United States Patent

[11] **3,603,394**

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[54] **WELL TOOLS**
14 Claims, 11 Drawing Figs.

[52] U.S. Cl. **166/224,** 137/460, 137/517
[51] Int. Cl. **E21b 33/00,** F16k 17/00
[50] Field of Search 166/224; 137/460, 517, 535

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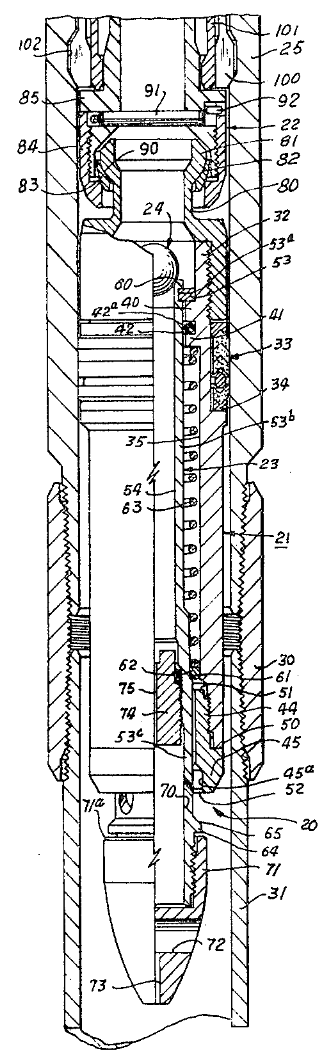
ABSTRACT: A combination standing valve and safety valve for a tubing string of a well including a ball valve which closes responsive to flow in the tubing string toward a well formation and a tubular valve which responds to predetermined flow conditions to close to prevent flow from the formation into the tubing string. The valve is installed and retrieved by wire line or pumpdown procedures.



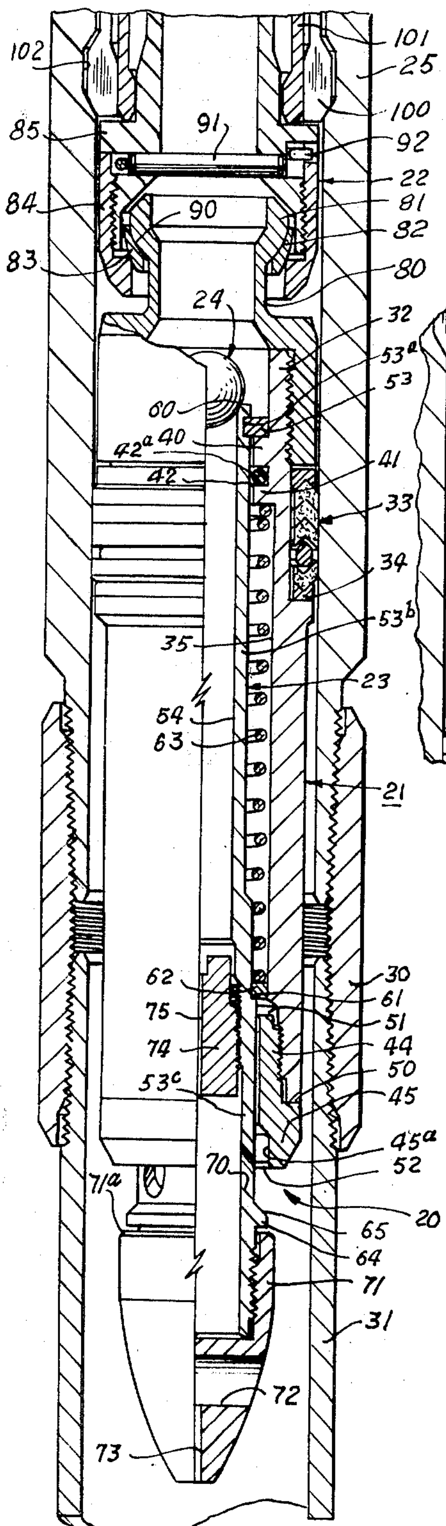


Fig.1

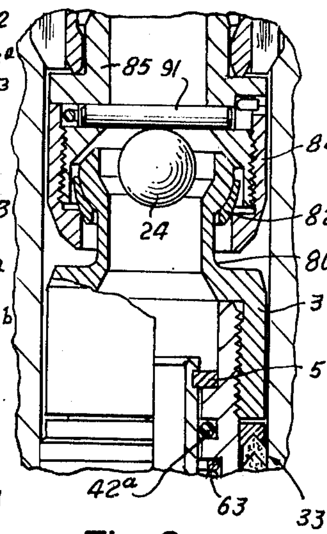


Fig.2

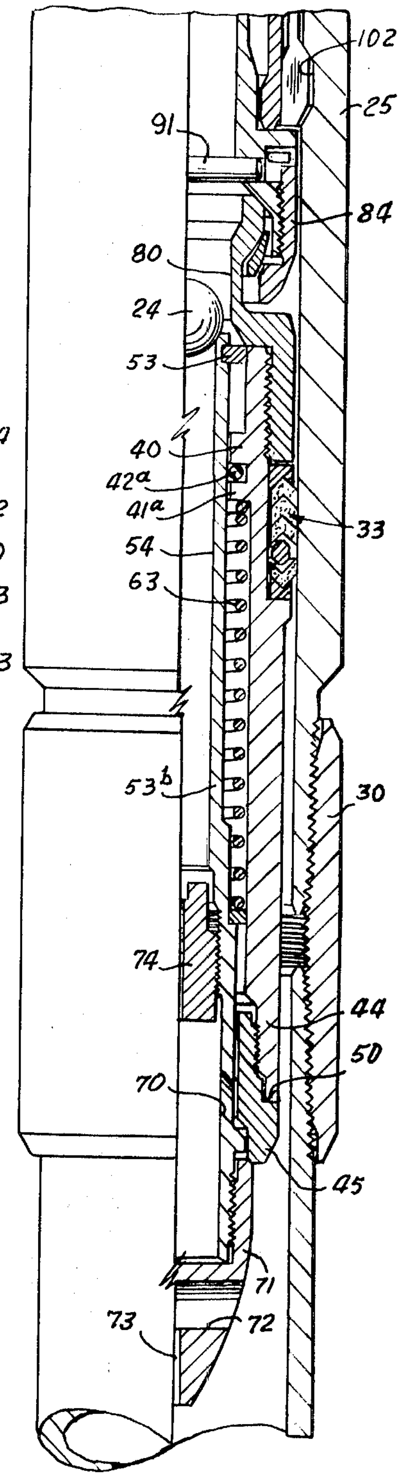


Fig.3

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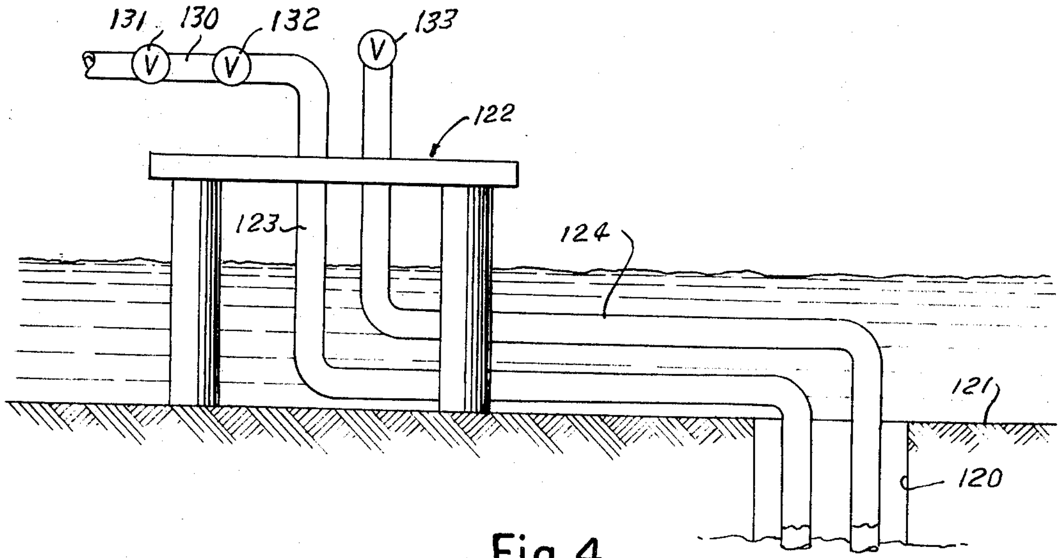

Fig. 4

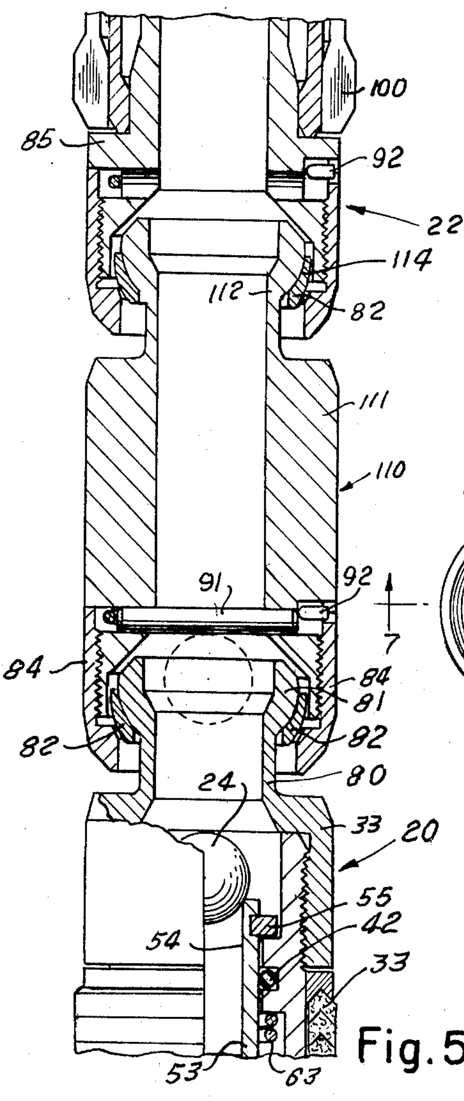

Fig. 5

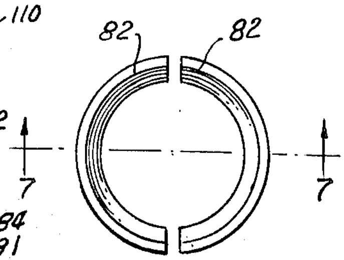

Fig. 6

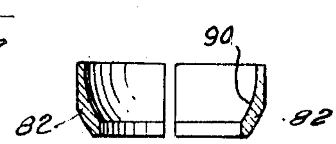

Fig. 7

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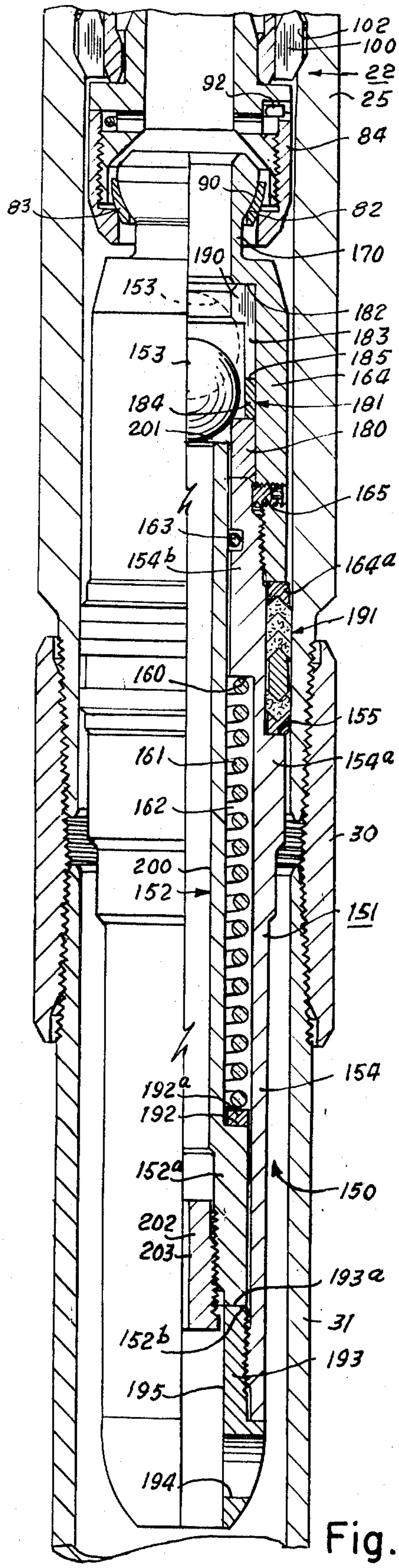

Fig. 8

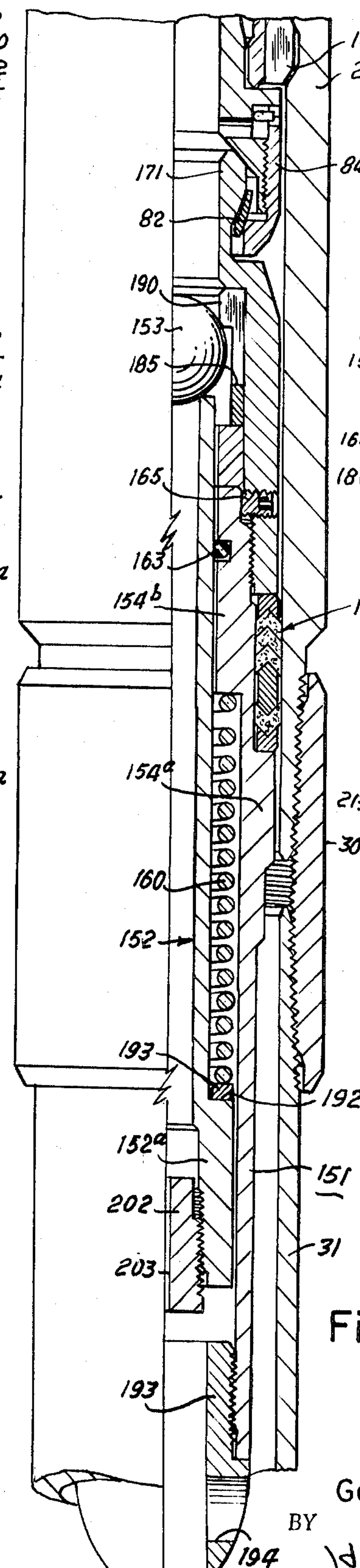

Fig. 9

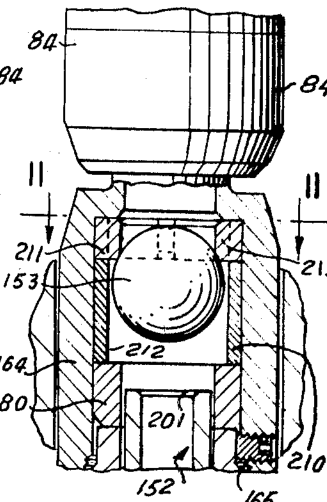

Fig. 10

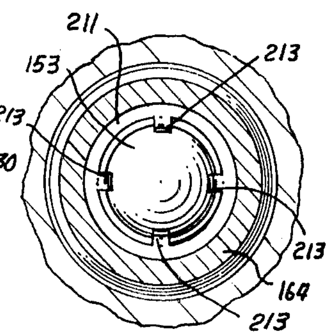

Fig. 11

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WELL TOOLS

This invention relates to well tools and more particularly relates to well tubing valves.

It is an especially important object of the invention to provide a new and improved well tool for preventing fluid flow from a tubing string to a surrounding well formation and for shutting off fluid flow from the formation into the tubing sting when certain predetermined flow conditions are reached.

It is another important object of the invention to provide a new and improved combined standing valve and safety valve for use in a tubing string of a well.

It is another object of the invention to provide a well valve having a ball-type standing or check valve which closes responsive to flow in the tubing string toward a surrounding well formation to prevent backflow of fluids from the tubing string to the formation.

It is another object of the invention to provide a well tool which includes a ball valve adapted to seat responsive to flow in one direction to prevent fluid flow in such direction through the well tool and held to limited movement in the opposite direction and engageable by a tubular valve member responsive to flow in such opposite direction to shut off such flow.

It is another object to protect well formations from excessive tubing pressure.

It is a further object of the invention to provide a well tubing valve which includes a ball check valve adapted to seat responsive to fluid flow through the tool in a first direction while permitting fluid flow through the tube in an opposite second direction an a tubular valve member adapted to seat responsive to predetermined fluid flow conditions through the tool in such second direction.

It is another object of the invention to provide a well valve having a standing valve and a safety valve, the standing valve seating on the upper end of the safety valve and the safety valve seating at a separate location at the lower end of the tool.

It is another object of the invention to provide a well tool comprising a combined standing valve and safety valve wherein the standing valve seats on a surface independent of and at the upper end of the safety valve and the safety valve seats against the ball valve member of the standing valve at the upper end of the safety valve.

It is still a further object of the invention to provide a combination standing and safety valve for a well including a safety valve which is spring biased to an open position responsive to flow through a choke or flow bean secured in a tubular valve member of the valve.

It is still another object of the invention to provide a well tool comprising a combination standing valve and safety valve which may be installed and retrieved by either wire line procedures or remotely controlled hydraulic pumpdown procedures.

It is still another object of the invention to provide an articulated-type combination standing valve and safety valve which readily traverses curved portions of well-tubing thereby permitting the valve to be manipulated to remote locations along a well bore.

It is another object of the invention to provide a combined standing and safety valve which may be supported below a crossover connection in a well-tubing string system from a landing nipple located above the crossover connection.

It is still another object of the invention to provide a combined standing valve and safety valve for well tubing which includes means for sealing around the valve within a flow conductor whereby fluids flowing in the flow conductor must flow through only the valve.

Additional objects and advantages of the invention will be readily apparent from reading the following description of devices constructed in accordance with the invention and by reference to the accompanying drawings thereof, wherein:

FIG. 1 is a vertical view, partly in section, of a well valve embodying the invention showing the standing valve closed and the safety valve open;

FIG. 2 is a vertical fragmentary view, partly in section, of the upper portion of the valve of FIG. 1 showing the standing valve open;

FIG. 3 is a vertical view, partly in section, of the valve of FIGS. 1 and 2 showing the safety valve closed and the standing valve resting on its seat;

FIG. 4 is a schematic view partly in section of a pumpdown-type well system showing the combination standing valve and safety valve locked in operating position in one of the tubing strings;

FIG. 5 is a fragmentary vertical view, partly in section, illustrating an extension assembly to adapt the valve to the particular type of installation illustrated in FIG. 4;

FIG. 6 is a top view in elevation of one of the pairs of ball pad bearing retainers used in the universal couplings connecting the well valve to a locking mandrel;

FIG. 7 is a view in section of the ball pads along the line 7—4 of FIG. 6;

FIG. 8 is a vertical view, partly in section, of another form of well valve embodying the invention wherein a ball valve functions both as a standing valve and as a seat for the safety valve, showing the standing valve closed;

FIG. 9 is a vertical view, partly in section, of the valve of FIG. 8 showing the safety valve closed;

FIG. 10 is a fragmentary vertical view, partly in section showing a modification of the valve of FIGS. 8 and 9; and

FIG. 11 is a view in section along the line 11—11 of FIG. 10.

Briefly stated, a well valve embodying the invention includes a tubular valve body housing a longitudinally movable tubular safety valve spring biased downwardly to an open position and including a choke or flow bean for effecting a pressure differential in fluids moving upwardly in a tubing string including the valve, which, when it exceeds a predetermined value forces the safety valve upwardly against the spring to a closed position. In one form of the well valve, the tubular safety valve has an external annular valve surface which seats against a corresponding annular valve seat on the valve body to shut off upward flow through the valve in the tubing string. In another form of the valve, the upper end of the tubular safety valve has a valve surface which seats against a ball standing valve shutting off flow through the valve In each form of the valve disclosed and claimed, a ball valve functions as a check or standing valve seating against an upwardly facing surface, in one form on the upper end of the safety valve member shutting off downward flow of fluids in the tubing string through the valve and in another form on an independent valve seat around the upper end of the safety valve.

Referring to the drawings, particularly FIG. 1, a well valve **20** embodying the invention includes a tubular housing **21** which is adapted to be releasably supported in a string of well tubing from a suitable locking mandrel **22** which may be adapted to be coupled with either wire line or pumpdown well-servicing tools for the insertion and removal of the well valve. A safety valve **23** and a check or standing valve **24** are movably disposed within the valve housing. The safety valve assembly functions to limit or shut off fluid flow up the tubing string when certain predetermined flow conditions are exceeded while the standing valve precludes fluid flow in the tubing string to the well below the location of the well valve. The well valve is illustrated at a locked position within a landing nipple **25** secured by a coupling **30** to a lower tubing string **31**. Upward flow in the tubing string through the well valve tends to move the safety valve assembly **43** upwardly to the closed position to prevent upward flow through the well valve. Downward flow in the tubing string through the well valve moves the standing valve **24** downwardly to a seated relationship preventing downward flow in the string through the well valve.

The upper end portion **32** of the valve housing is reduced and threaded to receive a head member **33** which couples the well valve to the locking mandrel and limits upward movement of a seal assembly **33** confined on the housing portion **32**. The seal assembly is held against downward movement by an upwardly facing external shoulder **34** provided on the valve housing at the base of the portion **32**. The valve housing has a longitudinal bore **35** and is provided near its upper end with spaced internal annular flanges **40** and **41** which define an internal recess **42** accommodating an O-ring seal **42***a* sealing within the valve housing around the safety valve **23**. The bore **35** of the valve housing **21** is enlarged and the housing is internally threaded along a lower end portion **44**. A closure ring **45** provided with an external annular upwardly facing stop shoulder **50** is threaded into the lower end of the valve body until the shoulder **50** abuts the lower end face of the valve body. The upper end of the ring **45** defines an upwardly facing internal annular shoulder **51** within the bore of the valve housing. The ring **45** is provided at its lower end with a downwardly and outwardly sloping annular valve seat surface **52**.

The safety valve **23**, which is movably disposed through the valve housing **21** for movement relative to the housing between open and closed positions, has a split retainer ring **53** disposed in an external annular recess **53***a* in the upper end portion of a tubular extension **53** *b* of the valve. The ring **53** is engageable with the top face of the internal flange **40** of the valve housing limiting the downward movement of the safety valve. The extension **53***b* of the safety valve has a bore **54** throughout its length through which fluids flow through the well valve. The upper end of the safety valve extension is provided with an internal annular valve seat surface **60** which coacts with the ball valve **24** to preclude fluid flow downwardly into the bore of the valve body when the well valve is functioning as a standing valve.

A lower end portion **53***c* of the valve body **53** is slightly enlarged defining an external annular upwardly facing stop shoulder **61** which supports a spring retainer ring **62** engaged by the lower end of the biasing spring **63** which bears at its upper end against the lower face of the valve housing flange **41**. Thus, the spring **63** biases the safety valve **23** in a downward direction, and in the absence of force of sufficient strength acting upwardly against the spring the safety valve is held by the spring at the open position illustrated in FIG. **1**. The lower end portion **53***c* of the safety valve extension tube has an external annular guide flange **64** provided with an upwardly and inwardly sloping upper surface **65**. The flange **64** is received within a counterbore **45***a* in the lower end of the ring **45** aiding in maintaining the alignment of the safety valve. Above the flange surface **65**, the safety valve extension tube has a plurality of circumferentially spaced flow ports **70** which allow flow into the bore of the valve when the valve is at the downward open position shown in FIG. **1**.

A valve nose **71** is threaded on the lower end of the valve extension **53***b* closing the lower end of its bore **54** so that fluids must flow through the ports **70** into the bore. The valve nose has a transverse bore **72** communicating with a longitudinal bore **73** to allow fluid flow past the nose if it engages or becomes lodged against another tool or a seat or the other restriction in the tubing string so that a pressure differential does not develop across the nose. The nose has a valve surface **71***a* on its upper end at an angle to seat against the valve surface **52** on the ring **45** for closing the safety valve.

A flow bean **74** provided with an orifice **75** is threaded into the valve extension tube portion **53***c* above the ports **70**. The size of the orifice **75**, the strength of the spring **63**, and the area within the seal ring **42***b* determine the fluid flow conditions necessary to move the safety valve upwardly to its upper closed position. The orifice **75** produces the pressure differential in the flowing fluid which effects the upward force against the spring **63** to close the safety valve. Thus, adjustments of the compression of the spring **63**, changes in the spring itself, and in the flow bean **74** provide flexibility in the control of the flow conditions which operate the safety valve.

The head member **33** has a reduced neck portion **80** provided with an outwardly flared end portion **81** having an external annular spherical surface portion **82**. The end portion **81** is confined within a pair of semicircular ball pads **83** held by a cap ring **84** threaded on the lower end of the locking mandrel body **85**. The ball pads **83** have internal spherical surfaces **90** which engage and coact with the spherical surface **82** on the head **81** to swivelly support the well valve head member **33** from the locking mandrel **22**. The ball pads **83** are constructed in two halves as seen in FIGS. **6** and **7**. In assembling the tool **20** and the locking mandrel **22**, the cap **84** is placed over the head **81** and lowered along the neck **80** until the ball pads **83** are maneuvered into place below the spherical surface **82**. The cap is then raised and threaded on the lower end of the mandrel body **85** of the locking mandrel. During assembly of the well valve and the locking mandrel a transverse pin **91** is inserted across the flow passage through the locking mandrel in suitably positioned holes provided through opposite sides of the mandrel body.

The pin **91** functions as an upper stop for the ball valve **24**, FIG. **2**. The sole function of the pin **91** is to confine the standing valve ball at the upper end of the well valve during up-flow through the well valve at which time the standing valve is, of course, inactive.

The locking mandrel **22** from which the well valve **20** is supported in the landing nipple **25** against both upward and downward movement, may be any suitable well tool locking device manipulated either by wire line or pumpdown equipment and procedures. The drawings show the lower portion of a Type "J" Lock Mandrel Assembly manufacture by Otis Engineering Corporation, Dallas, Tex. and illustrated in detail in the ENGINEERING CATALOG of Otis Engineering Corporation at pages 510 JO. 3 and 510 JO. 4, dated Aug. 12, 1968. The "J" Lock Mandrel Assembly is accommodated to the well valve **20** by inclusion of the stop pin **91** in the body mandrel **85** of the lock mandrel assembly. The lock mandrel assembly is supported from and coupled with wire line and pumpdown running and pulling tools of the Otis Type "GR" illustrated at pages 540 **I GR**. 1 and 541 GS. 1 of the Otis Engineering Catalog dated Aug. 12, 1968. Also, the well valve **20** may be supported from a Type "X" Otis Locking Mandrel illustrated and described at pages 3766 –3767 of the Composite Catalog of Oil Field Equipment and Services, 1968 –69 Edition, published by World Oil Company, Houston Tex. The well valve is coupled with the Type X Mandrel by minor modification of the lower end portion of the body of the Type X Mandrel to accommodate the stop pin **91** and receive the ball portion **81** of the head **33** on the well valve so that the retainer ring **84** is threaded on the lower threaded end portion of the Type X Otis Locking Mandrel. It will be evident, also, that other available locking mandrel assemblies which will lock the well valve against upward and downward movement may be adapted to support the well valve in a tubing string.

The locking dogs **100** of the locking mandrel **22** as illustrated in FIG. **1** are expanded by a locking sleeve **101** of the locking mandrel so that the locking dogs are received in an internal annular locking recess **102** of the landing nipple **25** for holding the well valve and locking mandrel assembly against both upward and downward forces in the well tubing string so that the well valve is maintained in position to function as either a standing valve or a safety valve.

In operation the well valve is run into the well tubing string to the landing nipple **25** of a well where the conditions prevailing in the well require protection of the formation against backflow from the tubing string by the standing valve and protection of the well system from excessive, possibly damaging, formation pressures by the safety valve. The standing valve function is especially important in situations where pumpdown techniques are employed for remote hydraulic servicing of wells and permits the required fluid pressures to be employed for fluid circulation in the pumpdown systems with the wells and with the pumpdown systems.

When the will valve **20** is installed at the position illustrated in FIG. **1**, and presuming for purposes of this discussion that the well is initially shut in and thus conditions are static within the well bore at the well valve, the safety valve spring **63** is expanded to its maximum extent. The lower end of the spring **63** bears against the ring **62** which engages the shoulder **61** on the safety valve extension tube **53***b* holding the safety valve at its full-open position as shown in FIG. 1 with the downward movement of the safety valve being limited by the engagement of the split ring 53 with the top face of the internal flange 40 of the extension tube. Thus, the ports 70 of the safety valve are exposed to the bore of the well tubing 31 below the ring 45 permitting fluid communication from the tubing string bore below the well valve into the bore 54 of the safety valve. Since fluid conditions are static in the well bore at the well valve, the standing valve 24 is caused by gravity to rest on the seat 60 at the top end of the safety valve extension 53*b*. When the well is then placed in production by whatever flow means are employed, such as by pumping, natural flow, and the like, fluid in the tubing string below the well valve flows upwardly in the string entering the well valve through the ports 70 and passing upwardly through the aperture 75 of the flow bean 74. The fluid flows upwardly in the safety valve bore 54, past the standing valve 24 which is lifted off its seat 60, and, if the fluid flow conditions are sufficient, the ball is lifted to the stop in 91 as shown in FIG. 2 which prevents further upward movement of the ball valve. The well fluids flow around the ball valve and on upwardly through the bore of the locking mandrel and the well tubing above the well valve and locking mandrel, not shown to the surface. So long as the well fluids flow upwardly in the tubing string below the operating level of the safety valve, the safety valve remains at its open position as shown in FIG. 1 with the standing valve lifted off its seat and more likely at the upper stop position of FIG. 2. As the fluid flow rate increases through the well valve, the pressure drop through the flow bean aperture 75 imposes an upward force on the safety valve which, when it exceeds the downward force of the spring 63, moves the safety valve upwardly until the valve is lifted to its closed position as represented in FIG. 3, shutting off tall upward flow through the well valve. The safety valve is fully closed when the valve seat 71*a* engages the seat 52 on the ring 45. The ports 70 of the safety valve are above the coengaging seats of the valve and the ring 45 and thereby exclude the well bore below the safety valve from communication with the safety valve bore above the ports 70. The safety valve remains in this closed position so long as the pressure differential across it is sufficient to provide a force which exceeds the downward force of the spring 63 and the hydrostatic head at the valve. The force of gravity causes the standing valve ball member to drop downwardly to rest on the seat 60 as in FIG. 3. When the pressure differential across the well valve drops below the predetermined level at which the safety valve closes, the spring 63 expands returning the safety valve downwardly separating the seats of the valve and the ring 45 to again permit the ports 70 of the valve to communicate with the well bore below the well valve.

At any time, during the production and servicing of the well, that there is downward flow in the tubing string through the well valve, the standing valve ball member 24 is carried by the flowing fluids to the seated relationship shown in FIG. 1 effecting a seal between the outer surface of the all with the seat surface 60 on the upper end of the safety valve shutting off downward fluid flow into the bore 54 of the safety valve. Thus, no backflow occurs through the well valve.

FIG. 5 well structure for supporting the well valve, particularly where it is to be used in a pumpdown well system of the character illustrated in FIG. 4. The well valve is spaced from a coupled with the locking mandrel 22 by an extension assembly 110 which has a body member 111 provided with a reduced upper neck portion 112 having an enlarged end portion 113 with an external spherical surface 114. The extension assembly is pivotally connected at its upper end to the locking mandrel 22 in the same manner as the well valve 20 is coupled with the locking mandrel in FIG. 1. A retainer ring 84 threaded on the lower end of the lock mandrel body 85 holds the ball pads 82 around the spherical surface portion 114. This provides a swivel coupling permitting sufficient relative movement between the extension assembly and the locking mandrel to negotiate the curved portions of the tubing string of the well system. The lower end of the extension assembly is pivotally connected with the well valve 20 in exactly the the standing manner using identical components as the connection between the lock mandrel and well valve shown in FIG. 1.

In the well system shown in FIG. 4 a well 120 is drilled into the ocean bottom 121 at a horizontally spaced position from a platform 122 which supports the necessary well head equipment for producing and servicing a well. Two tubing strings 123 and 124 extend from the platform along the ocean bottom into the well. Within the well, the tubing strings are interconnected by a crossover connection 125 so that a complete fluid circulation path may be established from the platform into the well and back to the platform. The platform end of the tubing 123 has a lubricator 130 between spaced valves 131 and 132 to provide means for introducing tools into the tubing string while the well is under pressure. A pump, not shown, is connected to the lubricator to apply fluid pressure to pump well tools through the tubing string. The platform end of the tubing string 124 is provided with a valve 133 and may be provided with flow lines and other equipment for producing and servicing the well. A plug 134 is releasably secured at the lower end of the tubing string 124 below the crossover 125. The landing nipple 25 is included in the tubing string 123 above the crossover 125 so that the locking mandrel 22 may be secured in the tubing string above the crossover.

A well valve 20 coupled with the extension assembly 110 is installed in the well system illustrated in FIG. 4 in accordance with known pumpdown procedures, certain steps of which are discussed and illustrated in U.S. Pat. No. 3,378,080, issued to John V. Fredd, Apr. 16, 1968. In accordance with these procedures, a tool train, not shown, including the well valve, extension assembly and locking mandrel 22 are pumped to and locked at the landing nipple 25 as illustrated in FIG. 4. At this position within the well, the extension assembly permits the locking mandrel to support the well valve below the crossover connection 125 while the locking mandrel is positioned above the crossover assembly so that the installing and retrieving tools may readily be pumped to the landing nipple and returned to the surface by remote hydraulic control. The tools will at all times remain above the crossover 125 and thus within the closed circuit fluid flow pattern necessary for pumping well tools into and out of the well. With the locking mandrel and installing and retrieving tools above the crossover and the well valve 20 below the crossover, fluid circulation is readily accomplished between the tubing strings 123 and 124 for servicing the well by pumpdown techniques while the standing valve of the well valve 20 protects the formation communicating with the tubing string 123 below the well valve from any pressures applied to the circulating fluid. It will be evident, of course, that this condition exists or is valid at those times only when the well valve is in position below the crossover. During such other times as when the well valve is being pumped to the desired depth in the tubing string 123 and when it is being removed and is above the crossover 125, it obviously cannot protect any of the well system below the cross over from the pressure of the circulating fluids.

FIGS. 8 and 9 illustrate another form of well valve embodying the invention and providing both standing valve and safety valve functions. Referring to FIG. 8, a well valve 150 embodying the invention is illustrated at a locked operating position within the landing nipple 25 which is connected with the lower tubing string portion 31 by the coupling 30. The well valve is supported in the landing nipple from the locking mandrel 22 which is coupled with the well valve and comprises the same components previously described.

The well valve 150 includes a tubular housing 151 enclosing a safety valve 152 and standing valve 153. The valve housing has a lower portion 154 which is internally threaded along its lower end portion, an enlarged central portion 154*a* providing an upwardly facing external stop shoulder 155, and a reduced upper end portion 154*b* which is externally threaded and provides an internal downwardly facing stop shoulder 160. The shoulder 160 is engaged by the upper end of a safety valve biasing spring 161 confined in an annular space 162 defined between the safety valve and the well valve housing **151**. The valve housing portion **154*b*** has an internal annular recess in which O-ring seal **163** is disposed to seal between the valve housing and the safety valve **152**. The well valve housing has a head member **164** threaded on the upper housing portion **154*b*** and locked against movement thereon by a setscrew **165** threaded through the head member against the outer surface of the housing portions **154*b*** . The head member has a reduced neck portion **170** provided with an enlarged ball-shaped end portion **171** held by the ball pads **82** in pivotal engagement with the locking mandrel **22**.

An annular standing valve seat **180** is supported on the upper end of the well valve housing **151** for engagement by the standing valve **153** as shown in FIG. **8** to shut off fluid flow downwardly through the well valve. An annular standing valve stop member **181** is supported on the valve seat **180** between the valve seat and an internal annular stop shoulder **182** within the head member **164**. The valve seat **180** and the standing valve stop member **181** are thus confined within and by the head member on the upper end face of the valve housing **151**. The stop member **181** has circumferentially spaced upwardly extending fingers **183** on a base ring **184** and defining circumferentially spaced upwardly opening slots **185**. The fingers **183** each have an inwardly thickened head portion **190**. The finger head portions of the stop member limit the upward movement of the standing valve ball **153** to the position of its broken line representation in FIG. **8**, while the finger configuration of the stop member provides the circumferentially spaced slots **185** through which upwardly flowing fluid may flow around the standing valve when it is at an upper open position above the seat **180**. Also, the finger head portions hold the standing valve ball member in place at an upper end position to cooperate with the safety valve in shutting off upward flow through the well valve as discussed in more detail below.

A seal assembly **191** is confined between the lower end face **164*a*** of the valve housing head member **164** and the stop shoulder **155** on the valve housing for sealing around the well valve within the landing nipple.

The safety valve **152** has an enlarged lower end portion **152*a*** providing an upwardly facing external stop shoulder **192** which supports a spacer ring **192*a*** urged downwardly by the lower end of the spring **161** to bias the safety valve downwardly. A tubular retainer ring **193** is threaded into the lower end of the valve housing **151**. The upper end face **193*a*** of the retainer **193** is engageable by the lower end face **152*b*** of the safety valve limiting the downward movement of the safety valve in the well valve housing. The retainer ring has a transverse bore **194** connecting with a longitudinal flow passage **195** extending throughout the length of the safety valve and coincident with the longitudinal bore **200** of the safety valve.

The upper end of the safety valve **152** is provided with an internal annular seat surface **201** which engages the standing valve ball **153** when the safety valve is at its upper end position shutting off upward fluid flow through the well valve. A flow bean **202** having an aperture **203** is threaded into the lower end of the bore of the safety valve to restrict flow through the safety valve. The pressure drop across the flow bean effects an upward force on the safety valve opposed by the spring **161**. When that force exceeds the resistance of the spring, the safety valve is moved upwardly to its closed position.

The assembly of the well valve **150** and the locking mandrel **22** is installed and retrieved with the same apparatus and by the same techniques, wire line or pump down, as described in connection with the handling of the well valve **20** illustrated in FIG. **1**. When the valve **150** is in operating position within the well tubing, the condition of the valve during normal shut-in pressure and flow conditions is as represented in FIG. **8**. The safety valve **152** is biased downwardly to a lower end position by the spring **161** tending to expand between the valve housing shoulder **160** and the ring **192*a*** bearing against the safety valve shoulder **192**, which is the open state of the valve. Gravity holds the standing valve ball member **153** on its seat **180** which position also represents the position of the standing valve responsive to any downward flow in the tubing string, thereby precluding downward flow in the tubing string through the well valve by virtue of the seated relationship of the ball valve member on its annular seat.

Upward flow in the tubing string enters the lower end of the bore **195** of the ring **193** flowing through the aperture **203** of the flow bean **202** into the bore **200** of the safety valve. The fluid flows upwardly around the ball **153** and from the upper end of the bore of the safety valve lifting the standing valve upwardly to the upper broken line position represented in FIG. **8**. The inwardly extending heads **190** on the fingers **183** prevent further upward movement of the standing valve while fluid is permitted to flow upwardly around the valve within the head **164** past the valve through the longitudinal paths provided by the slots **185** between the fingers of the valve retainer **181**. The upward flowing fluid flows above the standing valve through the locking mandrel **22** into the tubing string, not shown, above the locking mandrel and to the surface. When the upward flow through the well valve produces a pressure drop through the flow bean **202** over an area sealed by the O-ring **163** which effects an upward force on the safety valve exceeding the force of the spring **161**, the safety valve is lifted against the spring until the seat surface **201** on the upper end of the safety valve engages the face of the standing valve **153**, the ball being held against upward movement by the finger heads **190**. When the seat **201** engages the surface of the ball valve, upward flow through the well valve in the tubing string is stopped and remains stopped so long as the safety valve is at this upper end position against the ball valve.

When the pressure differential across the safety valve drops to a level below the holding capacity of the spring **161**, the spring expands returning the safety valve downwardly to its open position. Conditions which would produce a pressure equalization across the valve to permit it to open are valve leakage if the well is shut-in or injection into the well above the valve until the pressure is equalized across it. Any flow conditions which then tend to displace the fluid downwardly through the tubing string at the well valve moves the ball valve member **153** back downwardly to its seat **180** thereby preventing downward fluid flow through the well valve toward well formations communicating with the tubing string.

FIG. **10** illustrates a still further form of the well valve **150** shown in FIG. **8**, such modified valve being referred to by the reference numeral **150A**. The well valve **150A** is identical in all respects to the well valve **150**, except for the substitution of a spacer sleeve **210** and a circular spider **211** for the ball valve retainer **181**. The lower end of the spacer sleeve **210** is engaged with the top face of the ball valve seat member **180** and has a bore **212** larger than the ball valve **153** to allow fluid flow through the sleeve around the ball valve. The spider **211** rests on the top or upper end surface of the sleeve **210** with the spider and sleeve being clamped within the head **164** between its inner shoulder **182** and the top face of the seat **180**. The spider **211** has a plurality of circumferentially spaced inwardly extending fingers **213** for limiting the upward movement of the ball valve **153** while allowing upward flow past the ball valve between the fingers. The ball valve is shown in FIGS. **10** and **11** at its upper position to which it is carried by upwardly flowing fluid and at which it is held by the fingers **213**. The modified well valve **150A** functions both as a safety valve and a standing valve in exactly the same manner as the well valve **150**.

It will now be seen that a new and improved well valve has been described and illustrated. The well valve includes structure which performs the function of both a standing valve to prevent downward flow in a tubing string past the well valve and the functions of a safety valve for limiting upward flow in the tubing string past the well valve when certain predetermined flow conditions are exceeded. The well valve in its several illustrated and described forms includes a ball valve member which seats on a surface responsive to downward flow through the valve. The well valve also includes a tubular, downwardly biased, safety valve which is upwardly movable by fluid flowing through the valve in the tubing string for shutting off upward flow through the valve. One form of the new valve has a standing valve ball member seat on the upper end of the safety valve body while the lower end of the safety valve seats with a surface of the well valve housing to perform the safety valve function. In another form of the well valve, the standing valve ball member engages an annular valve seat around the safety valve for shutting off downward flow and the upper end of the safety valve body has a valve seat which is moved against the ball valve member responsive to upward movement of the safety valve shutting off upward flow through the well valve. Tn this latter form of this valve the ball member is held against upward movement by finger portions on ball valve retainers which restrict or limit the upward movement of the ball valve while allowing fluid to flow through the valve around the member.

The foregoing description of the invention is explanatory only and changes in details in the construction illustrated may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A tool for controlling fluid flow in a flow conductor comprising: tubular housing means; first valve means in said housing means movable to an open position responsive to fluid flow in a first direction and to a closed position responsive to fluid flow in a second opposite direction; and second valve means in said housing means, said second valve means having means for biasing said valve means to a normally open position and being closable responsive to fluid flow in excess of a predetermined value in said first direction.

2. A tool in accordance with claim 1 wherein said first valve means includes a ball valve and said second valve means includes a longitudinally movable tubular valve.

3. A tool in accordance with claim 2 wherein said tubular valve has a first valve seat at one end and said ball valve is engageable with said valve seat on said tubular valve to close said tool against fluid flow in said second direction.

4. A tool in accordance with claim 3 wherein said tubular housing means has a valve seat thereon and said tubular valve has a second valve seat engageable with said valve seat on said housing means for shutting off fluid flow through said tool in said first direction.

5. A tool in accordance with claim 4 including closure means on said tubular valve spaced from said second valve seat on said valve and port means in said tubular valve on the opposite side of said second valve seat from said closure means whereby fluid flow through said port means into said tubular valve is permitted when said second valve seat on said tubular valve is moved to a position spaced from said valve seat on said housing and is closed off when said valve seats on said tubular valve and said housing means are in coengaging relationship.

6 A tool in accordance with claim 5 wherein said biasing means comprises a spring confined between a shoulder on said tubular housing means and a shoulder on said tubular valve for biasing said valve toward an open position at which said valve seats on said housing and said tubular valve are spaced apart to permit fluid flow in said first direction through said well tool.

7. A tool in accordance with claim 3 wherein said tubular valve moves in said first direction against said ball valve to close said tool against fluid flow in said first direction.

8. A tool in accordance with claim 2 wherein a ball valve seat is supported by said housing and engaged by said ball valve responsive to fluid flow in said second direction to shut off flow in said direction and said tubular valve has a valve seat on the end thereof adjacent said ball valve for engaging said ball valve when said tubular valve is moved in said first direction to shut off flow in said direction.

9. A tool as defined in claim 8 including a tubular ball valve stop member secured in said housing means and having circumferentially spaced inwardly extending finger portions for limiting the movement of said ball valve away from said tubular valve and defining flow passage means around said ball valve for fluid flow in said first direction past said ball valve within said housing.

10. A tool in accordance with claim 8 including an annular spider member secured within said housing spaced from said tubular valve and having circumferentially spaced radially inwardly extending fingers for limiting the movement of said ball valve away from said tubular valve while permitting fluid flow within said housing around said ball valve.

11. A tool in accordance with claim 2 including an extension assembly pivotally connected at one end with an end of said tubular housing and pivotally connected at the other end with a locking mandrel for releasably securing said tool in a landing nipple in a tubing string.

12. A well valve for controlling fluid flow both upwardly and downwardly in a tubing string in a well bore comprising: a tubular housing having an upwardly facing internal stop shoulder near the upper end thereof; a tubular valve concentrically disposed within said tubular housing for longitudinal movement therein; seal means disposed in said housing below said stop shoulder for sealing around said tubular valve; a spring confined within said tubular housing around said tubular valve between shoulders on said housing and said tubular valve for biasing said valve downwardly; a stop ring secured around the upper end portion of said tubular valve and engageable with said upwardly facing stop shoulder within said housing for limiting the downward movement of said tubular valve in said housing to a lower end open position; an annular retainer ring secured to the lower end of said housing and having a valve seat surface on the lower end thereof; means providing a valve seat surface on said tubular valve below said valve seat surface on said retainer ring for shutting off upward flow through said well valve when said tubular valve is at an upper end closed position and adapted to be moved to a position spaced from said valve seat on said retainer ring at said lower open position of said tubular valve; closure means on said tubular valve below said valve seat surface thereon; said tubular valve being provided with port means above said valve seat surface thereof communicating with the bore of said tubular valve below said seat surface on said retainer ring when said tubular valve is at said lower open position; said tubular valve having a seat surface on the upper end thereof; a ball valve disposed within said tubular housing above said tubular valve and engageable with said seat surface on the upper end of said tubular valve to prevent downward flow through said well valve; stop means operatively secured with said housing above said ball valve for limiting the upward movement of said ball valve to a position spaced from said seat on the upper end of said tubular valve, said tubular housing being larger than said ball valve along the confined path of said ball valve within said housing to permit fluid flow within said housing past said ball valve when said ball valve is spaced from said seat on said tubular valve; and flow restriction means in said tubular valve for effecting a pressure drop through said valve responsive to upward flow through said well valve for moving said tubular valve to said upper closed position when fluid flow through said flow restriction means exceed a predetermined value.

13. A well valve for controlling both upward and downward fluid flow in a tubing string of a well bore comprising: a tubular housing; a tubular valve disposed within said housing for longitudinal movement therein between an upper closed and a lower open position; a spring confined within said housing around said tubular valve for biasing said tubular valve downwardly toward said lower open position; said tubular housing and said tubular valve having shoulder surfaces engageable with opposite ends of said spring whereby said spring exerts forces in opposite directions against said housing and said tubular valve for biasing said valve downwardly relative to said housing; a retainer ring secured in said tubular housing below said tubular valve limiting the downward movement of said valve within said housing; flow restriction means in said tubular valve for effecting a pressure differential across said

valve responsive to upward fluid flow through said valve whereby said valve is moved upwardly to a closed position when the fluid flow through said flow restriction exceeds a predetermined value; a ball check valve confined within said housing above said tubular valve; ball check valve retainer means secured within said tubular housing above said ball check valve and having circumferentially spaced inwardly extending stop members for limiting the upward movement of said ball check valve to a position spaced from said tubular valve when said tubular valve is downward from the upper closed position of said valve; said tubular valve having a seat on the upper end thereof engageable with said ball valve for shutting off fluid flow through said tubular valve when said seat on said tubular valve is engaged with said ball valve; said well tool shutting off upward fluid flow when said tubular valve is at an upper end position engaging said ball valve and said well tool shutting off fluid flow downwardly therethrough when said tubular valve is at a lower end position and said ball valve is seated on the upper end thereof.

14. A well valve in accordance with claim **13** including an annular ball valve seat in said housing around said tubular valve above said tubular valve when said tubular valve is at said lower end position whereby said ball valve engages said annular seat responsive to downward flow in said well valve shutting off downward flow through said well valve.