the production tubing T.

The bore closure means B includes a ball member **40** and a pair of pivot pins **41** which are excentrically mounted with the support member **20**. The ball member **40** includes an outer spherical sealing surface **40***a* and a bore **40***b* formed therethrough for enabling flow through the ball **40**. A portion of the ball **40** is removed to provide a pair of parallel flat surfaces **40***c* on the ball with each of the flat surfaces **40***c* having a radially extending recess or slot **40***d* formed therein. Each of the paralleled slots **40***d* receive a portion of the pivot pins **41** sharing a common longitudinal axis therein as they extend inwardly into the recesses **40***d*. Longitudinal movement of the ball **40** relative to the pivot pins **41** to rotate the ball **40** to and from the transverse or closed position (FIG. 2B) and the aligned or open position (FIG. 3B). IN the embodiment of the alternating valve V illustrated in FIGS. 2B and 3B, the ball **40** rotates open when the center of the ball **40** moves longitudinally from a position above the pivot pins **41** to a position below the pivot pins **41**. Likewise, movememt of the center of the ball **40** from a position below the pivot pins **41** to a location above the pivot pins **41** will effect rotation of the ball **40** from the open position to the closed position. One skilled in the art may change the positions of the slots **40***d* in the ball **40** to effect closing rotation on downward movement of the ball **40**. Reference is made to my co-pending application Ser. No. 72,034,filed Sept. 14, 1971, entitled " PRESSURE OPERATED SAFETY VALVE WITH LOCK MEANS," for a more detailed description and illustration of the rotation of the ball **40** to and from the open and closed positions.

The wash pipe **32** is longitudinally movable in the bore **20***d* of the support member **20** between an upper position (FIG. 2B) and a lower position (FIG. 3B). The tubular wash pipe **32** includes a bore **32***a* formed therethrough communicating with the bore **20***d* for enabling flow of fluid through the wash pipe **32** and an upper arcuate annular surface **32***b* operably engaging the spherical surface **40***a* of the ball **40** and a constant diameter outer surface **32***c* concentrically mounting the wash pipe **32** with the sleeve **20***g* for guiding the longitudinal movement of the wash pipe **32**. The sleeve **20**h carries a gapped expansible snap ring **33** adjacent a lower annular shoulder surface **32***d* of the wash pipe **32** providing a lower movement guide for the wash pipe **32**. The outer surface **32***c* includes an annular collar **32***e* formed thereon having a downwardly facing spring shoulder **32***f*. The operator mechanism M includes a spring means **34** positioned between a spring shoulder **30***k* of the tubular member **20***h* and spring **32***f* for normally urging the wash pipe **32** to move to the upper position and which also urges the engaged ball **40** to move to the closed position.

As illustrated in FIGS. 2A and 2B, the tubular plunger **31** includes a longitudinally extending bore **31***a* therethrough communicating with the bore **20***d* for enabling flow of fluid through the alternating valve V. The plunger **31** has a lower arcuate annular sealing surface **31***b* engaging the spherical surface **40***a* of the ball **40** for sealing thereto to block leakage of fluid about the ball **40** into the bore **31***a* of the plunger **31**. The plunger **31** extends upwardly from the shoulder **31***b* to a flat upper annular shoulder surface **31***c* (FIG. 2A). The plunger **31** is longitudinally movable in the bore **20***b* between an upper position (FIG. 2A and 2B) and a lower position (FIG. 3B) and is slideably sealed to the tubular member **20***f* by the **0**-ring **35** mounted therewith to block passage of fluid therebetween. When the ball **40** is in the closed position the plunger **31** effects seals with the support body **20** and the ball **40** to block flow of fluid therebetween upwardly through the bore **20***b* of the support body **20**. The plunger **31** includes a downwardly facing annular shoulder surface **31***d* formed below the **0**-ring **35** and an upwardly facing annular shoulder **31***e* which engages an inwardly projecting lug **20***m* formed on the support member **20** to provide an upper movement limit stop for the plunger **31**. The bore **31***a* of the plunger **31** has an upwardly facing annular shoulder **31***f* formed therein for a purpose to be described more fully hereinafter.

The operator mechanism M includes a biasing means or spring **36** concentrically mounted about the plunger **31** between the annular shoulder **31***d* and an annular shoulder **20***n* of the support member **20** to urge movement of the plunger **31** to the upper position (FIG. 2B) for cooperating with the spring **34** to position the ball **40** in the closed position.

The slide **30** is concentrically mounted in the bore **20***d* of the support member **20** and is longitudinally movable between a first or lower position (FIG. 3A and 3B) and a second or upper position (FIGS. 2A and 2B). The slide **30** includes a bore **30***a* therethrough communicating with the bore **20***d* for enabling flow of fluid through the alternating valve V. The tubular slide **30** extends downwardly from an upper annular shoulder **30***b* (FIG. 2A) to a lower annular shoulder **30***c* (FIG. 2B) with the upwardly facing annular shoulder **30***b* engaging a downwardly facing annular shoulder **20***p* of

the support member **20** to provide an upper movement limit stop for the slide **30.** The slide **30** carries an **0**-ring **37** adjacent the shoulder **30***b* for effecting a seal with support member **20** to block leakage of fluid therebetween.

The operator mechanism M includes an urging means or spring **38** concentrically mounted in the annular area between the support member **20** and the slide **30** and between the upwardly facing shoulder **31***c* of the plunger **31** and a downwardly facing annular shoulder **30***d* of the slide **30.** The spring **38** is dimensioned to provide little or no urging on the slide **30** and the plunger **31** when they are in their respective upper positions as illustrated in FIGS. 2A and 2B. When the spring **38** is compressed by downward movement of the slide **30,** the spring **38** will impart an upward movement urging to the slide **30** and a downward movement urging to the plunger **31.**

The operator mechanism M includes a cam means C for guiding movement of the slide **30** to position the slide **30** to co-act with the plunger **31** and the wash pipe **32** for effecting movement of the ball **40** to and from the open and closed position. The cam means C includes a guide means G and a guide follower means R. As illustrated in greater detail in FIGS. **4** and **5,** the guide means G includes an annular guide slot or cam recess **50** formed in an outer surface **30***e* of the slide **30.** Positioned in the cam recess **50** is the cam follower means R which includes a pair of opposed inwardly projecting pins or fingers **51,** secured to the sleeve **20***f* by a suitable securing means, such as threaded engagement at **51***a* and a pair of follower rollers **52** which rotate about the pins **51.** The rollers **52** enable the recess **50** to move about the fingers **51** with a smaller movement urging force by reducing the friction between the follower pins **51** and the recess **50.** As illustrated in FIG. **5,** the employment of the opposed pair of fingers **51** requires that the recess provide two identically formed tracks for the slide **30** to move. Those skilled in the art may vary the number of followers employed, with a corresponding change in the profile of the guide **50,** to obtain desired operation of the ball **40.**

In understanding the relative motion of the slide **30** and the rollers **52,** it must be remembered that the rollers are fixed and the entire slide unit **30,** including the recess **50** moves. When the slide **30** is in the upper position (FIG. 2A), the roller **52** is positioned in the recess **50,** as illustrated in FIG. **5,** and the ball **40** is in the closed position (FIG. 2B) with the spring **38** fully extended. Initial downward movement of the slide **30** will move the surface **50***a* of the recess **50** into engagement with the roller **52.** Continued longitudinal downward movement of the slide **30** will impart a rotation to the slide for rotating the slide **30** through an arc about its longitudinal axis until the roller **52** is in the position illustrated in phantom and designated **52***a*. The slide **30** has moved to the lower position and is blocked from further downward movement by the shape of a guide surface **50***b* and the guide surface **50***a*.

Thereafter, upward longitudinal movement of the slide **30** will engage a guide surface **50***c* with the cam roller **52** for imparting additional rotational movement to the slide **30** until the guide surface **50***c* cooperates with a guide surface **50***d* to block upward and rotational movement of the plunger **31** when the roller **52** is in the position illustrated in phantom and designated **52***b*. The slide **30** has been guided to move upwardly to an intermediate or operating position between the upper position (FIG. 2A) and the lower position (FIG. 3A).

Subsequent downward movement of the plunger **31** from the intermediate position will move the guide surface **50***e* into engagement with the roller **52** which will rotate the slide **30** until the roller **52** is in the position illustrated in phantom and designated as **52***c*. When the roller **52** is in this position, the slide **30** has again been guided to the lower position and is blocked from further downward movement by the shpae of the guide surface **50***e* and a guide surface **50***f*. Thereafter, an upward movement of the slide **30** will engage the guide surface **50***g* with the roller **52** which will again rotate the slide **30** and enables the slide **30** to return to the upper position, illustrated in FIG. **5,** with the annular shoulder **30***d* in engagement with the shoulder **30***c* of the support member **20.** It will be appreciated that the slide **30** is guided to move to the upper position, to the lower position when the roller **52** is at the positions indicated by **52***a* or **52***c* and to the intermediate position when the roller **52** is positioned at the location indicated as **52***b* by a sequence of moving the slide **30** downwardly and then upwardly.

As illustrated in FIG. 3A, the downward movement of the slide **30** is effected by a ball or bridge plug means D which is dropped, pumped or otherwise lowered down the bore O of the production tubing T to seat on the upwardly facing annular shoulder **30**b of the slide **30.** By increasing the pressure in the bore O of the production tubing T above the ball **60** a pressure differential across the ball **60** will be established to provide a downwardly urging thereon which is transmitted or imparted to the slide **30** by the engagement therewith.

The downward movement of the plunger **31** from the upper position will compress the spring **38** which will thereafter impart an upwardly urging to the slide **30.** When the pressure above the ball **60** is vented or otherwise reduced until the pressure differential across the ball **60** is unable to overcome the upwardly urging of the spring **38,** the spring **38** will urge the slide **30** to move upwardly to be guided to the upper position or the intermediate position depending on which location the slide **30** was previously in.

When the slide **30** is in the upper position the initial downward movement of the slide **30** will compress the spring **38** which initiates the downward urging of the spring **38** on the plunger **31.** The downward urging of the spring **38** when compressed is substantially greater than the upward urging provided by the springs **34** and **36** to the wash pipe **32** and the plunger **31,** respectively. The downward movement of the slide **30** to the lower position will also engage the lower annular shoulder **30***c* of the slide **30** with the annular shoulder **31***f* of the plunger **31,** for forcing the plunger **31** to move downwardly with the slide **30.** Thus, the spring **38** and the slide **30** will combine to move the engaged plunger **31,** the ball **40** and the tail pipe **32** downwardly to the lower position illustrated in FIGS. 3A and 3B. The longitudinal downward movement of the ball **40** will crank the ball about the eccentric pins **41** to effect rotation of the ball **40** to the open position. Thereafter, when the pressure above the ball **60** is reduced, the upward movement of the slide **30** is guided to the intermediate position, with the roller **52** in the position indicated at **52***b* which will space the shoulder **30***c* from the shoulder **31**f. By properly dimensioning the spring **38,** the urging

of the partially compressed spring **38** when the slide **30** is in the intermediate position will overcome the upwardly urging of the springs **34** and **36** to maintain the ball **40** rotated closed.

Thereafter an increase in the pressure above the ball **60** will move the slide **30** downwardly from the intermediate position to the lower position with the cam roller **52** in the position designated **52***c*. This downward movement of the slide **30** will additionally compress the spring **38** and will move the shoulder **30***c* back into engagement with the shoulder **31***f*, but will not effect a change in the position of the ball **40.** The subsequent reduction in the pressure above the ball **60** will enable the spring **38** to urge the slide **30** to move to the upper position with the rollers **52** in the position illustrated in FIG. **5.** As the slide **30** moves upwardly, the downwardly urging of the spring **38** will be reduced until the combined upwardly urging of the springs **34** and **36** will move the tail pipe **32,** the ball **40** and the plunger **31** to the upper position for effecting closing rotation to the ball **40.**

In the use and operation of the embodiment of the alternating valve V illustrated in FIGS. **2**A and **2**B, the alternating valve V is first secured with the mandrel L by threaded engagement thereto at **20***c*. The mandrel has a suitable running tool (not illustrated) connected there to and the connected mandrel L and the alternating valve V are then moved through the bore O of the production tubing T to the desired subsurface level for securing the alternating valve V in the bore O of the production tubing T. The alternating valve V and the connected mandrel L may be pumped or lowered on a wireline to the desired location in the tubing T both of which methods are well known in the art. When the alternating vavle V is at the desired subsurface location, the mandrel L is actuated to secure the alternating valve V in position and for effecting the seal between the mandrel L and the production tubing T. The running tool is then disconnected from the mandrel L and retrieved back to the surface.

The alternating valve V may be in either the open or closed position when running in the well W, but the open position is preferred, for it insures that a pressure differential will not be established across the ball **40** which may interfere with the securing and sealing of the mandrel L.

When it is desired to kill or shut in the well with the alternating valve V, the ball **60** is dropped or lowered down the bore O of the production tubing T until it seats on the annular shoulder **30***b* of the slide **30.** The pressure above the ball **60** is then increased for moving the slide **30** to the lower position to bring the guide surface **50***e* into contact with the roller **52** which enables the slide **30** to move to the lower position. In moving to the lower position with the ball **40** rotated open, the slide **30** effects no change in the position of the plunger **31,** the ball **40** and the wash pipe **32** from the lower position.

It will be immediately appreciated that in order to establish a pressure differential across the ball **60** for urging the slide **30** to move downwardly, the upwardly urging on the ball **60** of the shut in well pressure must be overcome. Therefore, the preselected pressure for operating the slide **30** must exceed the well shut in pressure which arrangement insures that well pressure conditions cannot inadvertently operate the alternating valve V.

When the pressure above the ball **60** is reduced, the spring **38** urges the slide **30** to move upwardly, to bring the guide surface **50***g* into engagement with the roller **52** for enabling the slide **30** to move to the upper position with the shoulder **30***b* moving back into engagement with the shoulder **20***p* of the support member **20.** This movement of the slide **30** decreases the urging of the spring **38** on the plunger **31** enabling the urging of the springs **34** and **36** to move the ball **40** upwardly for rotating the ball **40** closed.

To open the alternating valve V it is only necessary to increase the pressure in the bore O of the production tubing T above the ball **60** to the preselected pressure for moving the slide **30** down. The downward movement of the slide **30** brings the guide surface **50***a* in contact with the roller **52** as the slide **30** moves to the lower position. The movement of the slide **30** engages the shoulder **31***f* of the plunger **31** with the shoulder **30***c* for moving the plunger **31,** the ball **40** and the tail pipe **32** downwardly for rotating open the ball **40.** The subsequent reduction of the pressure above the ball **60** enables the slide **30** to move upwardly to the intermediate position in response to the urging of the spring **38** maintaining the plunger **31,** the ball **40** and the tail pipe **32** in the lower position. The alternating Valve V thus changes its position from the open to the closed position or vice-versa, each time the pressure in the bore O above the ball **60** is increased and then decreased, hence, the origin of the name alternating valve. One skilled in the art may change the shape of the guide surface employed to vary the sequence of pressure changes to operate the valve without departing from the scope of the present invention. Also, the arc of rotation through which the slide **30** moves in each sequence of operation may be varied.

In the second embodiment of the alternating valve of the present invention illustrated in FIG. **6**A and **6**B, identical reference characters, increased by the sum of **100,** will be used to reference like parts.

The flow control assembly F includes a tubular support member **120** which extends downwardly from an upwardly facing annular shoulder **120***a* (FIG. **6**A) to a lower annular shoulder **120***b* (FIG. **6**B). The tubular member **120** is secureable to the mandrel L by suitable fastening means, such as threads **120***c* located adjacent the annular shoulder **120***a*. Preferably, for ease of assembly, the tubular member **120** is formed of an upper sleeve **120***d* and a lower sleeve **120***e*, secured together by a suitable means such as by threaded engagement at **120***f* to form a single unit with an **0**-ring **121** effecting a seal to block leakage of fluid therebetween. The tubular member **120** has a longitudinally extending bore **120***g* formed therethrough for communicating the flow of fluid through the alternating valve V to the bore K of the mandrel L.

The operating mechanism M includes a slide member **130** concentrically mounted about an exterior surface **120***h* of the support member **120** and which extends downwardly from an upper annular shoulder **130***a* to a lower annular shoulder **130***b* which constitutes the lowermost portion of the alternating valve V. Preferably, for ease of assembly, the tubular slide **130** is formed of five sleeve members **130***c*, **130***d*, **130***e*,**130***f*and **130***g*, secured together to form a single unit. The sleeve **130***d* is secured to the sleeve **130***c* by threaded engagement at **130***h* and with the sleeve **130***e* by threads **130***i* while the sleeve **130***f* is secured with the sleeve **130***e* by

threads 130*j* and with the sleeve 130*g* by threads 130*k*. Threaded anti-rotation pins (not illustrated) may be employed to prevent inadvertent disassemble of the slide 130. The slide 130 has a longitudinally extending bore 130*m* into which the support member 120 partially extends for mounting the slide 130 therewith and which communicates with the bore 120*g* of the support member 120 for enabling flow of fluid through the alternating valve V. The support member 120 carries an 0-ring 121 to effect a seal with the slide 130 to block leakage of fluid therebetween. The slide 130 has a flow port 130*n* formed therethrough adjacent the threads 130*j* for enabling fluid communication between the bore 130*m* and an area adjacent an exterior surface 130*p* of the slide 130.

The bore closure means B includes the rotatable ball 140 having the outer spherical sealing surface 140*a* and the bore 104*b* formed therethrough and which is moveably disposed in the bore 130*m* of the slide 130 adjacent the sleeve 130*f* and the pivot pins 141 which are secured with the slide 130. The operating recesses 140*d* formed in the ball 140 for receiving the pivot pins 141 therein are positioned thereon to effect rotation of the ball 140 to the closed position when the center of the ball 140 is below the pins 141 and which rotate the ball 140 to the open position when the center of the ball 140 is above the pivot pins 141. The bore closure means B also includes a fixed annular seat ring 142 secured to the slide 130 below the ball 140 having an upwardly facing arcuate annular shoulder 142*a* which engages the spherical surface 140*a* for effecting a seal therebetween. The seal so effected blocks leakage of fluid from above the ball 140 to a location below the ball 140. Unlike the first embodiment of the alternating valve V, the ball 140 has a flow orifice or restriction 140*e* positioned in the bore 140*b* of the ball 140 to provide a differential pressure urging on the ball 140.

The operating mechanism M includes a plunger 131 which is longitudinally movable in the bore 130*m* of the slide 130 and is positioned above the ball 140. The tubular plunger 131 includes an upper annular shoulder surface 131*a* and a lower arcuate annular sealing surface 131*b* for engaging the spherical surface 140*a* of the ball 140 to effect an annular seal therebetween to block passage of fluid upwardly between the ball 140 and the plunger 131. The plunger 131 includes a bore 131*c* formed therethrough communicating with the bores 130*m* and 120*g* for enabling flow of fluid through the alternating valve V. Th

The plunger 131 includes a constant diameter outer surface 131*d* having an annular collar 131*e* formed thereon to provide a downwardly facing pressure responsive annular shoulder surface 131*f* adjacent the flow port 131*n* and an upwardly facing annular shoulder surface 131*g*. The collar 131*e* carries an 0-ring 135 to effect a sliding seal with the slide 120 to block leakage of fluid therebetween. The seals of the plunger 131 effected by the sealing surface 131*b* and the 0-ring 135 block upwardly flow through the alternating valve V when the ball 140 is rotated closed. The annular space between the plunger 131 and the slide 130 below the pressure responsive surface 131*f* as the plunger 131 forms an annular expansible chamber 137 communicating through the port 130*n* with the area adjacent the exterior surface 130*p* of the slide 130 for urging the plunger 131 to move upwardly in response to the pressure in the chamber 137.

The operator mechanism M includes a biasing means or spring 136 imparting a downwardly urging to the plunger 131 which is concentrically positioned about the plunger 131 between the upwardly facing annular shoulder 131*g* of the plunger 131 and a downwardly facing annular shoulder 130*g* of an inwardly projecting annular collar 130*r* formed on the slide 130. The collar 130*r* has an upwardly facing shoulder 130*s* which engages the downwardly facing annular shoulder 120*d* of the support member 120 to provide an upper movement of the plunger 131 to the lower position for normally maintaining the ball 140 rotated closed.

Movement of the slide 130 is guided by the cam means C which positions the slide 130 in the first or lower position, the second or upper position and the intermediate or operating position. The cam means C includes a guide surface G formed on the support member 120 and a cam follower roller R mounted with the slide 130. As illustrated in greater detail in FIG. 9, the guide surface G includes an annular guide recess 150 formed in the support member 120 adjacent the sleeve 130*b* of the slide 130.

The cam follower R includes a pair of inwardly projecting fingers 151 secured to the sleeve 130*b* by a suitable fastening means, such as engagement of threads 151*a* with each of the fingers 151*a* concentrically mounting thereon a rotatable ring-shaped roller 152 for moving through the guide recess 150 while reducing the friction therebetween. Because the roller 152 moves with the slide 130 instead of remaining stationary as in the first embodiment which was illustrated in FIG. 5, the projected annular guide recess 150 for the second embodiment, which is illustrated in FIG. 10 is a reverse profile of the guide recess of the first embodiment. The slide 130 is in the intermediate position when the rollers are positioned in the location designated 152*b* with subsequent downward movement of the slide 130 moving the rollers 152 to engage the guide surface 150*e* which will impart rotational movement of the slide 120 through an arc about its longitudinal axis until the roller 152 reaches the position designated 152*c* where the guide surfaces 150*e* and 150*f* cooperate to block further downward movement of the slide 130. Subsequent upward movement of the slide 130, will move the roller 152 from the location designated 152*c* upwardly into engagement with the guide surface 150*g* which will again impart a rotation to the slide 130 as the roller 152 and the slide 130 move upwardly to the position designated 152*d* which is the upper position for the slide 130.

A subsequent downward movement of the slide 130 moves the rollers 152 into engagement with the guide surface 150*a* until the rollers 152 move downwardly to the position designated 152*a* and in which it is held by cooperation of the guide surfaces 150*a* and 150*b*. An upward movement of the slide 130 thereafter moves the rollers 152 upwardly into engagement with the guide surface 150*c* for guiding the rollers 152 back to the roller position designated 152*b* which is the intermediate postion for the slide 130 between the lower position when the rollers 152 are positioned at either 152*a* or 152*c* and the slide 130 upper position where the rollers 152 are in the position designated 152*b*.

The operator mechanism M includes a biasing spring 138 which is concentrically mounted about the support member 120 between an upwardly facing annular shoulder 120*h* of the support member 120 and a down-

wardly facing annular shoulder **130***t* of the slide **130** to impart an upwardly urging to the slide **130** for moving the slide **130** to the upper position. The spring **138** is much stronger than the spring **136** and will overcome the urging of the spring **136** to move the slide **130** upwardly.

The second embodiment of the present invention dispenses with the need for the bridge plug means D. The rotatable ball **140** provides a sufficient flow restriction, as will be set forth in greater detail hereinafter, to effect operational movement of the slide **130** in response to the fluid pressure urging thereon. When the slide **130** is in the upper position, the shoulder **131**a of the plunger **131** engages the shoulder **120***c* of the support member **120** to force the center of the ball below the pivot pins **141** to keep the ball **140** rotated closed when the slide is in the upper position. The downward movement of the slide **130** to the lower position also moves the ball **140** and the plunger **131** downwardly with no relative movement therebetween and is effected by increasing the pressure in the bore O of the production tubing T above the ball **140** to establish a pressure differential across the ball **140** for providing a downwardly urging on the slide **130.** This urging will overcome the upwardly urging of the spring **138** to compress the spring **138** and move the slide **130** to the lower position.

By decreasing the pressure above the ball **140** to reduce the pressure differential across the ball **140,** the urging of the spring **138** will then move the slide **130** upwardly to be guided to the intermediate position as illustrated in FIGS. **6**A and **6**B. A further decrease in pressure above the ball **140** below the well shut in pressure, will then establish an upwardly urging pressure differential across the closed ball **140.** The shut in well pressure is also communicated through the port **130***n* into the expansible chamber **137** for providing an upwardly pressure urging on the pressure responsive surface **131***f* of the plunger **131.** This upwardly urging of the spring **136** to longitudinally move the plunger **131** and the ball **140** upwardly relative to the slide **130** to the position illustrated in FIGS. **7**A and **7**B. The upwardly movement of the ball **140** about the pivot pins **141** effects rotation of the ball **140** to the open position enabling flow through the alternating valve V.

The ball **140** remains in the open position for so long as there is flow up through the bore **140***c* of the ball **140** to produce a pressure drop across the orfice **140***e* in the ball **140** for effecting a sufficient pressure differential urging on the plunger **131.** As long as the pressure in the bore **130***m* is sufficiently less than the pressure urging upwardly on the surface **131***f* of the plunger **131** the differential pressure urging on the plunger **131** will be sufficient to overcome the urging of the spring **136** to maintain the plunger **131** in the upper position. When the well W is closed in and there is no flow through the bore **140***c* of the ball **140,** the pressure urging on the plunger **131** will equalize and the spring **136** will urge the plunger **131** to move downwardly for rotating the ball **140** to the normally closed position. In subsequently enabling flow from the well, the upwardly urging pressure differential across the ball **140** will again be established for rotating the ball **140** open and reestablishing the differential pressure urging on the plunger **131.**

When it is desired to close the alternating valve V the pressure in the bore O of the production tubing T above the alternating valve V is increased by a pump or other pressure generating means to equalize the pressure differential across the ball **140.** The increased pressure in the bore **130***c* above the ball **140** will urge downwardly on the plunger **131** and the ball **140** to overcome the upwardly urging of the well pressure on the plunger **131** downwardly to rotate the ball **140** closed. The pressure differential across the ball **140** will then be increased to urge the slide **130** to move downwardly to the lower position. When the pressure across the ball **140** is thereafter decreased, the spring **138** will then move the slide **130** to the upper position which blocks movement of the plunger **131** and the ball **140** from the lower position to maintain the ball **140** closed.

It will be immediately appreciated that normally biasing the ball **140** to the closed position with the spring **136** and making the movement of the plunger **131** responsive to a differential pressure, urging the need to lower a plug down the bore O of the production tubing T to operate the alternating valve V is eliminated.

In the use and operation of the second embodiment of the alternating valve V of the present invention, the valve V is secured with the mandrel L and is secured in the well W in the same manner as the first embodiment of the alternating valve V as set forth hereinabove. The method of operation is identical in that the ball **140** is alternately rotated between the open and closed positions when the pressure in the bore **0** in the production tubing T above the valve V is increased to a pressure above the well shut in pressure and subsequently decreased to a lower pressure.

When the alternating valve V is employed in a well W with the safety valve S, the safety valve S may be tested in place with the minimal risk of damage to the well W or the safety valve S. Normally, the well W will include a well casing X which extends downwardly from a christmas tree Z at the earth surface A to a location below a hydrocarbon producing formation H. The casing X has a plurality of openings or perforations J formed therethrough adjacent the producing zone H to enable flow of hydrocarbons to the casing X. The well W will normally include a packer P for effecting a seal between the production tubing T and the casing X for directing the flow of hydrocarbons to the earth surface A, through the bore O of the production tubing T to the christmas tree Z. The christmas tree Z includes a valve, indicated at **200,** for normally controlling flow of fluid through the well W from the producing formation H.

Any number of safety devices or valves S may be positioned above the alternating valve V but preferably the alternating valve is used in conjunction with a Hi-Lo valve which is disclosed in my co-pending application, Ser. No. 214,679, filed Jan. 3, 1972, entitled Hi-Lo Valve and which issued Jan. 29, 1974 as U.S. Pat. No. 3,788,594, for a subsurface safety valve which closes on either high or low well pressure conditions. The use of the alternating valve V of the present invention should not be considered to be limited to use with the Hi-Lo valve, but may be used in testing any surface or subsurface pressure of flow responsive well safety device.

For purposes of an example for this disclosure of the method of testing the safety device, arbitrary well conditions will be assumed. The actual conditions found in a well are unique and the well pressures and other values used herein are representative for the purpose of

describing the method only and and should not be considered as limiting the method of testing the safety device.

The depth of the secured alternating valve V below the surface A will be taken as 6,000 feet, while the depth of the Hi-Lo valve S will be 3,000 feet. At the 3,000 foot depth of the Hi-Lo valve S, the well shut in pressure is 4,000 psi and the normal well flowing pressure is 3,200 psi. The Hi-Lo valve S is set to close at an open flow or low pressure value of 2,500 psi. The preselected or reference pressure established in the dome of the Hi-Lo valve S for actuating the same is 3,600 psi, which, when exceeded by the well pressure will operate the safety valve S to close on the high well pressure. It is immediately apparent that these assumed pressures will have different values for different well depths which will be ignored for the purpose of this disclosure and all pressure will be considered at the Hi-Lo valve V level.

Normally, when commencing the method of testing, the alternating valve V and the safety valve S will be in the open position for enabling production of hydrocarbons. The control valve **200** on the christmas tree Z is used to control flow from the well and hence the pressure conditions in the well.

The initial step in testing the safety valve S is to close the control valve **200** on the christmas tree Z to increase the pressure in the bore **0** of the production tubing T to the well shut in pressure which will operate the safety valve S to close on the hi side when the well pressure exceeds 3,600 psi. Thereafter, the valve **200** is opened or vented to reduce the well pressure in the bore **0** of the production tubing T above the Hi-Lo valve S to the well pressure for operating it closed in response to low well pressure which has been established as 2,500 psi.

By using a pump or other means at the surface A for adding fluid into the bore **0** of the production tubing T above the safety valve S, the pressure above the Hi-Lo valve S will be increased to a reference pressure, which for the purpose of this disclosure will be taken as 4,100 psi, and which is greater than the well shut in pressure. The quantity of injected fluid into the bore O of the production tubing T required to increase the well pressure from the safety valve operating low well pressure to the reference pressure of 4,100 psi is measured to determine a reference quantity of injection fluid required to effect this pressure change. Now or immediately after closing the Hi-Lo valve S in response to high well pressure conditions, the pressure in the bore **0** of the tubing T above the safety valve V can be bled to zero to test the ability of the Hi-Lo valve S to hold the well shut in pressure.

At this point in the test, two things have been established. First, the Hi-Lo valve V will operate to close when the high well pressure condition occurs, and secondly, when closed the safety valve S will hold well shut in pressure without leakage.

To open the Hi-Lo valve S it is only necessary to increase the pressure in the bore **0** of the tubing T above the safety valve S to exceed the well shut in pressure and then reduce that pressure to some value less than the well shut in pressure. This sequence of increasing and decreasing the pressure above the Hi-Lo valve S enables flow of fluid in either direction for so long as the pressure in the bore **0** of the tubing T adjacent to the Hi-Lo valve V is maintained greater than the preselected reference pressure of 3,600 psi. Therefore, the pressure in the bore **0** of the tubing above the Hi-lo valve S will be increased to 4,100 psi and then reduced to 3,800 psi to open the Hi-Lo valve V for enabling downwardly flow through the Hi-Lo valve S.

With the ability to pump down through the Hi-Lo valve S, without affecting closure thereof, the pressure in the bore **0** of the tubing T above the alternating valve V can be increased to a value greater than the well shut in pressure at the level of the alternating valve V. If the first embodiment of the alternating valve V is employed it will be necessary to lower the ball **60** down the bore **0** of the production tubing T and the Hi-Lo valve V to effect the pressure responsive downward movement of the slide **30** for operating the alternative valve V. Thereafter, decreasing the pressure in the bore **0**, by venting through the valve **200**, below the well shut in pressure will enable the slide **30** to move upwardly for closing the alternating valve V to block or shut in the well W below the Hi-Lo valve S.

The pressure in the bore **0** of the tubing T can then be lowered by again slowly bleeding the pressure through the valve **200** until the well pressure at the Hi-Lo valve V level is 2,400 psi which should operate the Hi-Lo valve S to close on the low side when the pressure in the tubing T reaches 2,500 psi or less. Previously, to effect the low well pressure closure test, it has been necessary to open fully the valve **200** to produce a sufficient flow of hydrocarbons to reduce the well pressure to effect the low well pressure closure. The flow needed to reduce the well pressure frequently sanded up the well W besides increasing the risk of damage to the valve V from erosion by sand entrained in the flow of hydrocarbons.

At this point in the test, it has been determined that the well pressure has been bled to a pressure of 2,400 psi at the Hi-Lo valve S level, and that one valve, either the alternating valve V or the safety valve S, is holding the well pressure. Since both valves are supposedly closed, it is necessary to determine whether the Hi-Lo valve S did close to hold well pressure when the pressure reached 2,500 psi or if the alternating valve V along is holding the well pressure. This is accomplished by again injecting fluid into the bore **0** above the Hi-Lo valve V to increase the pressure in the well W to the referenced pressure of 4,100 psi while gauging the quantitiy of fluid injected into the well W to increase the pressure to the referenced pressure. By comparing the gauged quantity of fluid injected into the well W to the previously measured reference quantity of fluid for increasing the well pressure to the reference pressure, it can determine if the Hi-Lo valve S or the alternating valve V is holding well pressure. Since the alternating valve V is set at twice the depth of the safety valve V, if the gauged quantity of fluid injected in the wall W to increase the pressure to the reference pressure is twice that of the referenced quantity of fluid, it can be assumed that the Hi-Lo valve did not operate and the alternating valve V is holding the pressure. If in comparing the gauged quantity of fluid and the known reference quantity of fluid, the quantities are substantially identical, the Hi-Lo valve S has operated to shut in the well W.

This method of testing the low pressure operation of the Hi-Lo valve S can be repeated sequentially by lowering the well pressure in preselected increments while repeating the above sequence for determining the ac-

tual well pressure which effects closing operation of the Hi-Lo valve S.

In testing flow responsive safety valves S, it will be necessary to locate the alternating valve V a sufficient distance below the safety valve S for providing a sufficient volume of fluid in the bore O of the tubing T therebetween to flow through the safety valve S to effect closing thereof. In testing the operator will first effect closure of the alternating valve V to kill the well for blocking communication of the producing zone H and the safety valve S. Next, the surface control valve **200** is opened to enable sufficient upwardly flow in the tubing T to effect closure of the safety valve V while lowering the well pressure to the 2,400 psi level. While it may be necessary to inject a gauged quantity of fluid to increase the pressure in the Well W to the reference pressure to determine if the alternating valve V or the safety valve S is holding pressure in the manner set forth hereinabove, normally increasing the well pressure to the reference pressure is all that is required. The safety valve S is then operated open and if the well pressure above the safety valve V drops to a pressure less than the reference pressure, the safety valve V was holding pressure in the bore O of the tubing T below the safety valve V. If there is no change in this well pressure when opening the safety valve S, only the alternating valve V was holding well pressure and the safety valve V failed to close.

Depending upon the method of opening the subsurface flow responsive safety valve S employed in conjunction with the alternating valve V, it may be necessary to modify the above method of testing the operation of the safety valve S. Such modification should be considered to be within the spirit of the present method invention and my method should not be limited to that specifically disclosed as it is only the preferred embodiment.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials as well as the details of the illustrated construction may be made without departing from spirit of the invention.

What is claimed is:

1. A well tool for selectively shutting in a well conduit at a desired location, including:

a. a flow control assembly movable through a bore of a well conduit to the desired location and adapted to be secured with the well conduit at a desired operating location;

b. a bore closure means operably connected with said flow control assembly for movement to and from an open position to align a bore closure flow port with the bore of the well conduit for enabling flow of fluid through the bore of the well conduit and a closed position with the bore closure flow port positioned for blocking flow of fluid through the bore of the well conduit with said bore closure means;

c. said flow control assembly having means for effecting desired movement of said bore closure means, depending upon the initial position of the bore closure means, to either the open or closed positions in response to the urging of a controlled sequence of preselected fluid pressure changes in the bore of the well conduit wherein the well tool is operated.

2. The invention as set forth in claim **1,** wherein:

said bore closure means includes a ball member rotatable to and from the open and closed position, said ball having a flow passage therethrough which communicates the bore of the well conduit above and below said flow control assembly when said ball is in the open position to enable flow of fluid through the bore of the well conduit with said flow passage moving to a position enabling said ball in the closed position to block flow of fluid through the bore of the well conduit wherein rotation of the ball operates the well tool.

3. The invention as set forth in claim **1,** wherein said flow control assembly includes:

a. a support member mounting a means for releasably securing said support member in the desired location in the bore of the well conduit; and

b. an operator mechanism movably mounted with said support member and operably engaged with said bore closure means to effect desired movement thereof to and from the open and closed positions in response to the urging of the controlled sequence of preselected pressure changes wherein the well tool is operated.

4. The apparatus as set forth in claim **1,** wherein:

said bore closure means having a flow blocking member arranged for rotational movement to and from the open and closed position.

5. A well tool for selectively shutting in a well conduit at a subsurface location, including:

a. a flow control assembly movable through a bore of a well conduit to the subsurface location where said flow control assembly is adapted to be secured in the bore of the well conduit;

b. a bore closure means operably connected with said flow control assembly for movement to and from an open position enabling flow of fluid through the bore of the well conduit and a closed position blocking flow of fluid through the bore of the well conduit;

c. said flow control assembly having means for effecting desired movement of said bore closure means to and from the open and closed positions in response to the urging of a controlled sequence of preselected fluid pressure changes in the bore of the well conduit;

d. a support member mounting means for releasably securing said support member in the bore of the well conduit;

e. an operator mechanism movably mounted with said support member and operably engaged with said bore closure means to effect desired movement thereof to and from the open and closed positions in response to the urging of the controlled sequence of preselected pressure changes;

f. a slide member mounted with said support member and movable relative thereto in response to the urging thereon of the preselected pressure to and from a first position for enabling the bore closure means to change positions; and

g. a plunger movable relative to said slide for coacting therewith to effect movement of said bore closure means to and from the open and closed positions in response to the position of said slide wherein the well tool is operated.

6. The invention as set forth in claim **5,** wherein:

the movement of said slide member from the first position is guided to position said slide to co-act with

said plunger to effect movement of the bore closure means to the open position wherein the well tool enables flow of fluid.

7. The invention as set forth in claim 5, wherein:
the movement of said slide member from the first position is guided to position said slide to co-act with said plunger to effect movement of the bore closure means to the closed position wherein the well tool blocks flow of fluid.

8. The invention as set forth in claim 5, wherein:
the movement of said slide member from the first position is guided to effect a change in the position of said bore closure means from the position of said bore closure means prior to the movement of said slide to the first position wherein the well tool is alternately operated open and closed by the controlled sequence of preselected pressure changes.

9. The invention as set forth in claim 8, wherein:
the movement of said slide member from the first position is guided by a cam means for positioning said slide member to co-act with said plunger for effecting desired movement of said bore closure means.

10. The invention as set forth in claim 8, wherein said flow control assembly includes:
biasing means for urging movement of said slide from the first position when the urging thereon of the preselected pressure is reduced wherein venting the preselected pressure operates the well tool.

11. The invention as set forth in claim 8, wherein:
the movement of said slide member is guided to circumfrentially rotate said slide relative to said support member for positioning the slide to effect the desired change in the position of said bore closure means.

12. The invention as set forth in claim 8, wherein:
the movement of said slide member is guided to longitudinally move said slide relative to said support member for positioning the slide to effect the desired change in the position of said bore closure means.

13. The invention as set forth in claim 5, wherein:
said slide includes means for receiving a bridge plug therewith for urging movement of said slide to the first position in response to the preselected pressure urging on said bridge plug.

14 A method of operating a well tool having a closure operator and a closure member for shutting in a well at a subsurface location, including the steps of:
moving the well tool through he bore of a well conduit positioned in the well to the subsurface location;
securing the well tool in the bore of the well conduit at the subsurface location;
increasing the well pressure in the bore of the well conduit to a preselected pressure for actuating a closure operator of the well tool;
decreasing the well pressure sufficiently for guiding movement of the closure operator for selectively moving the closure member to either an open position aligning a closure member for enabling flow through the well and the closure member and a closed position for shutting in the well with the closure member depending upon the initial position of the closure operator.

15. The invention as set forth in claim 14, including the step of:
changing the position of the closure member each time the well pressure is increased to the preselected pressure and then decreased wherein the valve alternates between the open and closed position.

16 The invention as set forth in claim 14 including the step of:
rotating the closure member when moving between the open and closed positions.

17. The invention as set forth in claim 14 wherein the step of guiding the closure operator includes the step of:
rotating the closure operator circumferally while moving the operator longitudinally in the well.

18. The invention as set forth in claim 14, wherein the step of actuating the closure operator includes the step of:
rotating the operator circumferally while moving the operator longitudinally in the well.

19. The invention as set forth in claim 14, including the step of:
exceeding the well shut in pressure when increasing the well pressure to the preselected pressure for actuating the closure operator wherein well pressure is blocked from actuating the well tool.

20. A method of operating a well tool having a closure member for shutting in a well at a subsurface location, including the steps of:
increasing the well pressure to a preselected pressure for actuating a closure operator of the well tool;
decreasing the well pressure sufficiently for guiding movement of the closure operator for selectively moving the closure member to either an open position for enabling flow through the well and a closed position for shutting in the well depending upon the initial position of the closure operator; and
positioning a plug member in the well tool prior to performing the step of increasing the pressure in the well to the preselected pressure.

21. A method of testing a pressure responsive safety device in a well including the steps of:
a. shutting in the well at a location below the safety device;
b. lowering the pressure in the well above the shut-in location to operate the safety device to the closed position for blocking flow from the well wherein operation of the safety device is tested.

22. The invention as set forth in claim 21, including the steps of:
a. injecting fluid into the well above the safety device for increasing the pressure in the well to a known reference pressure after the step of varying the pressure in the well to operate the safety device;
b. gauging the quantity of fluid injected into the well to increase the pressure in the well to the known reference pressure; and
c. Comparing the guaged quantity of fluid injected into the well to a known reference quantity of fluid for increasing the well pressure to the known reference pressure to determine if the safety device operated when the well pressure has varied wherein operation of the safety device is determined.

23. The invention as set forth in claim 21, including the steps of:

a. injecting fluid into the well above the safety device for increasing the pressure in the well to a known reference pressure after the step of lowering the pressure in the well to operate the safety device;

b. gauging the quantity of fluid injected into the well to increase the pressure in the well to the known reference pressure; and

c. comparing the guaged quantity of fluid injected into the well to a known reference quantity of fluid for increasing the well pressure to the known reference pressure to determine if the safety device operated when the well pressure was lowered wherein operation of the safety device is determined.

24. The invention as set forth in claim **23,** including the steps of:

repeating sequentially the steps of lowering the well pressure, injecting fluid to increase the well pressure to the reference pressure, gauging the fluid required to increase the well pressure to the reference pressure and comparing the gauged quantity of fluid with the known reference quantity of fluid while lowering the pressure in the well in preselected increments in each sequence for determining the well pressure for effecting operation of the safety device wherein the actual operating pressure of the safety device is determined.

25. The invention as set forth in claim **23,** including the following steps performed prior to the step of shutting in the well at a location below the safety device:

a. operating the safety device to close;

b. reducing the pressure in the well to the pressure for operating the safety device to the closed position in response to low well pressure;

c. adding fluid into the well for increasing the pressure in the well to a reference pressure greater than the well shut in pressure;

d. measuring the quantity of injected fluid required to increase the well pressure from the safety device operating pressure to the reference pressure for establishing a reference quantity of fluid needed to effect this pressure change in the well above the safety device.

26. The invention as set forth in claim **21,** wherein the step of operating the safety device to close includes the steps of;

a. increasing the pressure in the well for operating the safety device to close in response to the increased pressure, and;

b. venting the well pressure above the safety device for determining if the safety device is holding well pressure.

27. A method of testing a pressure responsive safety device in a well including the steps of:

a. shutting in the well at a location below the safety device;

b. varying the pressure in the well above the shut-in location to operate the safety device to the closed position for blocking flow from the well wherein operation of the safety device is tested.

28 A well tool for selectively shutting in a well conduit at a desired location, including:

a. a flow control assembly adapted to be secured with the well conduit at a desired operating location;

b. a bore closure means operably connected with said flow control assembly for rotational movement to and from an open position to align a bore closure flow port with the bore of well conduit for enabling flow of fluid through the bore of the well conduit and a closed position for blocking flow of fluid through the bore of the well conduit; and

c. said flow control assembly having means for effecting desired movement of said bore closure means depending upon the initial position of the bore closure means, to either the open or closed positions in response to the urging of a controlled sequence of preselected fluid pressure changes in the bore of the well conduit wherein the well tool is operated.

29. The invention as set forth in claim **28,** wherein said flow control assembly is movable through the bore of the well conduit to the desired location and includes:

a. a support member mounting a means for releasably securing said support member in the desired location in the bore of the well conduit; and

b. an operator mechanism movably mounted with said support member and operably engaged with said bore closure means to effect desired movement thereof to and from the open and closed positions in response to the urging of the controlled sequence of preselected pressure changes.

30. A well tool for selectively shutting in the bore of a well conduit at a subsurface location in a well from the surface, including:

a. a tubular flow control assembly adapted to be mounted with the well conduit at a subsurface operating location in a well and having a longitudinal flow passage formed therethrough communicating the bore of the well conduit above and below said flow control assembly;

b. a bore closure means mounted with said tubular flow control assembly for pivotal movement traverse to said longitudinal flow passage to and from an open position enabling flow of fluid through said longitudinal flow passage and a closed position for blocking flow of fluid through said longitudinal flow passage; and

c. said flow control assembly having means for effecting desired movement of said bore closure means, depending upon the initial position of the bore closure means, to either the open or closed positions in response to the urging of a surface controlled sequence of preselected fluid pressure changes in the bore of the well conduit wherein the well tool is operated.

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