United States Patent [19]

Mott

[11] **3,901,321**

[45] **Aug. 26, 1975**

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

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[73] Assignee: **Hydril Company**

[22] Filed: **Dec. 26, 1973**

[21] Appl. No.: **427,978**

[52] **U.S. Cl.** ..... **166/314;** 137/629; 166/224 A; 251/160

[51] **Int. Cl.²** **E21B 43/12**

[58] **Field of Search** ..... 166/224 A, 314; 137/629; 251/160, 188, 159, 174, 351

[56] **References Cited**

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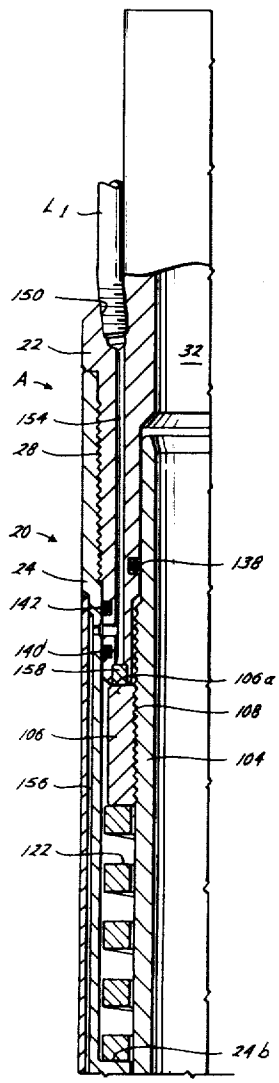
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Primary Examiner—James A. Leppink
Attorney, Agent, or Firm—Pravel & Wilson

[57] **ABSTRACT**

A remote controlled safety valve adapted for use in a well to shut-in production flow at a subsurface location. The valve operates by rotating a ball-type closure element after spacing the element from a pair of valve seats and then resealing the seats with the element after rotation is complete.

76 Claims, 24 Drawing Figures



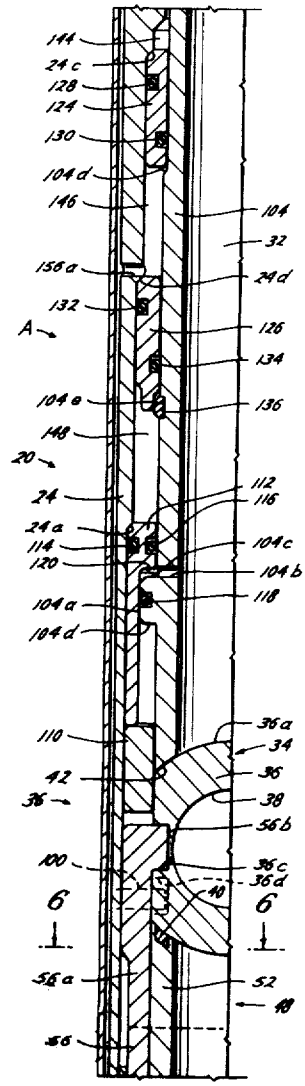


Fig. 1A

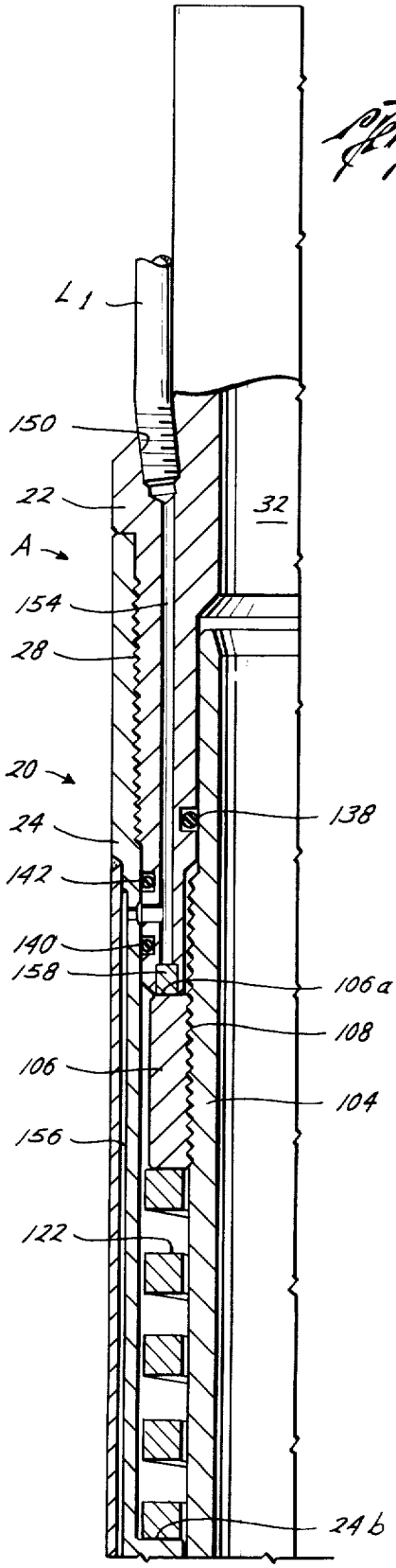
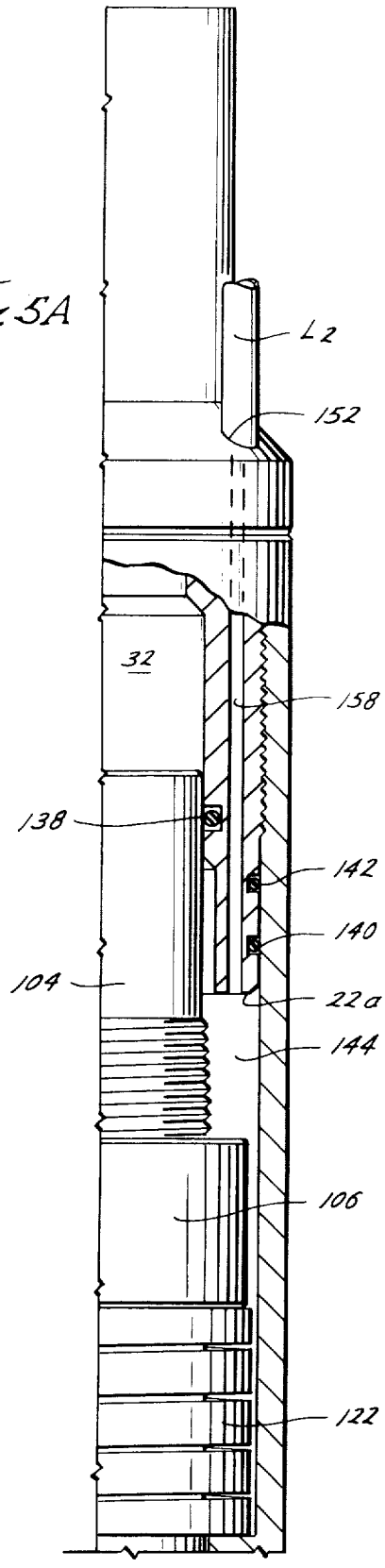

L1
150
22
32
A
154
28
20
24
138
142
140
158
106a
108
106
104
156
122
24b

Fig. 5A


L2
152
32
158
138
142
140
104
22a
144
106
122

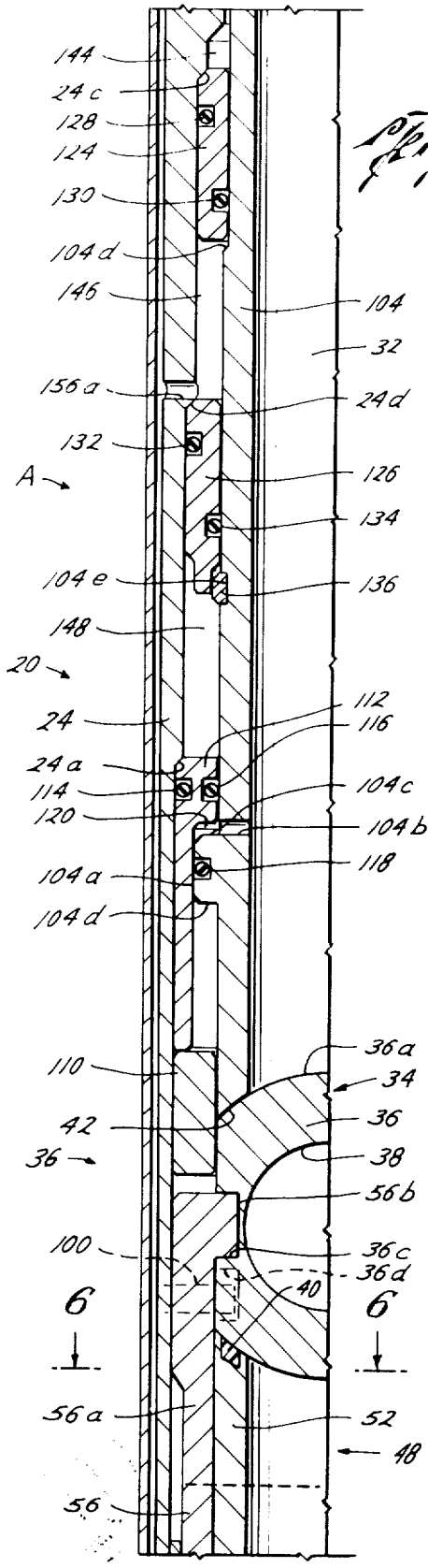
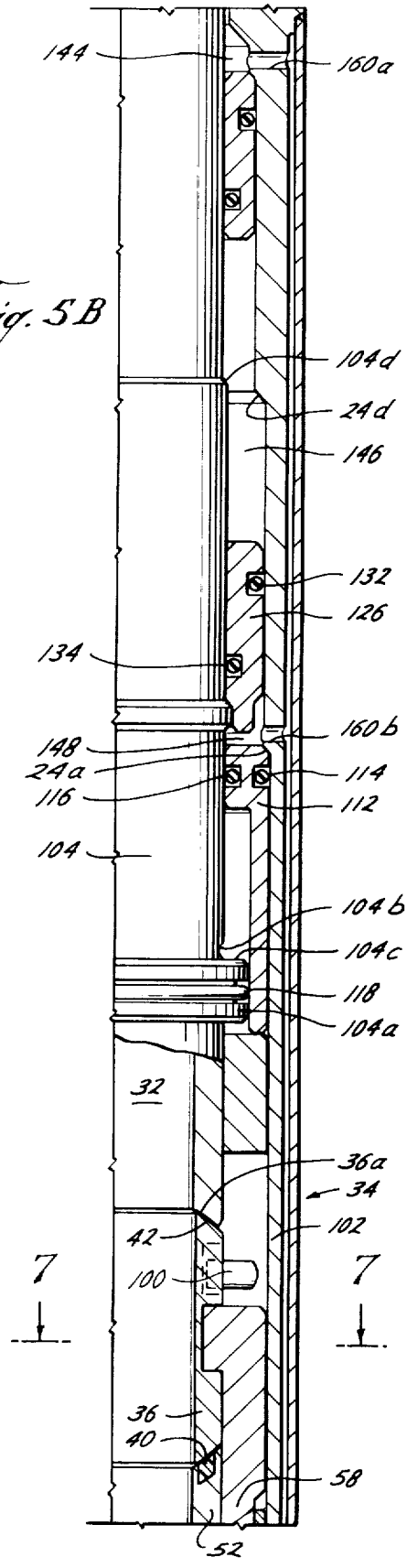

144
24c
128
124
130
104d
146
104
32
156a
24d
132
126
A
134
104e
136
148
20
112
24
116
24a
104c
114
120
104b
104a
118
104d
110
36a
34
42
36
36
38
56b
100
36c
36d
40
6
6
56a
52
48
56

Fig. 1B

Fig. 5B


144
160a
104d
24d
146
132
126
134
160b
148
24a
114
116
112
104
104b
104c
118
104a
32
36a
34
42
102
7
100
7
36
40
58
52

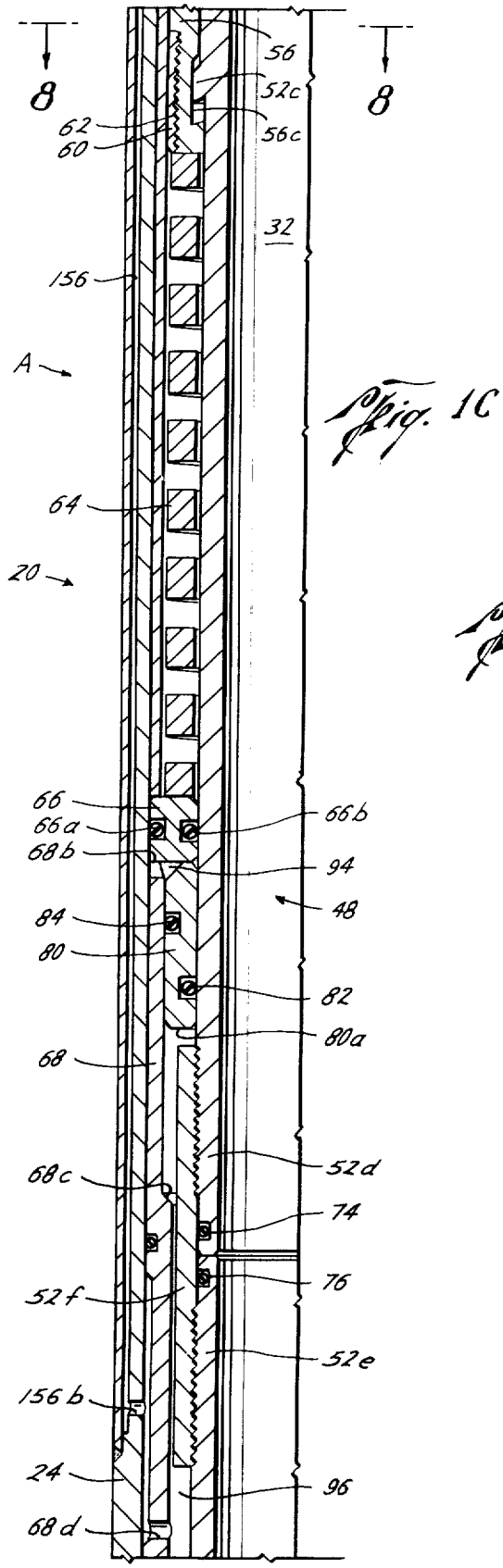

8
8
56
52c
56c
62
60
32
156
A
64
20
66
66a
68b
66b
94
48
84
80
82
80a
68
52d
68c
74
76
52f
52e
156b
24
96
68d

Fig. 1C

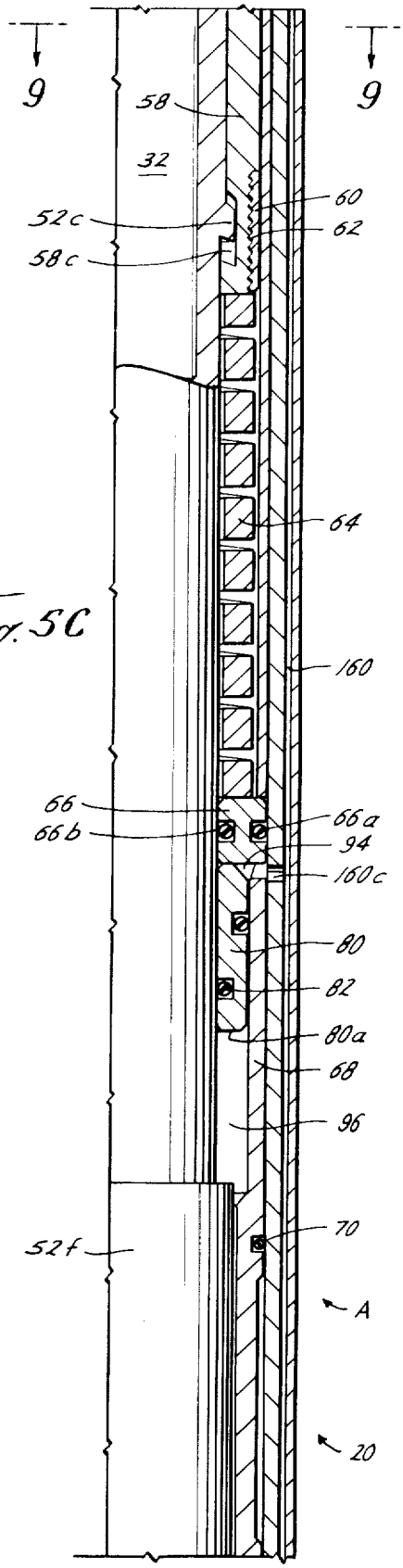

9
9
58
32
60
52c
62
58c
64
160
66
66a
66b
94
160c
80
82
80a
68
96
52f
70
A
20

Fig. 5C

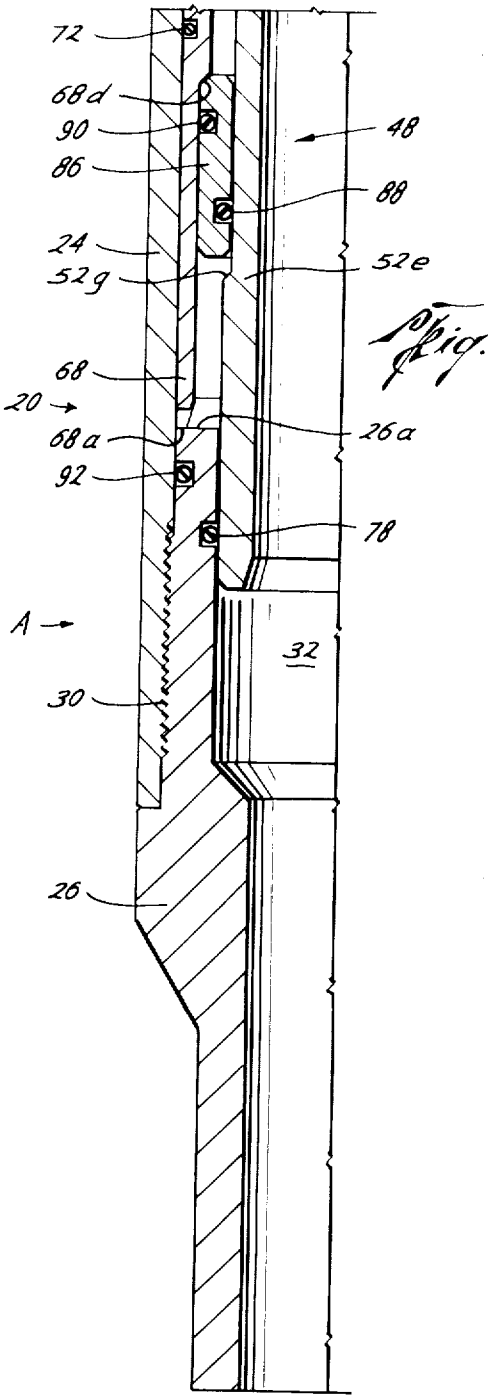

72
68d
90
86
24
52g
68
20
68a
92
A
30
26
48
88
52e
26a
78
32

Fig. 1D

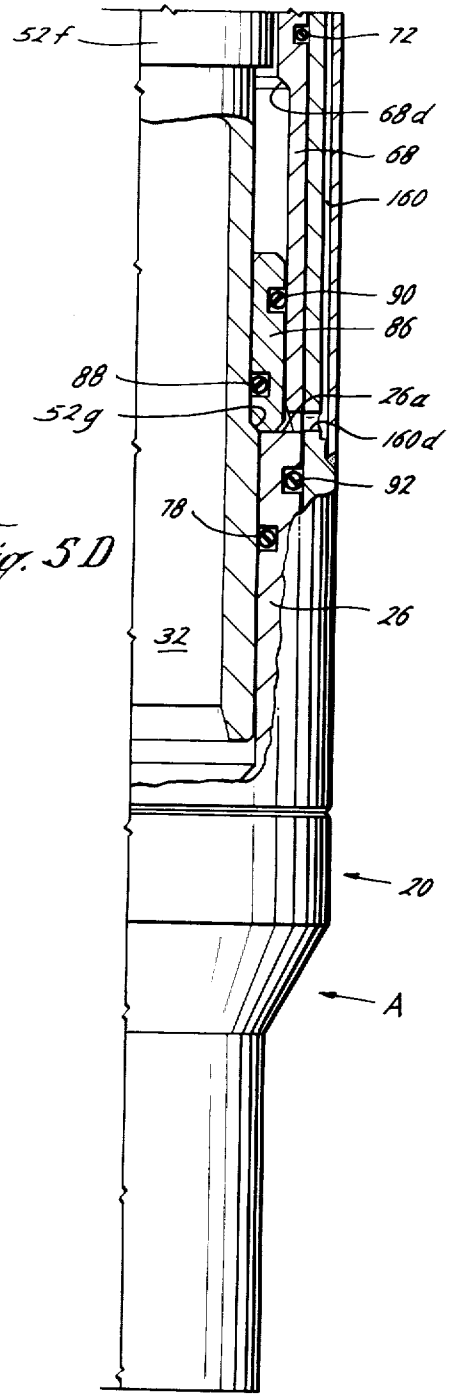

52f
72
68d
68
160
90
86
88
52g
26a
160d
92
78
26
32
20
A

Fig. 5D

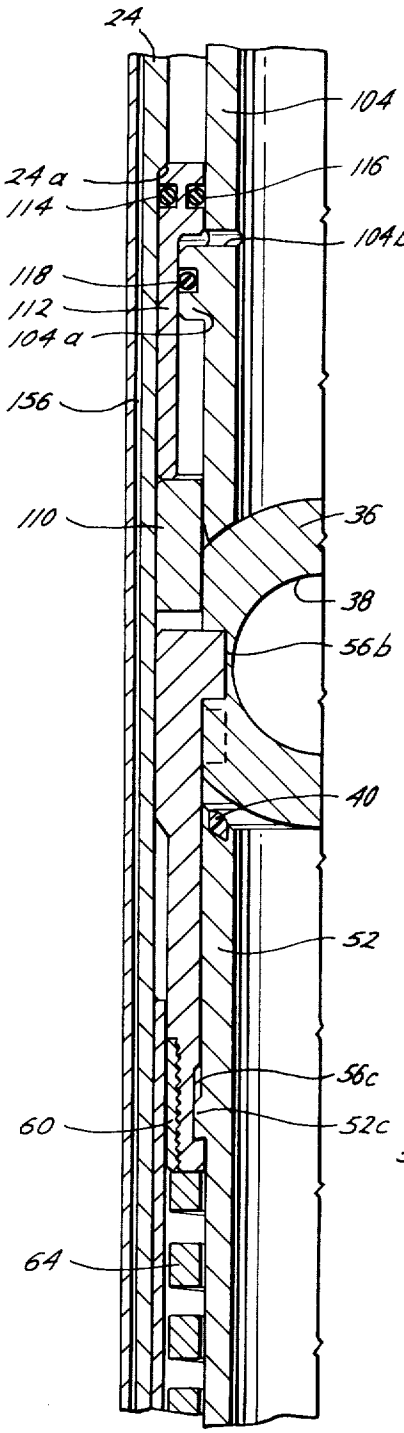


Fig. 2

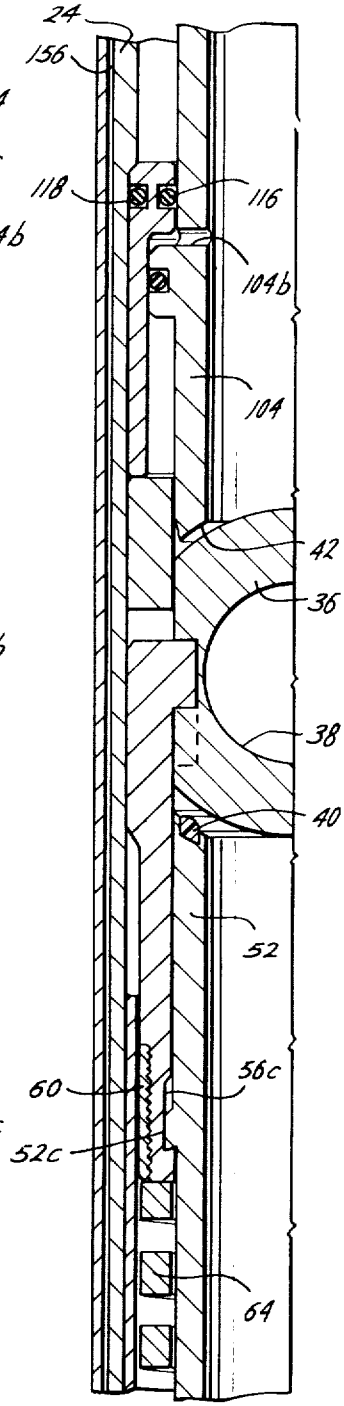


Fig. 3

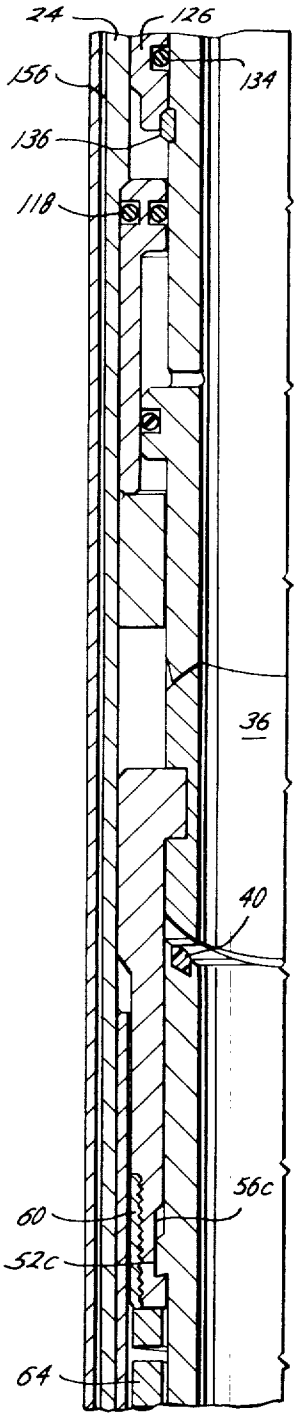


Fig. 4

Fig. 6

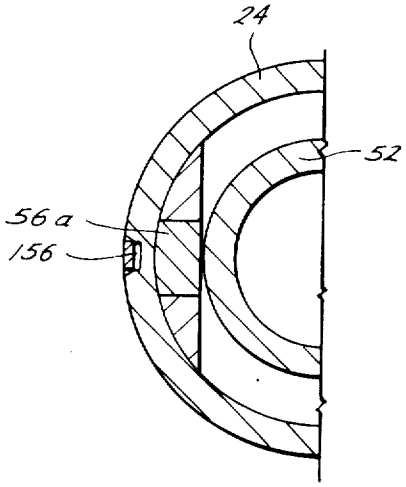


Fig. 7

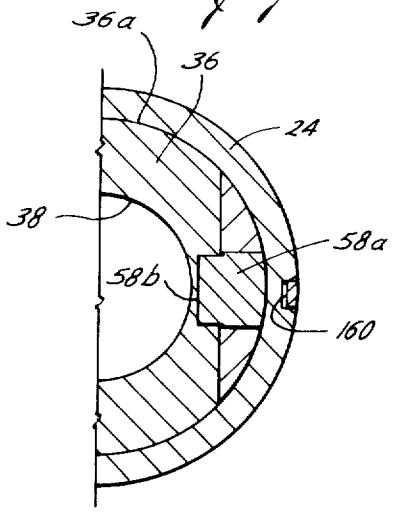


Fig. 8

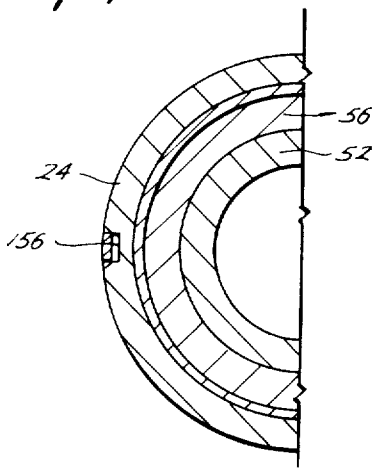


Fig. 9

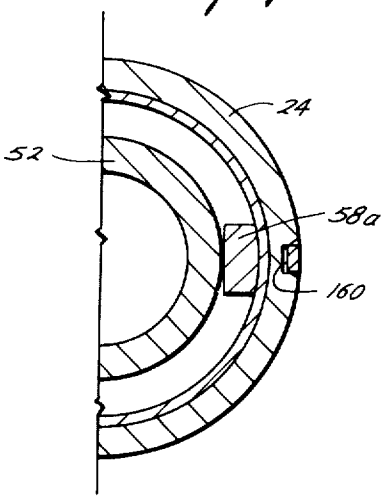


Fig. 10

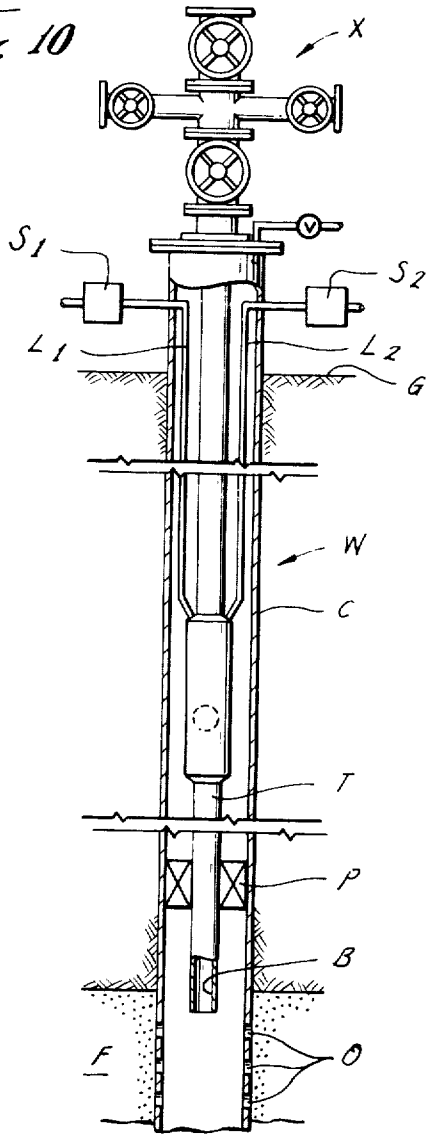
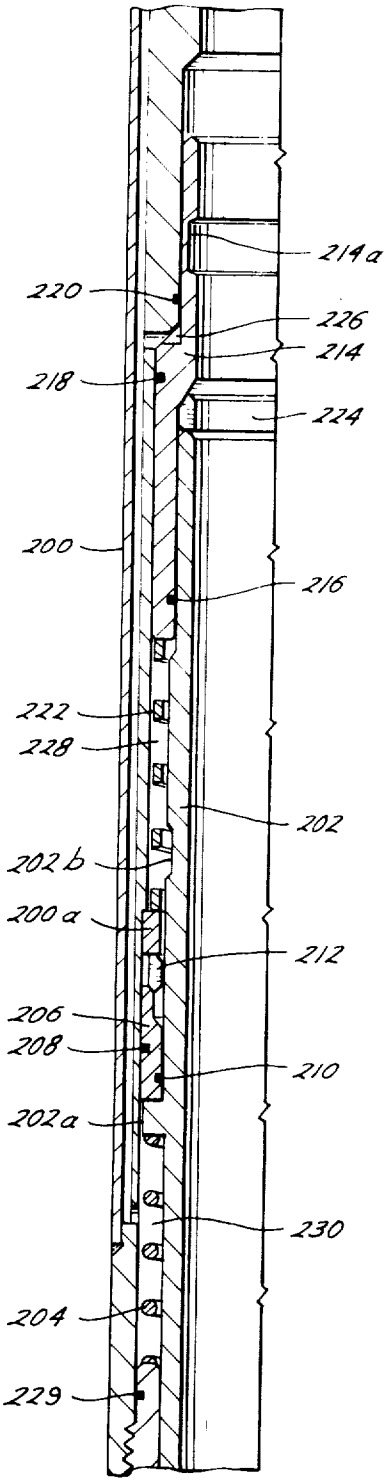


Fig. 11



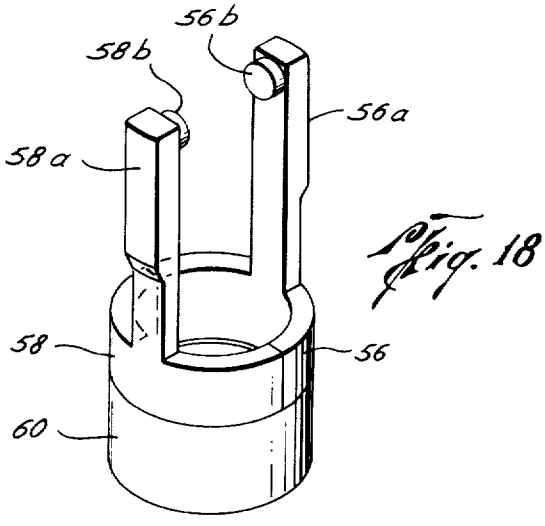


Fig. 18

Fig. 12

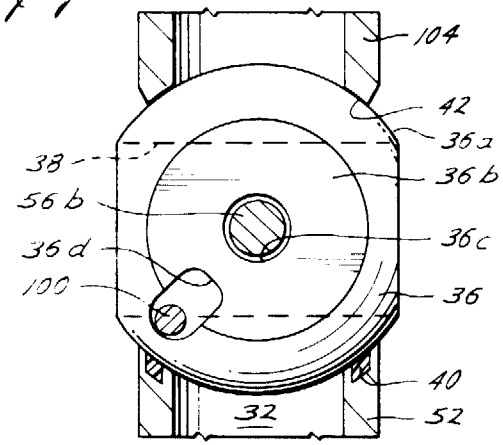


Fig. 13

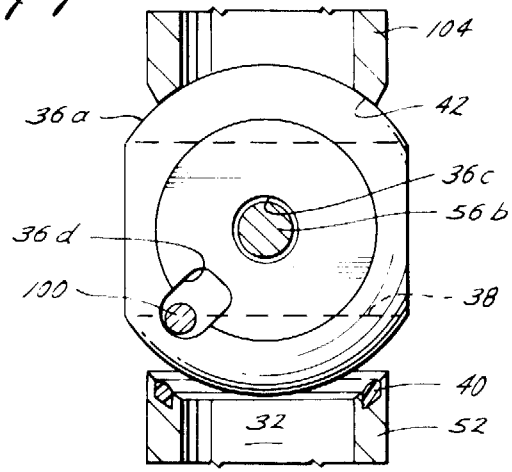
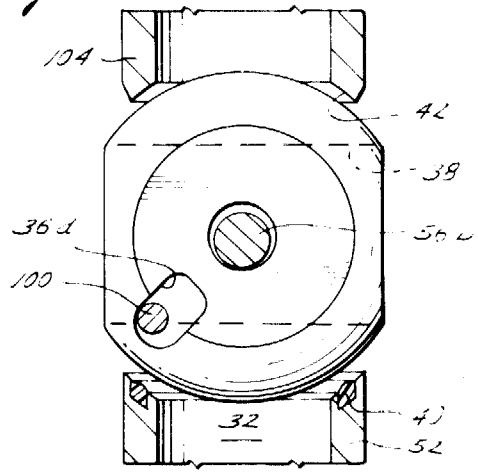


Fig. 14



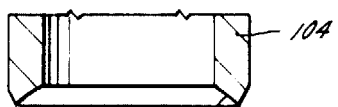


Fig. 15

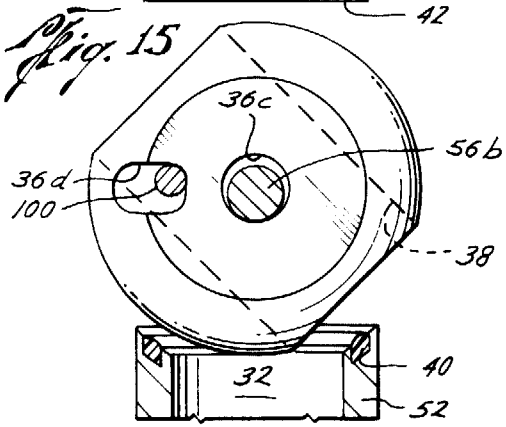


Fig. 16

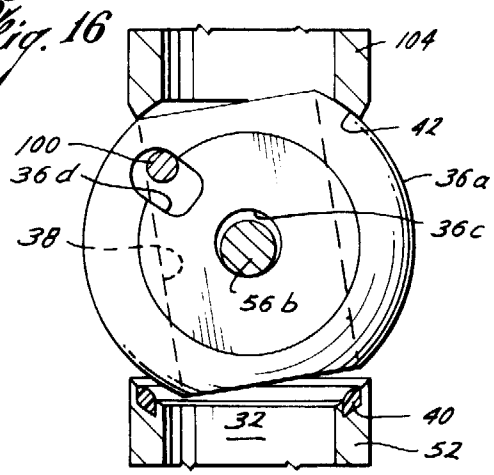
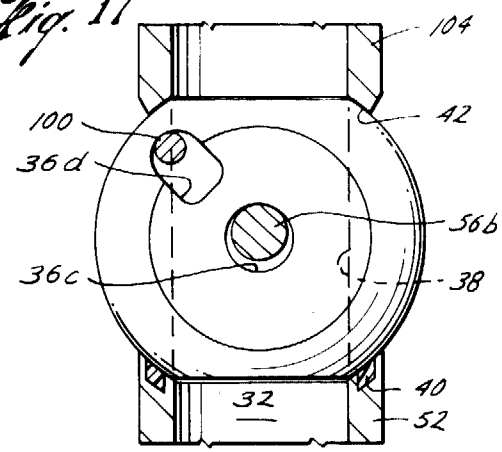


Fig. 17



SAFETY VALVE METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

This invention relates broadly to the field of a safety valve method and apparatus and particularly to remote controlled subsurface safety valves for wells.

Many prior art patents, such as U.S. Pat. Nos. Re. 25,109; 2,785,755; 2,786,535; and Re. 25,471 have disclosed remote controlled subsurface safety valves having pivoted or rotating flow closure elements for shutting in a well at a subsurface locations. Due to their subsurface location the cost to repair or replace this type of valve have been substantial, since the valve maintenance operation required that the well be killed and the tubing removed from the well to gain access to a defective or malfunctioning valve.

In some prior ball-type safety valve patents, such as U.S. Pat. Nos. 2,998,077; 3,035,808; and 3,750,751, an operator sleeve was urged to move downwardly while sealably engaging the ball for moving the ball open. During opening rotation of the ball, large forces were required to overcome sealing or other contact surface friction and to overcome the pressure differential across the ball. Such large forces tended to decrease the reliability of the valve since frequent damage to the seats and ball resulted from the high stresses incurred during valve operation.

Several methods have been tried to increase the reliability of ball valves. In U.S. Pat. Nos. 2,894,715 and 3,509,913 a spring housing arrangement was disclosed for maintaining the seats in sealing engagement with a lesser force than required to operate the ball. U.S. Pat. Nos. 3,200,837 and 3,233,860 disclosed a ball valve improvement of an annular sleeve surrounding the ball for effecting unitary longitudinal movement of the lower and upper operator and thereby reducing the forces on the ball. Another approach has been to employ an equalizing valve feature for equalizing the well pressure across the ball prior to moving the ball downwardly for effecting opening rotation. Examples of such equalizing valves include U.S. Pat. Nos. 3,703,193 and 3,583,442 and my U.S. Pat. No. 3,762,471 which also includes a lost motion linkage for reducing the force required to rotate the ball open. Another approach has been to employ two spaced ball elements operated by a single control line such as disclosed in U.S. Pat. No. Re. 27,464.

Still another method has been to employ wire-line retrievable or through the bore movable valves, such as those disclosed in U.S. Pat. Nos. 3,675,720; 3,747,682 and 3,763,933. Other prior art patents, for example, U.S. Pat. Nos. 3,696,868; 3,763,932 and 3,744,564 have disclosed the use of a wire-line retrievable valve in combination with and operated by the controls of the tubing retrievable valve.

Recent literature setting forth the state of the art includes an article by G. M. Raulins entitled "Platform Safety by Downhole Well Control", which appeared in the March 1972 issue of *Journal of Petroleum Technology*, published by Society of Petroleum Engineers, Dallas, Texas and the June 5, 1972 and June 12, issues of *Oil and Gas Journal*, published by the Petroleum Publishing Co., Tulsa, Oklahoma, which in a two part article entitled "New Surface-Controlled Downhole Valves" by W. B. Bleakley considers features of valves available from six manufacturers. More detailed description of the valves considered in the latter mentioned article may be found in the current *Composite Catalogue of Oil Field Equipment and Services*, published by World Oil, Houston, Texas.

In U.S. Pat. No. 3,741,249 the use of a resilient or soft annular seat or seal member in a ball-type valve is disclosed, but an operator sleeve is employed to move toward the ball for engaging the ball to effect its downward movement with the undesired large forces being induced in the ball. Previously mentioned Pat. Nos. 2,894,715 and 3,744,564 as well as U.S. Pat. No. 3,347,318 disclose ball valves in which the operator sleeves move in a manner to avoid inducing high stress levels in the ball, but the valve seats are not spaced from the ball prior to rotating. Other patents of interest with respect to this type of valve operation include U.S. Pat. Nos. 3,414,059; 2,883,146; 3,695,579 and 3,703,193.

SUMMARY OF THE INVENTION

This invention relates to a new and improved safety valve method and apparatus.

A remote controlled subsurface safety valve apparatus adapted for controlling flow in a well with a rotating closure element disposed between movable seal members. prior to rotating the closure element open the seals are spaced from the element to equalize fluid pressure about the closure element. Opening rotation is effected by an operator, connected with the closure element, moving longitudinally away from the closure element. The seal members move to again sealably engage with the closure element in the open position.

An object of the present invention is to provide a new and improved safety valve apparatus.

A further object of the present invention is to provide a new and improved method of operating a safety valve.

Yet another of the present invention is to provide a new and improved well safety valve method and apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A**, **1B**, **1C** and **1D** are side views, in section, of half of the well tool of the present invention and arranged in alphabetical sequence from top to bottom;

FIGS. **2**, **3** and **4** are views similar to FIG. **1B** illustrating the rotation of a ball-type flow closure element;

FIGS. **5A**, **5B**, **5C** and **5D** are views similar to FIGS. **1A**, **1B**, **1C** and **1D**, respectively, illustrating the well tool of the present invention in the open position;

FIG. **6** is a view taken along line **6—6** of FIG. **1B**;

FIG. **7** is a view taken azlong line **7—7** of FIG. **5B**;

FIG. **8** is a view taken along lihne **8—8** of FIG. **1D**;

FIG. **9** is a view taken along line **9—9** of FIG. **5C**;

FIG. **10** is side view, in section, of a well having the well tool of the present invention operably located therein;

FIG. **11** is a schematic view, in section, of an alternate embodiment of a partial arrangement of the control system for operating the well tool of the present invention; and

FIGS. **12–17** are sequential side views in numerical order illustrating in detail the operating step relationship of the ball seats and pivot pins during opening rotation of the ball; and

FIG. **18** is a perspective view of the assembled connector alone.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As illustrated in FIG. **10**, a safety valve apparatus A of the present invention is preferably mounted in a well conduit or production tubing T at a subsurface location in a well W for controlling flow of well fluids through a bore B of the production tubing T. While the valve apparatus A is disclosed in the environment of a subsurface application in a well, it should be understood that the valve apparatus A may be used to control flow of fluids in other applications and environments.

Referring now to FIGS. 1A through 1D, the valve apparatus A includes a tubular flow control housing **20** which is adapted to be mounted with the production tubing T at a desired subsurface location in the well W. Suitable connections (not illustrated) may be provided at the upper end of the housing **20** (FIG. 1A) and the lower end of the housing (FIG. 1D) for mounting or connecting the housing **20** with the production tubing T as is well known in the art.

The housing **20**, for ease of assembly is preferably formed by three tubular members **22**, **24**, and **26** secured together by suitable means to form an integral unit. The upper housing sleeve or tubular member **22** is connected with the intermediate tubular member or housing sleeve **24** by threaded engagement at **28** (FIG. 1A) while the lower end of the intermediate housing sleeve **24** is connected with the lower housing sleeve or tubular member **26** by threaded engagement at **30** (FIG. 1D). Suitable anti-rotation pins (not illustrated) may be utilized to prevent undesired threaded disengagement at **28** and **30** as is well known in the art. For ease of understanding the present invention FIGS. 1A and 5A have been illustrated on the same drawing sheet with the stationary parts of the valve apparatus in alignment to aid in visualizing movement of the movable parts during operation of the valve apparatus A as will be set forth in greater detail hereinafter.

The flow housing **20** includes a flow passage for bore **32** formed therethrough which communicates with the bore B of the production tubing T above and below the housing **20** for enabling flow of well fluids through the housing **20**. Preferably, the bore **32** is of the same size as the bore B of the production tubing T to provide a full bore opening through the housing **20** to enable movement of other well tools through the housing **20** to enable well operations to be performed below the housing **20**.

As illustrated in FIGS. 1B and 5B, a movable bore or flow closure means **34** which is movable to and from a closed position (FIG. 1B) for blocking flow of fluid through the bore **32** and the production tubing T and an open position (FIG. 5B) for enabling flow of fluid through the bore **32** in the production tubing T. In the illustrated embodiment, the bore closure means **34** includes a rotatable ball-type valve member or element **36** having a flow passage **38** formed therethrough. The ball element **36** rotates or pivots to and from the open position placing the flow passage **38** in communication or alignment with the bore **32** to enable flow through the flow passage **38** and the closed position where the flow passage **38** is placed out of communication or alignment with the bore **32** for substantially blocking flow through the bore **32** with the ball element **36**. While the preferred embodiment of the present invention is disclosed using a ball-type valve, it should be readily apparent to those skilled in the art that the present invention is equally applicable to other types of rotating or pivoting closure members, such as, but not limited to, flapper-type valves and plug-type valves.

The bore closure means **34** includes a lower resilient annular valve seat **40** sealably engaging a spherical surface **36***a* of the ball **36** to block passsage or leakage of fluid therebetween. The bore closure means **34** also includes a second or upper annular seat ring **42** which sealably engages the spherical surface **36***a* of the ball **36** at a location spaced from that of the sealable engagement by the lower seat ring **40**. As will be set forth in greater detail hereinafter, the lower seat ring **40** and the upper seat ring **42** cooperate with the ball **36** to block passage of fluid through the bore **32** at two space locations when the ball **36** is in the closed position. The upper seat ring **42** and the lower seat ring **40** also engage the spherical surface **36***a* of the ball **36** in the open position to block entry of foreign material between the seat **40** and **42** in the ball **36** which may damage the sealing surfaces and enable leakage of fluid when the ball **36** is in the closed position.

The valve apparatus A includes operator means, generally designated **44**, for effecting desired movement of the bore closure means **34** to and from the open and closed position. As illustrated in FIG. 1B and 5B, the operator means **44** includes means for pivoting or rotating the ball **36** to and from the open and closed positions. The ball **36** is formed with a pair of spaced parallel surfaces or flats **36***b*, which is best illustrated in FIG. **7**, to provide clearance between the ball **36** and the housing sleeve **24** adjacent the ball **36**.

The operator means **44** further includes a lower operator assembly, designated **48** (FIGS. 1B, 1C and 1D) and an upper operator assembly, designated **50** (FIGS. 1A and 1B) which coact with the ball **36** and the pivot means **46** for effecting the desired rotation of the ball **36** in a manner to be set forth in greater detail hereinafter.

The first or lower operating assembly **48** includes a lower operator sleeve or member **52** concentrically disposed in the bore **32** and which extends upwardly from a lower downwardly facing annular shoulder (FIG. 1D) to an upwardly facing annular shoulder **52***b* (FIG. 1B) mounting the lower resilient seal ring **40** for sealable engagement with the ball **36**. The lower operator sleeve **52** is movable in opposite longitudinal directions in the bore **32** from a first or upper position (FIGS. 1B, 1C, and 1D) to a second or lower position (FIGS. 5B, 5C, and 5D) for effecting desired operation of the valve apparatus A.

The lower operator assembly **48** includes a connector, generally designated **54**, for operably connecting the lower operating sleeve **52** with the ball **36** to effect rotation of the ball **36** upon longitudinal movement of the lower operating sleeve **48**. For ease of assembly, the connector or control frame **54** is formed of two mating half sleeve members **56** and **58** which are held in concentric relationship by a securing ring **60** which threadedly engages the lower portion of the half sleeves **56** and **58** at **62** for maintaining the half sleeves **56** and **58** in the desired relationship. As best illustrated in FIG. **18**, each of the half sleeves **56** and **58** includes an upwardly extending portion or arm **56***a* and **58***a*, respectively. Each of the upwardly extending arms **56***a* and **58***a* have an inwardly projecting pin or lug formed

thereon with the longitudinal axis of the pins **56***a* and **58***a* in alignment.

Each of the flats **36***b* of the ball **36** have a concentric recess **36***c* formed therein for receiving the pins **56***b* and **58***b* on opposite sides of the ball **36** for connecting the ball **36** with the connector **54.** In the preferred embodiment the ball connector pins **56***b* and **58***b* are alinged to engage the ball **36** in concentric relationship, but as will become more readily apparent hereinafter to those skilled in the art the pins **56***b* and **58***b* could be arranged to engage or connect with the ball at alinged eccentric locations.

As best illustrated in FIGS. **1C** and **5C**, each of the half sleeves **56** and **58** has an inner annular recess **56***c* and **58***c*, respectively, located adjacent the threaded engagement at **62** with the securing ring **60.** The recesses **56***c* and **58***c* cooperate to form an annular recess for receiving therein after an annular ring **52***c* formed on the lower operator sleeve **52.** The ring **52***c* is dimensioned to enable limited longitudinal movement of the lower operator sleeve **52** relative to the connector **54** for purposes that will be set forth in greater detail hereinafter.

The lower operating assembly **48** further includes a spring **64** or other means for urging the lower operating sleeve **52** and the connector **54** to move upwardly. The spring **64** is concentrically disposed between the lower operating sleeve **52** and the hosuing **20** below the connector **54.** The spring **64** is mounted at its lower end with a sealing member or ring **66** which serves to block leakage of fluid between the housing sleeve **24** and the movable operator sleeve **52** with O-rings **66***a* and **66***b*, respectively, carried by the seal ring **66.** The ring **66** is blocked from downward movement by a support member or sleeve **68** concentrically positioned between the lower operator sleeve **52** and the intermediate housing sleeve **24.** The lower housing sleeve **26** provides an upwardly facing annular shoulder **26***a* which engage the lower annular shoulder **68***a* to block downward movement of the support sleeve **68** and to support the ring **66** against downward movement. The urging of the spring **64** between the ring **66** and the connector **54** maintains the ring **66** adjacent an upper annular shoulder **68***b* of the support sleeve **68.** Both the upper shoulder **68***b* and the lower shoulder **68***a* have notches or recesses formed therein for enabling passage of fluids between the seal rings **66** and the sleeve **68** in the lower housing sleeve **26** for pusposes to be set forth hereinafter. The support sleeve **68** carries spaced O-rings **70** and **72** for effecting annular fluid type seals with the tubular member **24** to block leakage of fluid therebetween at those fixed locations.

For ease of assembly, the lower operator sleeve **52** may be formed of an upper tubular section **52***d* carrying the annular ring **52***c* and a lower tubular section which are secured together by each section threadedly engaging coupling **52***f*. The tubular sections **52***d* and **52***e* mount O-rings **74** and **76** for sealably engaging with the coupling **52***f* to block leakage of fluid along the threaded engagement. The lower tubular section **52***e* includes a larger diameter outer portion adjacent the housing sleeve **26** for effecting a fluid type seal with an O-ring **78** carried by the lower housing **26.** The enlarged portion provides a tapered upwardly facing annular shoulder **52***g* for purpose to be set forth in greater detail hereinafter.

Movably disposed in concentric relationship between the support sleeve **68** and the lower operator sleeve **52** is an upper or first piston ring **80.** The piston ring **80** (FIG. **1C**) is disposed below the sealing ring **66** which limits longitudinal upward movement of the upper piston ring **80** and the coupling **52***f* of the lower operator sleeve **52.** Downward movement of the upper piston ring will bring a lower annular shoulder **80***a* of the upper piston ring **80** into engagement with the coupling **52***f* for moving the coupling **52***f* and the lower operator sleeve **52** downwardly until the piston **80** engages an upwardly facing annular shoulder **68***c* formed by the support sleeve **68.** The upper piston ring **80** carries O-rings **82** and **84** for effecting sliding annular fluid seals with the lower operator sleeve **52** and the support sleeve **68** to prevent leakage of fluid about the longitudinally movable upper piston ring **80.**

As illustrated in FIG. **1D** a second or lower piston ring **86** is concentrically disposed between the lower operator sleeve **52** and the support sleeve **68** above the annular shoulder **52***e* of the lower operator sleeve **52.** The lower piston ring **86** carries O-rings **88** and **90** for effecting sliding fluid tight annular seals with the lower operator sleeve **52** and the support sleeve **68** to block leakage of fluid about the lower piston ring **86.** The lower piston ring **86** is longitudinally movable from an upper position (FIG. **1D**) where it engages a downwardly facing annular shoulder **68***d* formed by the support sleeve **68** to limit upward movement of the piston ring **80** to a lower position (FIG. **5D**) where the lower piston ring **80** engages the shoulder **26***a* of the lower housing sleeve **26** to limit downward movement of the lower piston ring **80.** In moving to the lower position the piston ring **80** engages the annular shoulder **52***g* of the lower operator sleeve **52** for effecting movement of the lower operator sleeve to its lower position. The lower housing sleeve **22** carries an O-ring **92** for blocking leakage of fluid along threaded engagement **30** with the intermediate housing sleeve **24.**

The seals effected by the O-rings **70, 66***a*, **66***b*, **82** and **84** thus defined an upper expansible chamber **94** above the piston ring **80.** The seals effected the the O-rings **70, 84, 82, 74, 76,** and O-rings **88** and **90** carried by the lower piston ring **86** thus defined an intermediate expansible chamber **96** between the upper piston ring **80** and the lower piston ring **86.** The seals effected by the O-rings **78, 88, 90** and **92** define a lower expansible chamber **98** below the lower piston ring **86.** Increased fluid pressure introduced into the upper expansible chamber **94** will effect movement of the upper piston ring **80** downwardly for engaging the coupling **52***f* and moving the lower operator sleeve **52** to the lower position. Increased fluid pressure introduced into the intermediate expansible chamber **96** will move the upper piston ring **80** upwardly to engage the stationary sealing ring **66** for maintaining the upper piston ring **80** in the upper position and for urging the lower piston ring **86** to move downwardly for engaging the shoulder **52***g* to move the lower operator sleeve **52** to the lower position. Thus increased fluid pressure in either the upper expansible chamber **94** or the intermediate expansible chamber **96** will effect movement of the lower operator sleeve **52** to the lower position. Increased fluid pressure in the lower expansible chamber **98** will effect movement of the lower piston ring **86** to the upper position, but will not resist downward movement of the lower

operator sleeve **52** in response to increased fluid pressure in the upper expansible chamber **94.**

The pivot means **46** includes a pair of longitudinally aligned pins **100** and **102** which are eccentrically mounted with the housing **20** and extend inwardly for engaging parallel extending recesses or slots **36***d* formed on the flats **36***b* of the ball **36.** The longitudinally downward movement of the ball **36** and lower operator assembly **48** relative to the eccentric pins **100** and **102** pivot or rotate the ball **36** from the closed position to the open positon as is best illustrated by comparing FIGS. **1B** and **5B.** The pins **100** and **102** extend inwardly adjacent the upwardly extending arms **56***a* and **58***a* to provide the necessary clearance to enable the longitudinal movement of the connector **54.**

As illustrated in FIG. **1A** and **1B,** the upper operator assembly **50** includes an upper operator sleeve **104** which is concentrically disposed in the bore **32** above the ball. The upper operator sleeve either carries or forms the upper annular sealing surface **42** for sealably engaging with the ball **36** and is longitudinally movable between a first or upper position (FIGS. **1A** and **1B**) and a lower or second position (FIGS. **5A** and **5B**) for cooperating with the longitudinal movement of the lower operator assembly **48** for effecting movement of the ball **36** to and from the open and closed positions. Concentrically disposed between the intermediate housing sleeve **24** and the upper operator sleeve **24** is a ring member **106** which is secured with the upper operator sleeve **104** by any suitable means, such as by threaded engagement at **108.** The collar **106** provides an upwardly facing annular shoulder **106***a* which engages a downwardly facing annular shoulder **22***a* provided by the upper housing section **22** to limit upward movement of the upper operator sleeve **104.** Concentrically disposed adjacent the ball **36** is a guide ring **110** which is fixedly secured to the housing **20** by suitable means such as inwardly projecting threaded pins (not illustrated). Also concentrically mounted between the upper operator sleeve **104** and the housing sleeve **24** is a sealing member **112** which is blocked from longitudinal movement by engagement with the guide ring **110** at its lower end and by engagement with a downwardly facing annular shoulder **24***a* formed by the intermediate housing sleeve **24.** The seal member **112** carries an O-ring **114** for effecting an annular fluid tight seal with intermediate housing sleeve **24** and a annular sliding seal with the upper operator sleeve **104** to block the passage of fluid about the seal member **112.** The upper operator sleeve **104** includes a collar **104***a* formed thereon adjacent the seal member **112** which carries an O-ring **118** for effecting a sliding annular seal with the lower portion of the seal member **112.** LOcated immediately above the collar **104***a* is a port **104***b* formed through the upper operator sleeve **104** for communicating fluid pressure in the bore **32** above the ball **36** to an upwardly facing annular shoulder **104***b* formed by the collar **104***a* of the upper operator sleeve **104.** The seals effected by the O-rings **114, 116** and **118** thus defined an annular expansible chamber **120** which communicates through the port **104***b* with the bore **32.** Fluid pressure in the seal expansible chamber **120** urges on an upwardly facing annular shoulder **104***c* formed by the collar **104***a* between the seals effected by the O-rings **116** and **118** for providing a downwardly urging on the upper operator sleeve **104** for purpose to be set forth hereinafter. By controlling the area of the shoulders **104***c* and **104***d* between the O-rings **116** and **118** the magnitude of downwardly and upwardly urging of fluid pressure on the upper operator sleeve **104** may be controlled.

As illustrated in FIG. **1A,** the upper operator assembly **50** includes a spring **122** below the collar **106** for urging or biasing the collar **106** and the upper operator sleeve **104** to the upper position. The lower end of the spring **122** is mounted with an upwardly facing annular shoulder **24***b* formed by the intermediate housing section **24.**

The upper operator assembly **50** further includes an upper or first piston ring **124** and a second or lower piston ring **126** which are both concentrically located between the upper operator sleeve **104** and the intermediate housing sleeve **24.** The upper piston ring **124** is longitudinally movable between an upper position (FIG. **1B**) where it engages downwardly facing annular shoulder **24***c* formed by the intermediate housing sleeve **24.** In moving to the lower position, the piston ring **124** engages an upwardly facing annular shoulder **104***d* of the upper operator sleeve **104** for moving the operator sleeve **104** to the lower position. The upper piston ring **124** mounts a pair of O-rings **128** and **130** for effecting annular slidable seals with the intermediate housing section **24** and the upper operator sleeve **104,** respectively.

The lower piston ring **126** carries O-rings **132** and **134** for effecting fluid tight sliding annular seals with the intermediate housing sleeve **24** and the upper operator sleeve **104,** respectively. The lower piston ring **126** is movable longitudinally from an upper position (FIG. **1B**) where it is blocked or stopped from further upward movement by engagement with downwardly facing annular shoulder **24***d.* In moving to the lower position the lower piston ring **126** engages a detent ring **136** which is secured in an annular recess **104***e* formed on the upper operator sleeve **104** for moving the upper operator sleeve **104** to the lower position along with the lower piston ring **126.**

The upper housing sleeve **22** carries an O-ring **138** for effecting a fluid tight annular seal with the upper operator sleeve **104** above the collar **106.** The upper housing sleeve **22** also carries O-rings **140** and **142** for blocking leakage or fluid between the upper housing sleeve **22** and the intermediate housing sleeve at spaced locations as will be set forth in greater detail hereinafter.

The upper piston ring **124** and the lower piston ring **126** cooperate to form an upper expansible chamber **144,** an intermediate expansible chamber **146** and a lower expansible chamber **148** for the operator means **44** in a manner similar to that formed by the piston rings **80** and **86** below the ball **36.** The upper expansible chamber **144** is defined by the seals effected by the O-rings **140** and **138** (FIG. **1A**) at its upper end and by the O-rings **128** and **130** mounted with the upper piston ring **124** (FIG. **1B**) at the lower end of the upper expansible chamber **144.** The intermediate expansible chamber is defined by the O-rings **128** and **130** carried by the upper piston ring **124** and the O-rings **132** and **134** carried by the lower piston ring **126.** The lower expansible chamber **148** is defined by the O-rings **132** and **134** mounted with the movable lower piston ring **126** and the O-rings **114** and **116** carried by the sealing member **112.**

Increased fluid pressure in the upper expansible chamber will urge downwardly up on the upper piston **124** for effecting downward movement of the upper operator sleeve **104**. Increased fluid pressure in the intermediate expansible chamber **146** will maintain the upper piston ring **124** in the upper position and will effect downward movement of the upper operator sleeve **104** by moving the lower piston ring **126** to the lower position (FIG. 5B). Increased fluid pressure in the lower expansible chamber **148** will maintain the lower piston ring **126** in the upper position, but will not oppose movement of the upper operator sleeve **104** to the lower position in response to increased fluid pressure in the upper expansible chamber **144**.

The operator means **44** further includes means for communicating control fluid pressure to the expansible chambers **94, 96, 98, 144, 146** and **148** in a desired pattern or manner. As illustrated in FIG. 1A and 5B, controlled fluid pressure is preferably supplied to the housing **20** at a pair of spaced inlet ports **150** and **152** formed in the upper housing sleeve **22**. The inlet port **150** preferably communicates with both intermediate expansible chambers **146** and **96** for urging both the upper operator assembly **50** and the lower operator assembly **48** to the lower position and effecting opening rotation of the ball **36**. Referring now to FIG. 1A, the inlet port **150** communicates with the passageway **154** formed in the upper housing section which in turn communicates between spaced O-rings **140** and **142** with a passageway **156** in the intermediate housing section **24**. A plug **158** blocks communication of the fluid pressure in the passage with **154** into the upper expansible chamber **144**. The expansible chamber **146** communicates with the passageway **156** through a port **156***a* (FIG. 1B) while the lower intermediate expansible chamber **96** communicates with the passageway **156** through a lower port **156***b* and a port **68***d* formed through the support sleeve **68** which is in spaced relationship ith the intermediate housing sleeve **24** between the ports **156***b* and **68***d*.

The inlet port **152** formed in the upper housing sleeve **22** communicates directly with the upper expansible chamber **144** through passageway **158** formed therethrough. The intermediate housing sleeve **24** forms a second passageway **160** (FIG. 5B) which communicates with the upper expansible chamber **144** through port **160***a*. The passageway **160** in turn communicates with the lower expansible chamber **148** through port **160***b*. The passageway **160** communicates with the upper expansible chamber **94** through a port **160***c* adjacent the sealing ring **66** (FIG. 5C). The lower end of the passageway **160** (FIG. 5D) communicates with the lower expansible chamber **98** through the port **60***d*. The fluid pressure communicated to the port **152** is communicated into both upper expansible chambers **144** and **94** and both lower expansible chambers **148** and **98**. Thus, increased control fluid pressure communicate to the port **52** will also effect downward movement of both the upper operator assembly **50** and the lower operator assembly **48** to the lower position for effecting opening rotation of the ball **36**.

An alternate embodiment of the upper operator assembly **50** is illustrated in FIG. **11**. Such alternate embodiment is substantially similar to that disclosed in U.S. Pat. No. 3,744,564 which issued to me on July 10, **1973** and which is assigned to the Assignee of the present invention and specific reference to the patent is made for the purpose of incorporation herein a more detailed description of the structure and operation of such a safety valve system. As disclosed in that patent, the alternate embodiment illustrated schematically in FIG. **11**, provides the valve apparatus **20** with the capability to lock open the ball **34** when desired. It further gives the valve apparatus A the capability to temporarily constrict the bore for landing a through the bore retrievable valve in the housing and for effecting operation of the retrievable valve with the controls of the tubing retrievable valve.

Referring now to FIG. **11**, the tubular housing is referenced as **200** while the longitudinally movable upper operator sleeve is referenced as **202**. Mounted with the housing **200** is a spring **204** for urging the longitudinally movable operator sleeve **202** to remain in the upper position. Concentrically disposed between the operator sleeve **202** and the housing **200** is a lower piston ring **206** carrying O-rings **208** and **210** for effecting fluid tight annular slidable seals with the housing **200** and the tubular operator **202**. Located immediately above the lower piston **206** is a radially expansible gapped detent locking ring **212**. The upper piston is formed by a sleeve **214** which carries an O-ring **216** to form a sliding fluid type seal with the operator sleeve **202**. The sleeve **214** carries an O-ring **218** for effecting a sliding fluid type annular seal with the housing **200** while the housing **200** carries an O-ring **220** for effecting a fluid type annular sliding seal with the sleeve **214** above the operator sleeve **202**. A second spring **222** urges the sleeve **214** to the upper position. Position between the sleeve **214** and the sleeve **202** is the gapped landing ring **224** which may be radially constricted when desired to form a landing shoulder for the wire-line retrievable valve.

The seals effected by the O-rings **220** and **218** define an upper expansible chamber **226** for urging the upper sleeve **214** downwardly in response to increased control fluid pressure in the chamber **226**. Downward movement of the upper sleeve **214** engages the landing ring **224** and the operator sleeve **202** for also effecting their downward movement in response to increased control fluid pressure in the upper chamber **226**. The O-rings **216** and **218** define the upper portion of an intermediate expansible chamber **228** while the O-rings **208** and **210** mounted with the longitudinally movable piston **206** defines the lower portion of the intermediate expansible chamber **228**. The housing **200** carries an O-ring **229** which along with O-rings **208** and **210** define a lower expansible chamber **230**.

Control fluid pressure communicated into the intermediate annular chamber **228** urges on the lower piston ring **206** urging it to move downwardly and engaging a collar **202***a* formed on the operator sleeve **202** for effecting downward movement of the operator sleeve **202**. The increased control fluid pressure in the intermediate chamber **228** urges upwardly on the upper sleeve **214** for maintaining the sleeve **214** in the upper position. Thus, increased control fluid pressure in either the upper expansible chamber **226** or the intermediate expansible chamber **228** effects downward movement of the operator sleeve **202**.

Increased fluid pressure in the lower expansible chamber **230** will urge the lower piston ring **206** to move upwardly towards the detent **212**. By communicating increased control fluid pressure into the upper expansible chamber **226** and the lower expansible chamber **230** the sleeve **214** will effect downward

movement of the operator sleeve **202** while the lower piston ring **206** is blocked from upward movement by engagement with the detent **212** which in turn engages inwardly projecting annular collar **200***a* of the housing **200.** When the upper sleeve **214** has sufficient downward movement of the operator sleeve **202** to align recess **202***b* with detent **212** the lower piston ring **206** forces the detent **212** into the recess **202***a* and locks or maintains the detent **212** in the recess **202***b*. When the control fluid pressure and the upper expansible chamber **226** and the lower expansible chamber **230** is vented or reduced the spring **204** is unable to move the operator sleeve **202** upwardly because of the engagement of the detent **212** with the collar **200***a*, but the spring **222** is able to move the upper sleeve **214** to the upper position. In this manner the upper operator sleeve **202** may be locked in the lower position to lock the valve in the open position. To release the operator sleeve **202** from the lower position it is only necessary to increase the fluid pressure in the intermediate expansible chamber **228** which moves the lower piston ring **206** downwardly for releasing the detent **212** from the recess **202***b* and enabling the spring **204** to move the operator sleeve **202** to the upper position when the control fluid pressure in the intermediate expansible chamber **228** is reduced. With the operator sleeve **202** locked in the open position, the wire-line retrievable valve operably engages recess **214***a* in the sleeve **214** and is operated open by increasing the control fluid pressure in the upper expansible chamber **226** and the lower expansible chamber **230.**

OPERATION

In the use and operation of the present invention, the well apparatus A is made up in the production tubing T at a desired location therein and run in the well W as well known in the art. Prior to lowering the well apparatus A into the well a first or normal control fluid conduit L1 is connected to the port **150** and a second or balanced line control conduit L2 is connected to the port **152.** When the well apparatus A is at the desired depth in the well W a packer P is set for sealing between the production tubing T and a casing C for directing flow of well fluids through the bore B of the producting tubing T. While the casing may not extend continuously from the packer P to the ground surface G sufficient casing C is located adjacent the surface G to enable mounting of the well head flow apparatus or christmas tree X at the surface. Provisions are made adjacent the surface G for bringing the control fluid conduits L1 and L2 to remote controllers S1 and S2, respectively. Such controllers S1 and S2 normally include a supply of control fluid which may be pressured or vented as desired. An example of a control system may be found in U.S. Pat. No. 3,035,808 which issued to G. S. Knox and which is assigned to the Assignee of the present invention. With the well so completed, the normal flow pattern for well fluids in a subsurface producing formation F is to flow through perforation O into the casing C where they are directed to flow up the bore B of the production tubing T by the packer P. Normally such flow is controlled at the surface by the valves located on the christmas tree X.

To enable flow through the bore B or the productin tubing T it is necessary to operate the valve apparatus A to the open position for enabling flow to the surface. This is preferably accomplished by increasing the control fluid pressure in the normal control fluid conduit L1 using the first control fluid supply means S1 while venting the second control fluid supply means S2 to prevent a pressure build-up in the second control fluid conduit L2 during operation of the valve apparatus A. By using the intermediate expansible chambers **146** and **96** for normal operation, the second control fluid conduit L2 which communicates with the lower expansible chambers **148** and **98** can serve as a balance line and therefore enable the running of the valve apparatus A at greater depths since the springs **122** and **64** will not be required to support the hydrostatic head of control fluid in the control fluid conduit L1.

Also by increasing the control fluid pressure in the conduits L2 and venting the control fluid pressure in the conduit L1 increased control fluid pressure will be communicated into the upper expansible chambers **144** and **94** and the lower expansible chambers **148** and **98** which effect the same opening rotation operation of the ball **36** as that by increased control fluid pressure in the intermediate expansible chambers **146** and **98.**

Prior to the increase of control fluid pressure in the conduit L1, the valve apparatus A is in the condition illustrated in FIGS. **1A, 1B, 1C, 1D** and **12** with the high pressure well fluids shut-in below the ball. Both the metal seal between the upper seat **42** and the ball **36** and engagement of the ball **36** with the lower resilient seat **40** serve to shut-in or block flow through the bore **32.** The engagement of the lower seat ring **40** with the ball **36** creates a small unbalanced pressure urging on the lower operator sleeve **52** for urging the sleeve **52** upwardly into the sealing engagement with the ball and for urging the ball **36** into engagement with the upper seat **42.** Thus the greater the well shut-in pressure the greater the sealing force of the seals **42** and **40** with the ball **36.**

Referring now to FIGS. **12–17,** the ball **36** and seats **40** and **42** are illustrated in FIG. **12** in the closed position prior to increasing the control fluid pressure. The initial response to increased control fluid pressure is illustrated in FIG. **13** where the sleeve **52** has commenced to move downwardly for spacing the lower seat **40** from the ball **36** and equalizing well pressure adjacent the ball **36.** Due to the length of the recesses **56***c* and **58***c*, the sleeve **52** is free to move this distance by overcoming the small upwardly urging of well pressure on the sleeve **52.** Continued downward movement of the sleeve **52** moves the connector **54** downward to engage the ball **36** with the concentric pins **56***b* and **58***b* (FIG. **14**).

As downward movement of the sleeve **104** is delayed by well pressure urging upwardly on shoulder **104***d*, the ball **36** is pulled downwardly by the pins **56***b* and **58***b* for spacing the seat **42** from the ball **36** (FIG. **14**). This spacing enables equalizing of well pressure adjacent the ball **36** and equalizes the pressure urgings on the upper operator sleeve **104.**

When the ball **36** ad the upper seat **42** are spaced, the eccentric pins **100** and **102** engage the walls of the eccentric recesses **36***d* for effecting rotation of the ball (FIG. **15**). Due to the length of recesses **56***c* and **58***c*, the lower operator sleeve **52** is unable to completely pull the ball **36** open and it is necessary to engage the ball **36** with the upper operator sleeve **104** (FIG. **16**) for moving the ball **36** downwardly a small longitudinal distance to rotate the ball **36** for completely aligning the flow passage **38** with the bore **32.** The ball **36** may

be teflon coated by a number of known processes to those skilled in the art for minimizing friction during the last portion of opening rotation.

As the spring **64** does not engage the lower operator sleeve **52**, the connector **54** will move the ball **36** from engagement with the lower operator sleeve **52** upwardly when rotating the ball **36** closed. To space the upper seat **42** from the ball **36** during closing rotation thereof, the upward movement of the lower operator sleeve **52** is retarded relative to that of the upper operator sleeve **104.** This may be achieved either by having the lower pistons **80** and **86** larger in pressure responsive area and therefore volume than the upper pistons **124** and **126** or by restricting the flow area of the ports **160***c*, **160***d* and **156***b* communicating with the expansible chambers **94, 98** and **86,** respectively. Thus, closing rotation would be essentially a reversal of the steps of rotating open the ball **36.**

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

I claim:

1. A method of operating a well tool mounted with a well conduit at a subsurface location and having a tubular housing mounting a rotatable ball element with a flow passage formed through the ball element for controlling flow of well fluids through the bore of the well conduit by rotational movement of the ball element, including the steps of:

spacing the ball element from an annular seat that is sealably engaged by the ball element for blocking flow of fluid through the bore;

rotating the ball element to enable flow of well fluids through the flow passage and well conduit; and

sealing the ball element with the annular seat for excluding therebetween undesired foreign material in the well fluids by moving the annular seat to sealingly engage the ball element.

2. The method as set forth in claim **1,** including the step of:

moving the ball element longitudinally in the tubular housing while rotating the ball element to enable flow of well fluids.

3. The method as set forth in claim **1,** including the step of:

moving the ball element longitudinally for spacing the ball elements and seat.

4. The method as set forth in claim **1,** including the step of:

equalizing the well fluid pressure about the ball element after spacing the ball element and seat. w

5. A method of operating a well tool mounted with a well conduit at a subsurface location and having a tubular housing mounting a rotatable ball element with a flow passage formed through the ball element for controlling flow of well fluids through the bore of the well conduit by rotational movement of the ball element, including the steps of:

spacing the ball elements from a seat that is sealably engaged by the ball element for blocking flow of fluid through the bore;

rotating the ball element to enable flow of well fluids through the flow passage and well conduit;

sealing the ball element with the seat for excluding therebetween undesired foreign material in the well fluids; and

spacing the ball element from a second seat that sealably engages the ball element at a location spaced from the sealable engagement of the first mentioned seat prior to the step of rotating the ball element to enable flow.

6. The method as set forth in claim **5,** including the step of:

equalizing the well fluid pressure adjacent the ball element after spacing the ball element and the second seat.

7. The method as set forth in claim **6,** including the step of:

moving the ball element longitudinally while rotating the ball element to enable flow of well fluids.

8. The method as set forth in claim **6,** including the step of:

engaging the ball elements with the first and second seats for effecting fluid seals after rotating the ball element to enable flow of well fluids.

9. A method of operating a well tool mounted with a well conduit at a subsurface location and having a tubular housing mounting a rotatable ball element with a flow passage formed through the ball element for controlling flow of well fluids through the bore of the well conduit by rotational movement of the ball element, including the steps of:

spacing the ball element from an annular seat that is sealably engaged by the ball element for blocking flow of fluid through the bore;

contacting the ball element at locations on opposite sides of the ball element for imparting an urging to the ball element in a direction to effect opening rotation of the ball element;

urging in a direction on the ball element at the two contacting locations for moving the ball element;

rotating the ball element to enable flow of well fluids through the flow passage and well conduit in response to the urging on the ball element at the two contacting locations; and

moving the annular seat to sealingly engage the ball element for excluding therebetween undesired foreign material.

10. The method as set forth in claim **9,** including the step of:

moving the ball element longitudinally while rotating the ball element by urging on the ball element at the two contacting locations.

11. A method of operating a well tool mounted with a well conduit at a subsurface location and having a tubular housing forming a bore and mounting a rotatable ball element with a flow passage formed through the ball element for controlling flow of well fluids through the bore by rotational movement of the ball element, including the steps of:

spacing the ball element from a first seat that is sealably engaged by the ball element for blocking flow of fluid through the bore;

spacing the ball element from a second seat that sealably engages the ball element at a location spaced from the sealable engagement of the first mentioned seat;

contacting the ball element at locations on opposite sides of the ball element for rotating the ball element;

urging on the ball element in a direction at the two contacting locations for rotating the ball element;

rotating the ball element to enable flow of well fluids through the flow passage and well conduit; and

sealing the ball element with the seats for excluding therebetween undesired foreign material in the well fluids by moving one of the seats to sealingly engage the ball element with both seats.

12. A method of operating a subsurface well flow control valve having a housing mounting a valve seat means and a movable flow closure element, said valve seat means including upper and lower annular seats engageable with said flow closure element, including the steps of:

spacing the flow closure element from engagement with the upper and lower annular seat means;

moving the flow closure element to enable desired flow by urging on the flow closure element at two spaced locations on opposite sides of the flow closure element; and

engaging the flow closure element with upper and lower annular seat means while flow is enabled.

13. The method as set forth in claim **12**, including the step of:

moving the flow closure element longitudinally in the housing while rotating the flow closure element to enable flow.

14. A method of operating a well flow control valve mounted with a well tubing at a subsurface location in a well and having a housing mounting a movable valve seat and a movable flow closure element, including the steps of:

moving the seat for spacing the flow closure element from flow sealing engagement the seat;

moving the flow closure element longitudinally in the housing while rotating the flow closure element to enable desired flow through the well tubing; and

sealing the flow closure element with the seat while flow is enabled to block entry of undesired matter between the flow closure element and the seat;

15. A method of operating a well flow control valve mounted with a well tubing at a subsurface location in a well and having a housing mounting a valve seat and a movable flow closure element, including the steps of:

spacing the flow closure element from flow sealing engagement with the seat;

moving the flow closure element longitudinally in the housing while rotating the flow closure element to enable desired flow through the well tubing flow; and

moving the seat for sealing with the flow closure element to block entry of undesired matter between the flow closure element and the seat.

16. The method as set forth in claim **15**, including the step of:

equalizing the well fluid pressure adjacent the flow closure element after spacing the flow closure element from flow sealing engagement with the seat.

17. A method of operating a well flow control valve mounted with a well tubing at a subsurface location in a well and having a housing mounting a valve seat and a movable flow closure element, including the steps of:

spacing the flow closure element from flow sealing engagement with the seat;

engaging the flow closure element at spaced locations on opposite sides of the flow closure element for effecting movement of the flow closure in a direction to enable desired flow;

urging on the flow closure element at the engaged spaced locations for moving the flow closure element;

moving the flow closure element to enable desired flow through the well tubing; and

sealing the flow closure element with the seat while flow is enabled by moving the seat to engage the flow closure element to block entry of undesired matter between the flow closure element and the seat.

18. The method as set forth in claim **17**, including the step of:

urging on the flow closure element at the two engaged locations for moving the flow closure element longitudinally to effect rotation of the flow closure element.

19. A method of operating a well flow control valve mounted with a well tubing at a subsurface location in a well and having a housing mounting a valve seat and a movable flow closure element, including the steps of:

spacing the flow closure element from flow sealing engagement with the seat;

moving the flow closure element to enable desired flow through the well tubing;

sealing the flow closure element with the seat while flow is enabled to block entry of undesired matter between the flow closure element and the seat; and

spacing the flow closure element from a second seat that sealably engages the flow closure element at a location spaced from the sealable engagement of the first mentioned seat prior to the step of moving the flow closure element to enable flow.

20. The method as set forth in claim **18**, including the step of:

equalizing the well fluid pressure adjacent the flow closure element after spacing the flow closure element from flow sealing engagement with the second seat.

21. A method of operating a subsurface safety valve mounted with a well conduit at a subsurface location in a well for controlling flow of well fluids through the bore of the well conduit, said safety valve having valve seat means and a movable flow closure element, said valve seat means including first and second seats engaging said flow closure element on opposite sides of said flow closure element, including the steps of:

spacing the flow closure element from engagement with the first and second valve seat means;

engaging the flow closure element at spaced locations on opposite sides of the flow closure element for effecting movement of the flow closure element in a direction to enable flow; and

urging on the flow closure element at the engaged spaced locations for moving the flow closure element in the direction to enable flow of well fluids through the bore of the well conduit.

22. The method as set forth in claim **21**, including the step of:

engaging the flow closure element only at the two spaced locations for effecting longitudinal movement of the flow closure element.

23. The method as set forth in claim **21**, including the step of:

equalizing the well fluid pressure about the flow closure element by spacing the flow closure element from the valve seat means.

24. The method as set forth in claim **21**, including the step of:

rotating the flow closure element to enable flow in response to the urging on the flow closure element.

25. The method as set forth in claim **24**, including the step of:

moving the flow closure element longitudinally while rotating to enable flow of well fluids.

26. The method as set forth in claim **22**, including the step of:

actuating a control means from a location exteriorly of the well for rotating the flow closure element to enable flow.

27. The method as set forth in claim **21**, including the step of:

moving the flow closure element longitudinally for spacing the flow closure element from a second sealable engagement with the valve seat means in response to the urging on the flow closure element.

28. The method as set forth in claim **27**, including the step of:

rotating the flow closure element to enable flow of well fluids after spacing the flow closure element from the second sealable engagement with the valve seat means.

29. The method as set forth in claim **28**, including the step of:

equalizing the well fluid pressure adjacent the flow closure element prior to rotating the flow closure element.

30. A method of operating a subsurface safety valve mounted with a well conduit at a subsurface location in a well for controlling flow of well fluids through the bore of the well conduit with a valve seat means and a movable flow closure element, including the steps of:

spacing a flow closure element from sealable engagement with a valve seat means by moving the seat means from sealable engagement with the flow closure element for spacing the seat means and flow closure element;

engaging the flow closure element at spaced locations on opposite sides of the flow closure element for effecting movement of the flow closure element; and

urging on the flow closure element at the engaged spaced locations for moving the flow closure element to enable flow of well fluids through the bore of the well conduit.

31. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means having an annular resilient seal movably disposed in said bore for sealably engaging with said flow closure element in the open and closed positions for controlling flow of fluid through said bore; and

operator means operably connected with said flow closure element for effecting movement of said flow closure element to and from the open and closed position, said operator means spacing said annular resilient seal and said flow closure element from sealable engagement prior to moving said flow closure element from the closed to the open position wherein the valve apparatus controls the flow of fluid.

32. The apparatus as set forth in claim **31**, wherein:

said valve seat means having a seat member engageable with said closure element in the open position.

33. The apparatus as set forth in claim **31**, wherein:

said valve seat means and said flow closure element arranged for equalizing the fluid pressure adjacent said flow closure element when said valve seat means and said flow closure element are spaced by said operator means.

34. The apparatus as set forth in claim **31**, including:

said valve seat means having an annular seat member for sealably engaging with said flow closure element to block passage of fluid therebetween when said flow closure element is in the closed position.

35. The apparatus as set forth in claim **34**, including:

said operator means spacing said annular seat member from said flow closure element prior to moving said flow closure element open.

36. The apparatus as set forth in claim **35**, including:

said flow closure element in moving to the open position sealably engages with said annular seat member.

37. The apparatus as set forth in claim **31**, wherein:

said flow closure element formed by a ball-type valve element having a flow passage formed therethrough, said ball-type valve element rotatable to enable flow through said flow passage in the open position and to block flow with said ball-type valve element in the closed position.

38. The apparatus as set forth in claim **37**, wherein:

said operator means effecting rotational movement of said ball-type valve element to the open position after spacing said ball-type valve element from said valve seat means.

39. The apparatus as set forth in claim **37**, wherein:

said valve seat means sealably engaging with said ball-type valve element when said ball-type valve element is substantially rotated open.

40. The apparatus as set forth in claim **39**, wherein:

said valve seat means having a first annular seat member for sealably engaging said ball-type valve element to block passage of fluid therebetween at a first location; and

said valve seat means having a second annular seat member for sealably engaging said ball-type valve element to block passage of fluid therebetween at a second location spaced from said first location wherein said valve seat means effects two flow blocking sealing engagements with said ball-type valve element in the closed position.

41. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position wherein the valve apparatus controls the flow of fluid;

said valve seat means having a first seat member for sealably engaging with said flow closure element to block passage of fluid therebetween; and

said valve seat means having a second seat member for sealably engaging with said flow closure element at a location spaced from the sealable engagement with the first seat member to block passage of fluid between both said first seat member and said flow closure element and said second seat member and said flow closure element when said flow closure element is in the closed position, said operator means spacing said first seat member and said second seat member from said flow closure element prior to moving said flow closure element to the open position.

42. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position wherein the valve apparatus controls the flow of fluid;

said valve seat means having a first seat member for sealably engaging with said flow closure element to block passage of fluid therebetween;

said valve seat means having a second seat member for sealably engaging with said flow closure element at a location spaced from the sealable engagement with the first seat member to block passage of fluid between both said first seat member and said flow closure element and said second seat member and said flow closure element when said flow closure element is in the closed position, said operator means spacing said first seat member and said second seat member from said flow closure element prior to moving said flow closure element to the open position; and

said operator means spaces said flow closure element and said second seat member for equalizing fluid pressure adjacent said flow closure element prior to moving the flow closure element to the open position.

43. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position wherein the valve apparatus controls the flow of fluid;

said valve seat means having a first seat member for sealably engaging with said flow closure element to block passage of fluid therebetween;

said valve seat means having a second seat member for sealably engaging with said flow closure element at a location spaced from the sealable engagement with the first seat member to block passage of fluid between both said first seat member and said flow closure element and said second seat member and said flow closure element when said flow closure element is in the closed position, said operator means spacing said first seat member and said second seat member from said flow closure element prior to moving said flow closure element to the open position; and

said operator means moves said first seat member for spacing said first seat member from said flow closure element.

44. The apparatus as set forth in claim **43**, wherein:

said operator means moves said flow closure element for spacing said second seat member from said flow closure element.

45. The apparatus as set forth in claim **44**, wherein:

said operator means rotates said flow closure element to the open position after spacing said first seat means and said second seat means from said flow closure element.

46. The apparatus as set forth in claim **45**, wherein:

said flow closure element is formed by a ball-type valve element having a flow passage formed therethrough, said ball-type valve element rotatable to enable flow through said flow passage in the open

position and to block flow with said ball-type valve element in the closed position.

47. The apparatus as set forth in claim **46**, wherein:

said operator means spaces said ball-type valve element from said second seat member prior to rotating said ball-type valve element to the open position.

48. The apparatus as set forth in claim **47**, wherein:

said operator means moves said ball-type valve element longitudinally in said bore of said housing when rotating said ball-type valve element to and from the open and closed position.

49. The apparatus as set forth in claim **47**, wherein:

said operator means maintains said first seat member and said second seat member spaced from said ball-type element when rotating said ball-type element to the open position.

50. The apparatus as set forth in claim **49**, wherein:

said first seat member and said second seat member sealably engage with said ball-type valve element when said ball-type valve element is substantially rotated open.

51. The apparatus as set forth in claim **50**, wherein:

said operator means moves said ball-type valve element longitudinally in said bore of said housing when rotating said ball-type valve element to and from the open and closed positions.

52. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position wherein the valve apparatus controls the flow of fluid;

said flow closure element formed by a ball-type valve element having a flow passage formed therethrough, said ball-type valve element rotatable to enable flow through said flow passage in the open position and to block flow with said ball-type valve element in the closed position;

said valve seat means sealably engaging with said ball-type valve element when said ball-type valve element is substantially rotated open;

said valve seat means having a first annular seat member for sealably engaging said ball-type valve element to block passage of fluid therebetween at a first location;

said valve seat means having a second annular seat member for sealably engaging said ball-type valve element to block passage of fluid therebetween at a second location spaced from said first location wherein said valve seat means effects two flow blocking sealing engagements with said ball-type valve element in the closed position; and

said operator means effecting rotational movement of said ball-type valve element to the open position after spacing said ball-type valve element from said first annular seat member and said second annular seat member.

53. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position;

said flow closure element formed by a ball-type valve element having a flow passage formed therethrough, said ball-type valve element pivotally connected with said housing for effecting rotation to enable flow through said flow passage in the open position and to block flow with said ball-type valve element in closed position;

a first operator member disposed in said bore and mounted with said housing for longitudinal movement relative thereto said operator member engageable with said ball-type valve in the closed position; and

means pivotally connecting said first operator member and said ball-type valve element for moving said ball-type valve to effect rotation of said ball-type valve element between open and closed positions upon movement of said operator member in opposite longitudinal directions said means for connecting arranged to move said ball-type valve to effect opening rotation after spacing said operator member from engagement with said ball-type valve wherein the valve apparatus controls the flow of fluid.

54. The apparatus as set forth in claim **53**, wherein:

said first operator member moves in a longitudinal direction away from said ball-type valve element for rotating said ball-type valve element to the open position.

55. The apparatus as set forth in claim **53**, wherein said means for rotating said ball-type valve element, including:

a control frame connected with said first operator member for limited longitudinal movement relative thereto; and

lugs on one of said control frame or on opposite sides of said ball-type valve element operatively engaging with recesses on the other of said control frame or on opposite sides of said ball-type valve element for rotating said ball-type valve element between opened and closed positions upon movement of said control frame in opposite longitudinal directions with said first operator member.

56. The apparatus as set forth in claim **53,** wherein:

said valve seat means including a first seat member mounted with said first operator member for sealably engaging with said ball-type valve element.

57. The apparatus as set forth in claim **56,** wherein:

said first operator member moves said first seat member from sealable engagement with said ball-type valve element prior to rotating said ball-type valve element to the open position.

58. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position wherein the valve apparatus controls the flow of fluid;

said flow closure element formed by a ball-type valve element having a flow passage formed therethrough, said ball-type valve element rotatable to enable flow through said flow passage in the open position and to block flow with said ball-type valve element in the closed position;

a first operator member mounted with said housing for longitudinal movement relative thereto;

means connecting said first operator member and said ball-type valve element for rotating said ball-type valve element between open and closed positions upon movement of said operator member in opposite longitudinal directions;

said first operator member moves in a longitudinal direction away from said ball-type valve element for rotating said ball-type valve element to the open position; and

said operator means including means for urging said first operator member towards said ball-type valve element for rotating said ball-type valve element to the closed position.

59. The apparatus as set forth in claim **58,** including:

first control means for moving said first operator member in a longitudinal direction away from said ball-type valve element in response to a first control signal initiated at a location remote from said flow housing.

60. The apparatus as set forth in claim **59,** including:

second control means for moving said operator member in a longitudinal direction away from said ball-type valve element in response to a second control signal initiated at a location remote from said flow housing wherein said first or second control means operates said ball-type valve element open.

61. Valve apparatus for subsurface use in wells, including:

a flow housing having a bore therethrough and means for mounting said flow housing with a well conduit at a desired subsurface location in a well;

bore closure means mounted with said housing for movement to and from an open position for enabling flow of fluid through said bore and a closed position for blocking flow of fluid through said bore, said bore closure means, comprising:

a flow closure element movably disposed in said bore to and from open and closed positions for controlling flow of fluid through said bore;

valve seat means disposed in said bore for sealably engaging with said flow closure element for controlling flow of fluid through said bore;

operator means operatively connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed position, said operator means spacing said valve seat means and said flow closure element from sealable engagement prior to moving said bore closure means to the open position wherein the valve apparatus controls the flow of fluid;

said flow closure element formed by a ball-type valve element having a flow passage formed therethrough, said ball-type valve element rotatable to enable flow through said flow passage in the open position and to block flow with said ball-type valve element in the closed position;

a first operator member mounted with said housing for longitudinal movement relative thereto;

means connecting said first operator member and said ball-type valve element for rotating said ball-type valve element between open and closed positions upon movement of said operator member in opposite longitudinal directions;

a control frame connected with said first operator member for limited longitudinal movement relative thereto;

lugs on one of said control frame or on opposite sides of said ball-type valve element operatively engaging with recesses on the other of said control frame or on opposite sides of said ball-type valve element for rotating said ball-type valve element between open and closed positions upon movement of said control frame in opposite longitudinal directions with said first operator member;

said valve seat means having a first seat member mounted with said first operator member for sealably engaging with said ball-type valve element to block passage of fluid therebetween; and

said control frame connected with said first operator member for enabling said first operator member to move said first seat member from sealing engagement with said ball-type valve prior to rotating said ball-type valve element to the open position.

62. The apparatus as set forth in claim **61,** including:

a second operator member mounted with said housing for longitudinal movement relative thereto;

a second seat member mounted with said second operator member for sealably engaging with said ball-type valve element at a second location to block passage of fluid therebetween; and

said control frame moving said ball-type valve from sealing engagement with said second seat member prior to rotating said ball-type valve element to the open position.

63. The apparatus as set forth in claim **62,** wherein:

said first operator member moves in a direction away from said ball-type valve element when effecting rotation of said ball-type valve element to the open position.

64. A well tool valve apparatus adapted for mounting with a well conduit at a subsurface location in a well for controlling flow of well fluids through the bore of the well conduit, including:

a housing adapted for mounting with a well conduit at the subsurface location in the well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of well fluids through the bore of the well conduit and a closed position for blocking flow of well fluids through the bore of the well conduit;

said bore closure means comprising:

a movable flow closure element mounted with flow housing for controlling flow of well fluids through the bore of the well conduit by movement to and from the open and closed positions;

valve seat means for sealably engaging with said flow closure element for blocking flow of fluid between said flow closure element and said valve seat means; and

operator means operatively connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed positions in response to movement of said operator means in opposite directions in said housing, said operator means in moving in a direction away from said flow closure element spacing said valve seat means and said flow closure element from sealable engagement prior to moving said flow closure element to the open position.

65. The apparatus as set forth in claim **64,** wherein:

said flow closure element including a ball-type valve having a flow passage formed therethrough, said ball-type valve rotating to and from the open position for enabling flow of well fluids through said flow passage and the bore of the well conduit and the closed position for blocking flow of well fluids through said flow passage and the bore of the well conduit.

66. A well tool valve apparatus adapted for mounting with a well conduit at a subsurface location in a well for controlling flow of well fluids through the bore of the well conduit, including:

a housing adapted for mounting with a well conduit at the subsurface location in the well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of well fluids through the bore of the well conduit and a closed position for blocking flow of well fluids through the bore of the well conduit;

said bore closure means comprising;

a movable flow closure element mounted with flow housing for controlling flow of well fluids through the bore of the well conduit by movement to and from the open and closed positions;

valve seat means for sealably engaging with said flow closure element for blocking flow of fluid between said flow closure element and said valve seat means;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed positions in response to movement of said operator means in opposite directions in said housing, said operator means in moving in a direction away from said flow closure element spacing said valve seat means and said flow closure element from sealable engagement prior to moving said flow closure element to the open position;

said flow closure element including a ball-type valve having a flow passage formed therethrough, said ball-type valve rotating to and from the open position for enabling flow of well fluids through said flow passage and the bore of the well conduit and the closed position for blocking flow of well fluids through said flow passage and the bore of the well conduit;

a first operator member mounted with said housing for longitudinal movement relative thereof; and

means connected said first operator member and said ball-type valve for rotating said ball-type valve between open and closed positions upon movement of said operator member in opposite longitudinal directions.

67. A well tool valve apparatus adapted for mounting with a well conduit at a subsurface location in a well for controlling flow of well fluids through the bore of the well conduit, including:

a housing adapted for mounting with a well conduit at the subsurface location in the well;

bore closure means mounted with said flow housing for movement to and from an open position for enabling flow of well fluids through the bore of the well conduit at a closed position for blocking flow of well fluids through the bore of the well conduit;

said bore closure means comprising;

a movable closure element mounted with flow housing for controlling flow of well fluids through the bore of the well conduit by movement to and from the open and closed positions;

valve seat means for sealably engaging with said flow closure element for blocking flow of fluid between said flow closure element and said valve seat means;

operator means operably connected with said bore closure means for effecting movement of said bore closure means to and from the open and closed positions in response to movement of said operator means in opposite directions in said housing, said operator means in moving in a direction away from said flow closure element spacing said valve seat means and said flow closure element from sealable engagement prior to moving said flow closure element to the open position;

said flow closure element including a ball-type valve having a flow passage formed therethrough, said ball-type valve rotating to and from the open position for enabling flow of well fluids through said

flow passage and the bore of the well conduit and the closed position for blocking flow of well fluids through said flow passage and the bore of the well conduit;

a first operator member mounted with said housing for longitudinal movement relative thereto;

means connecting said first operator member and said ball-type valve for rotating said ball-type valve between open and closed positions upon movement of said operator member in opposite longitudinal directions; and

said valve seat means having a first seat member mounted with said first operator member for sealably engaging with said ball-type valve to block passage of well fluids therebetween, said first operator member moving said first seat member from sealable engagement with said ball-type valve prior to rotating said ball-type valve to the open position.

68. The apparatus as set forth in claim **67**, wherein said means for rotating said ball-type valve between open and closed positions includes:

a control frame connected with said first operator member for limited longitudinal movement relative thereto; and

lugs on one of said control frame or on opposite sides of said ball-type valve operatively engaging with recesses on the other of said control frame or on opposite sides of said ball-type valve for effecting rotation of said ball-type valve upon movement of said control frame in opposite longitudinal directions with said first operator member.

69. The apparatus as set forth in claim **68** including:

urging means mounted with said housing for urging said first operator member in a longitudinal direction to rotate said ball-type valve closed; and

control means for moving said first operator in a longitudinal direction to rotate said ball-type valve open wherein operation of said ball-type valve is controlled.

70. The apparatus as set forth in claim **69**, wherein:

said control means moves said first operator in a direction away from said ball-type valve.

71. The apparatus as set forth in claim **68**, including:

second control means for moving said first operator in a longitudinal direction to rotate said ball-type valve open wherein said ball-type valve is controllable by either said first or said second control means.

72. A well tool valve apparatus adopted for mounting with a well conduit at a subsurface location in a well for controlling flow of well fluids through the bore of the well conduit; including:

a tubular housing having means for mounting with the well tubing at the subsurface location, said housing having a bore formed therethrough for communicating with the bore of the well conduit above and below said housing;

a ball-type valve having a flow passage formed therethrough movably disposed in said bore of said housing, said ball-type valve rotating to and from an open position for enabling flow of well fluids through said flow passage and the bore of the well conduit and a closed position for blocking flow of well fluids through said flow passage and the bore of the well conduit;

first seat means movably disposed in said bore of said housing below said ball-type valve for engaging with said ball-type valve to control flow of well fluids through said bore of said housing;

second seat means movably disposed in said bore of said housing above said ball-type valve for sealing engagement with said ball-type valve to control flow of well fluids through said bore of said housing;

first operator member means movably disposed in said bore of said housing and mounting said first seat means; said first operator member means operably connected with said ball-type valve for substantially moving said ball-type valve to and from the open and closed positions upon controlled movement of said first operator member means;

second operator member means movably disposed in said bore of said housing and mounting said second seat means for sealing engagement with said ball when said ball-type valve is in the open and closed positions; and

means actuated remotely from said housing for effecting coordinated movement of said first and second operator member means to space said first seat means from said ball-type valve and said ball-type valve from said second seat means prior to rotating said ball-type valve substantially to the open position from the closed position with said first operator member means wherein flow of well fluids is enabled.

73. A method of operating closed a subsurface rotatable ball-type safety valve from the open position, including the steps of:

spacing an upper seat from engagement with the ball-type valve in the open position;

spacing the ball-type valve from a lower seat; and

rotating the ball-type valve closed wherein the ball-type valve is operated closed.

74. The method as set forth in claim **73**, including the step of:

sealably engaging the ball-type valve with the upper seat for blocking flow of fluid therebetween.

75. The method as set forth in claim **73**, including the step of:

sealably engaging the ball-type valve with the lower seat for blocking flow of fluid therebetween.

76. The method as set forth in claim **73**, including the step of:

sealably engaging the ball-type valve with the lower and upper seats for blocking flow of fluid between each of the seats and the ball-type valve.

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