United States Patent

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Pat. No. 3,411,576.
[45] Patented Mar. 9, 1971
[73] Assignee Otis Engineering Corporation
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[54] **WELL TOOLS**
15 Claims, 21 Drawing Figs.

[52] **U.S. Cl.** **137/613,** 137/614.2
[51] **Int. Cl.** **E21b 23/00**

[50] **Field of Search** 137/613, 614.2, 495, 496; 251/62; 166/224

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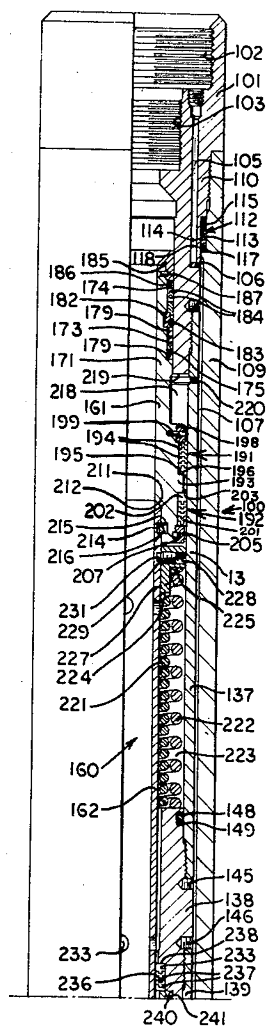
ABSTRACT: This invention relates to well tools and more particularly to a flow conductor assembly for use in a well installation employed during the drilling of a well and to well tools usable in such flow conductor assembly.



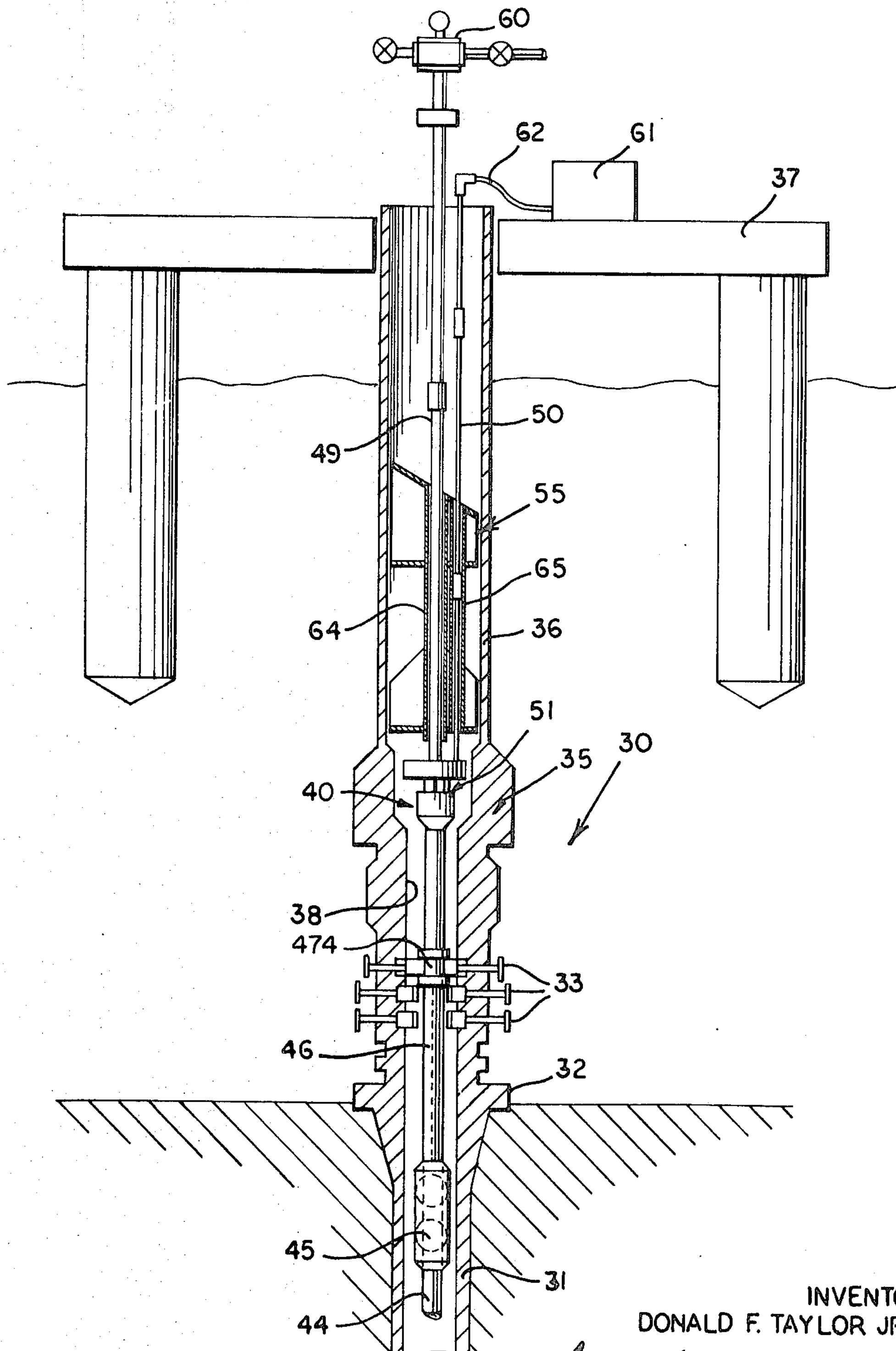


FIG.-1

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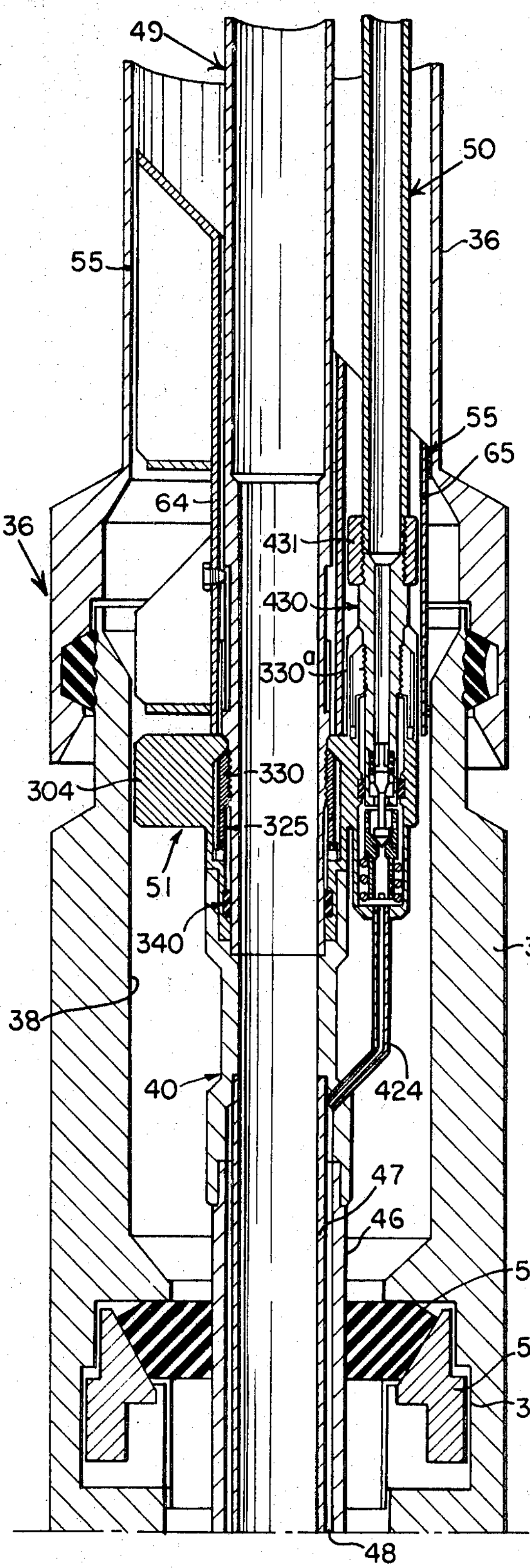

FIG.-2

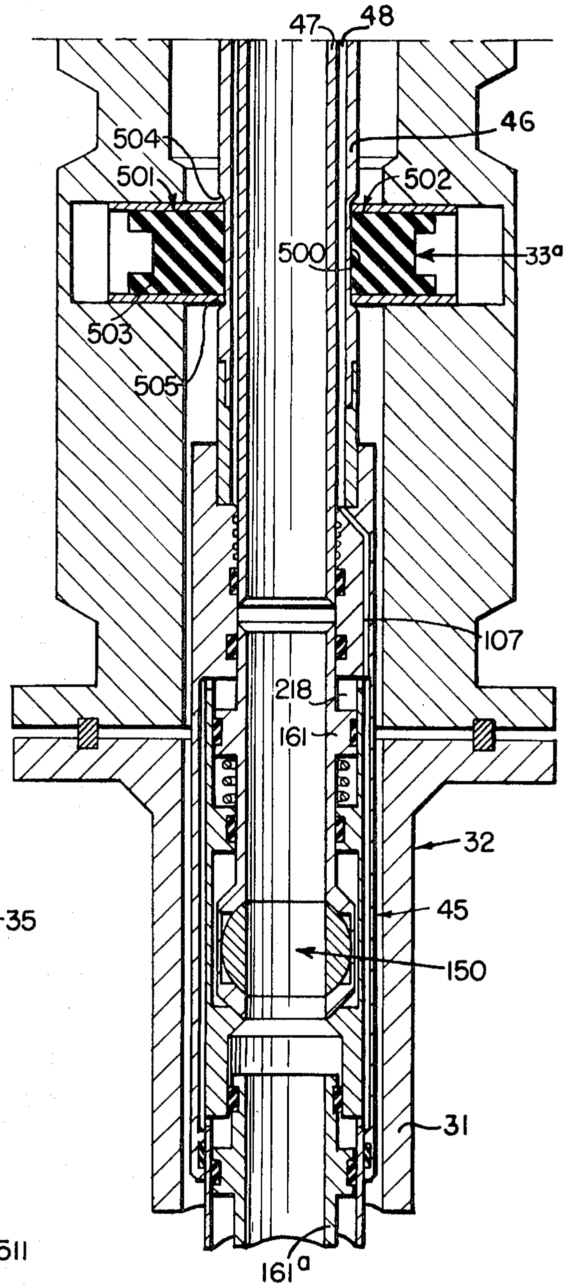

FIG.-3

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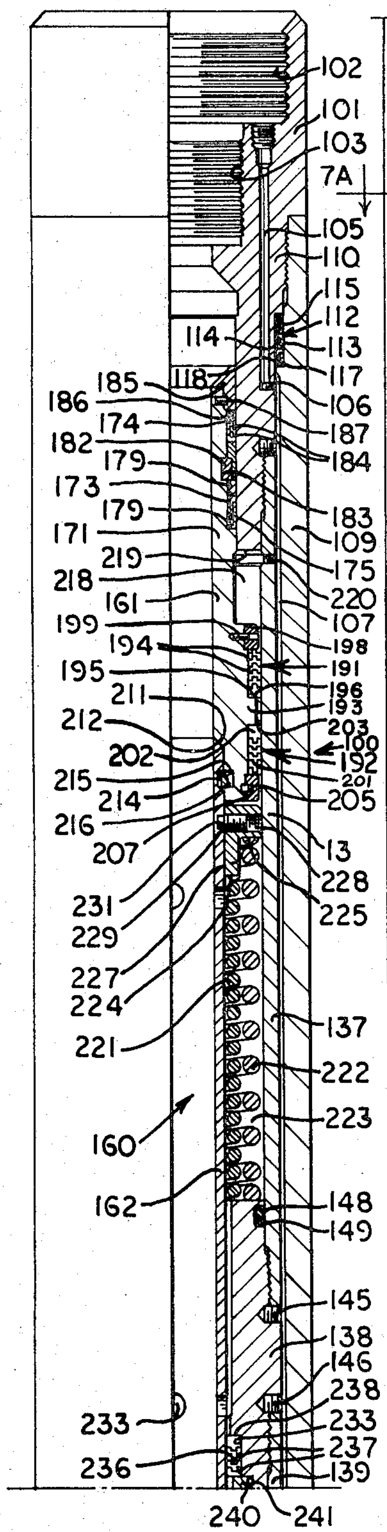

FIG.-4

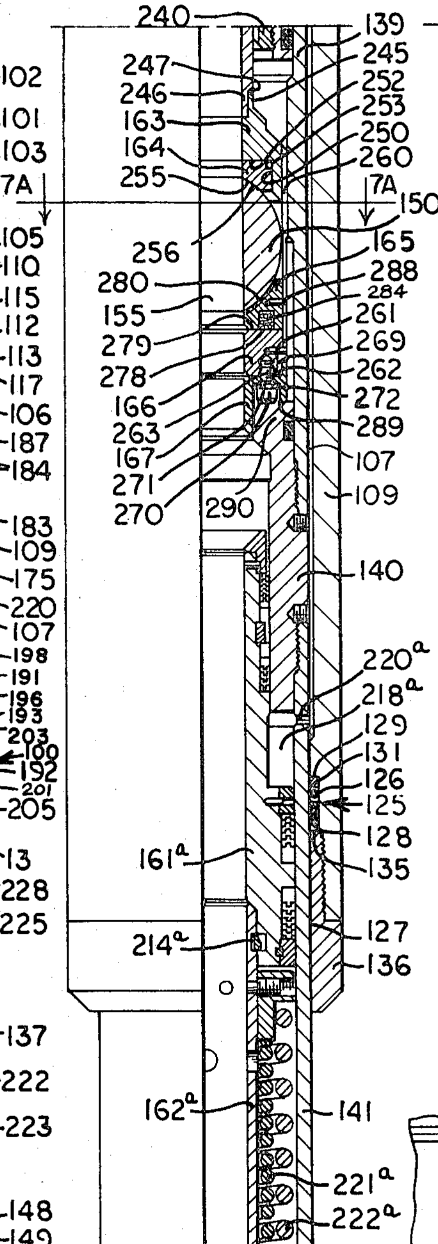

FIG.-5

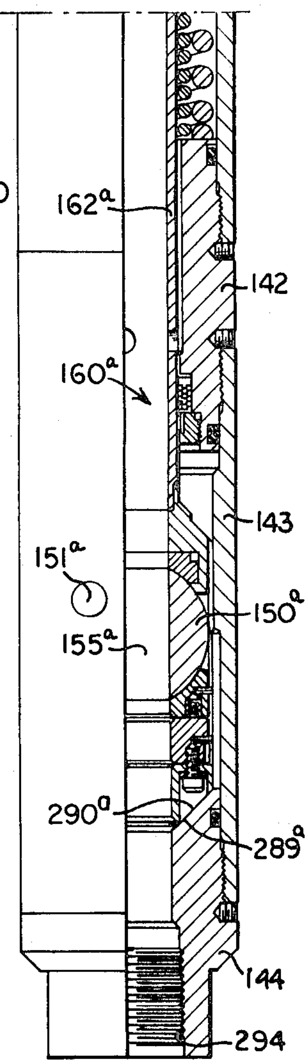

FIG.-6

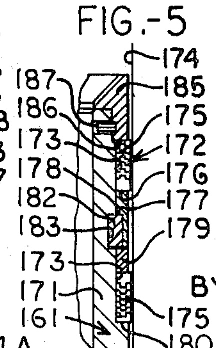

FIG.-4A

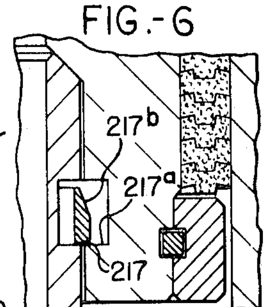

FIG. 4-B

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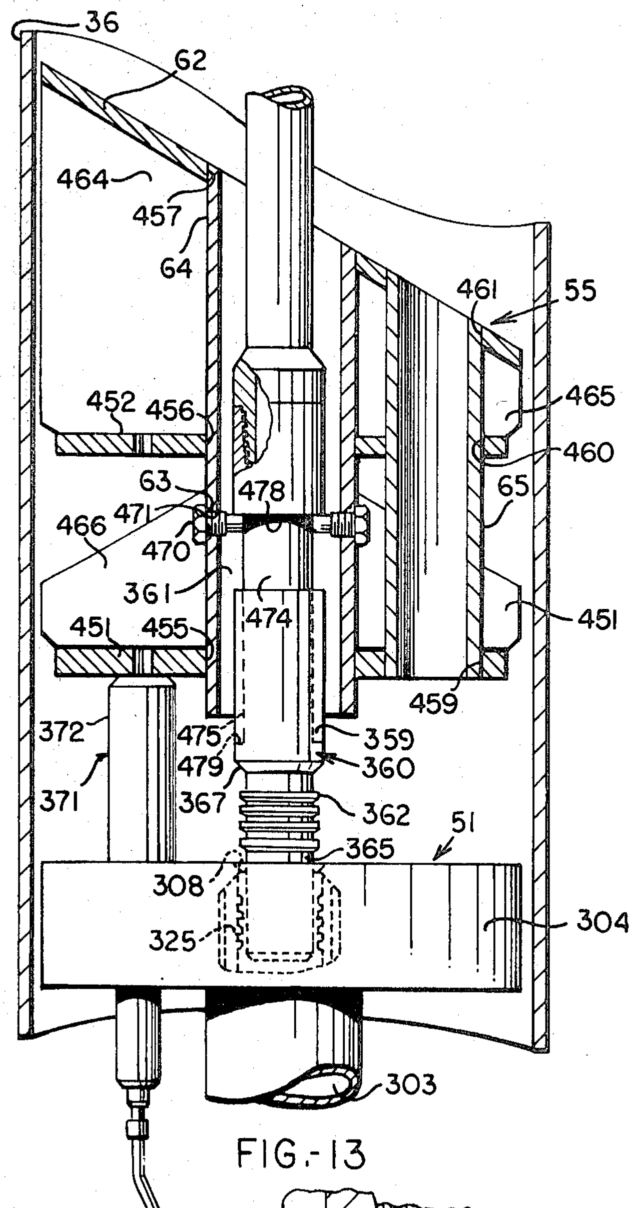

FIG.-13

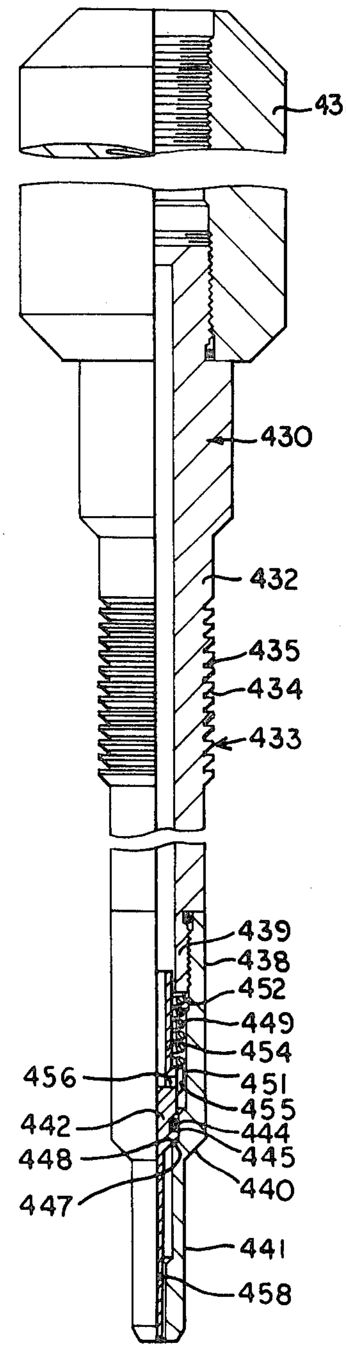

FIG.-12

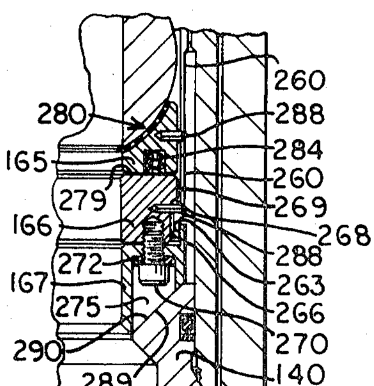

FIG.-7

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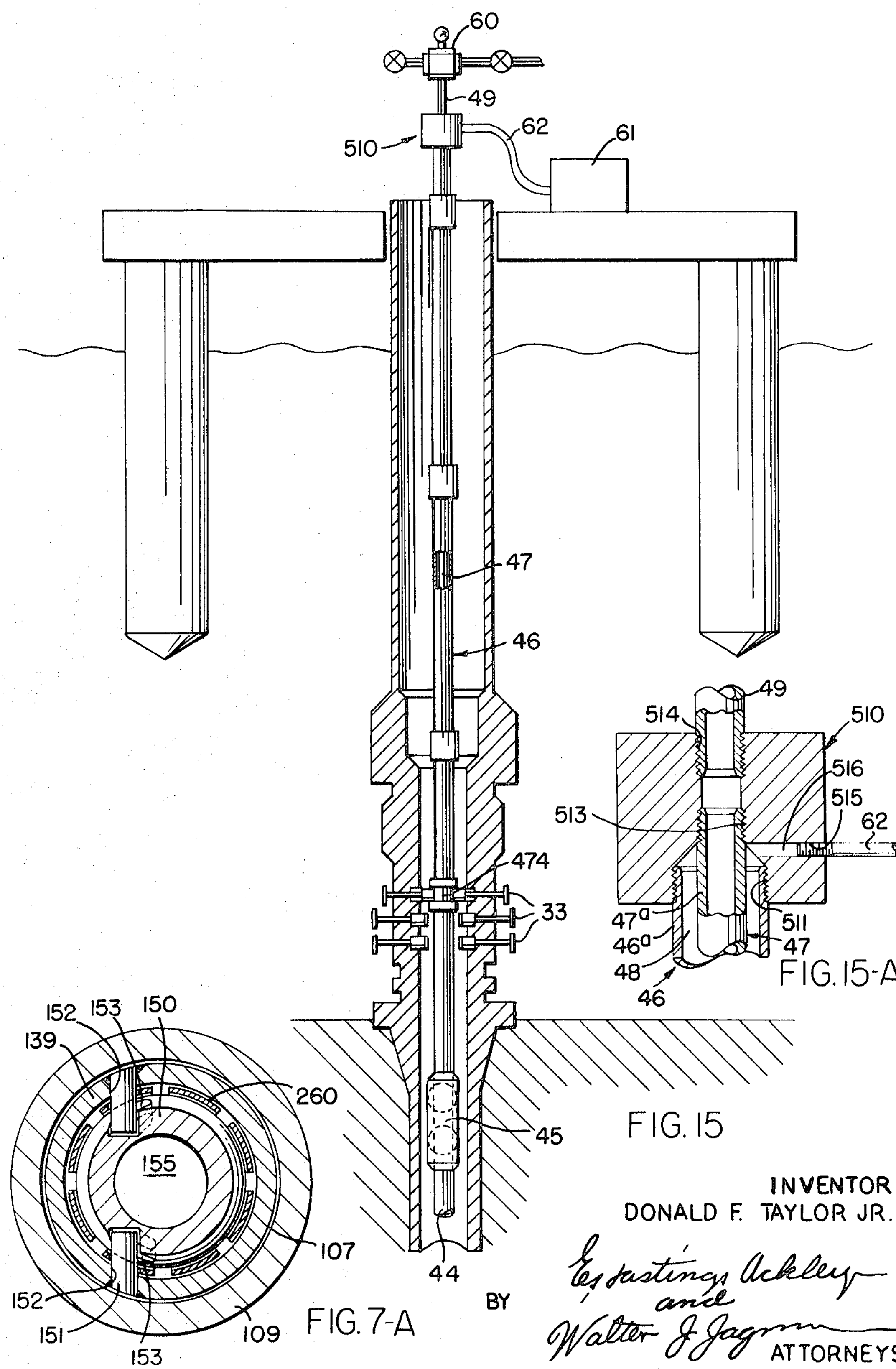

FIG. 15-A

FIG. 15

FIG. 7-A

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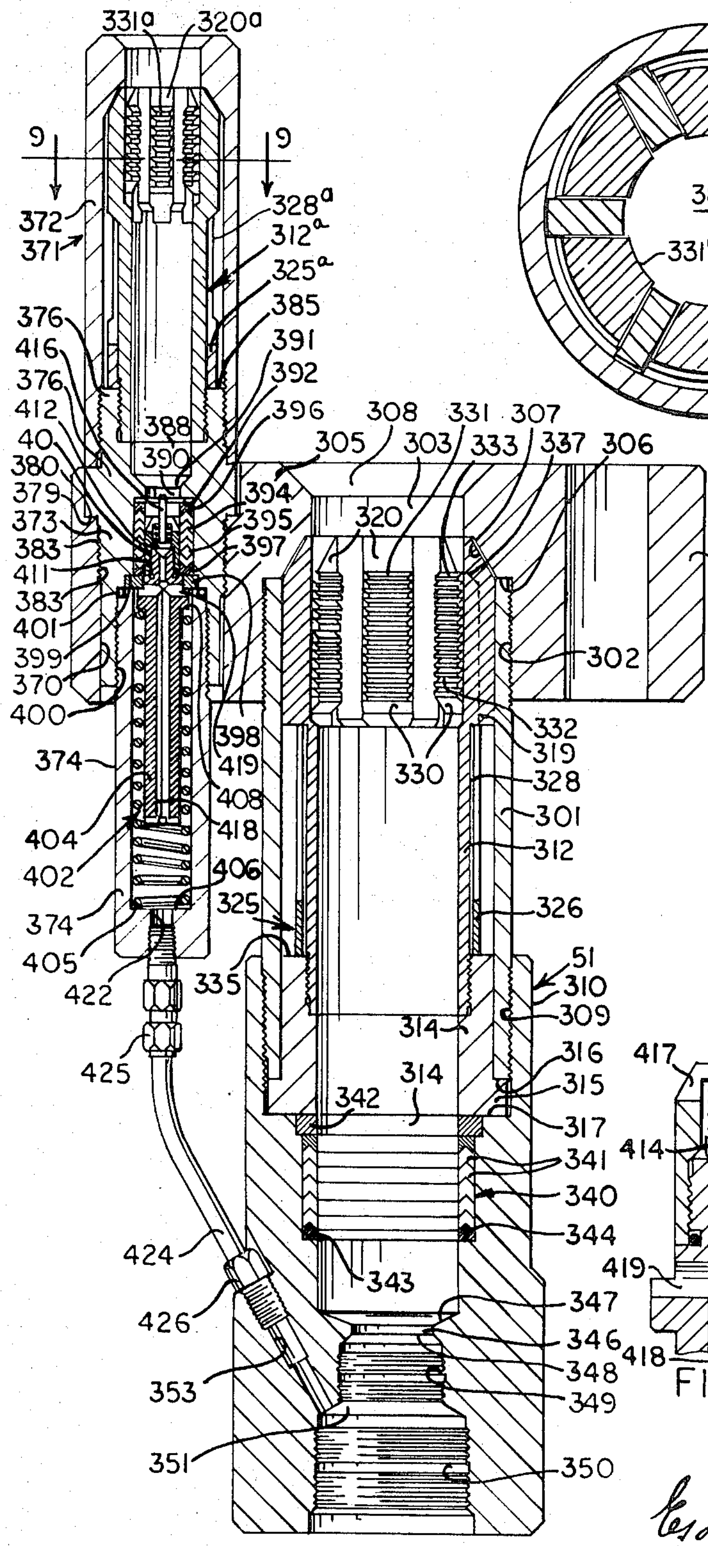

FIG.-8

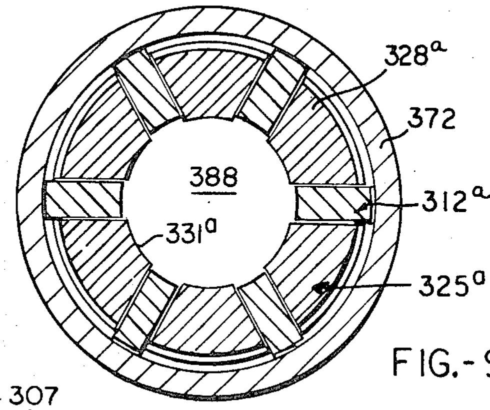

FIG.-9

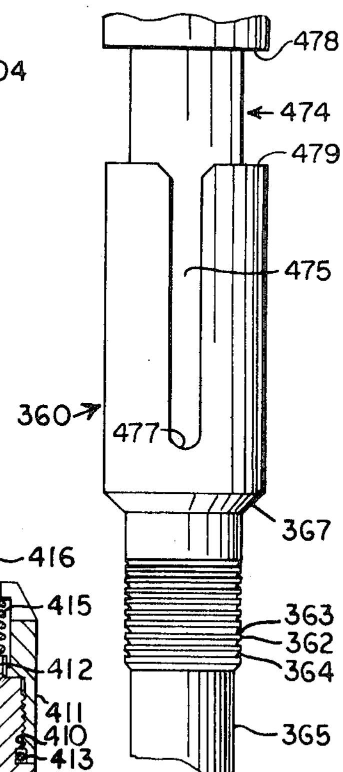

FIG.-10

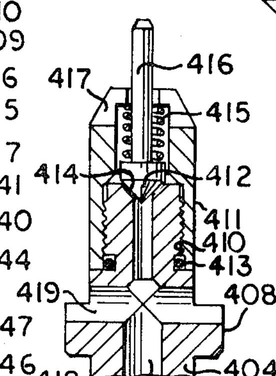

FIG.-11

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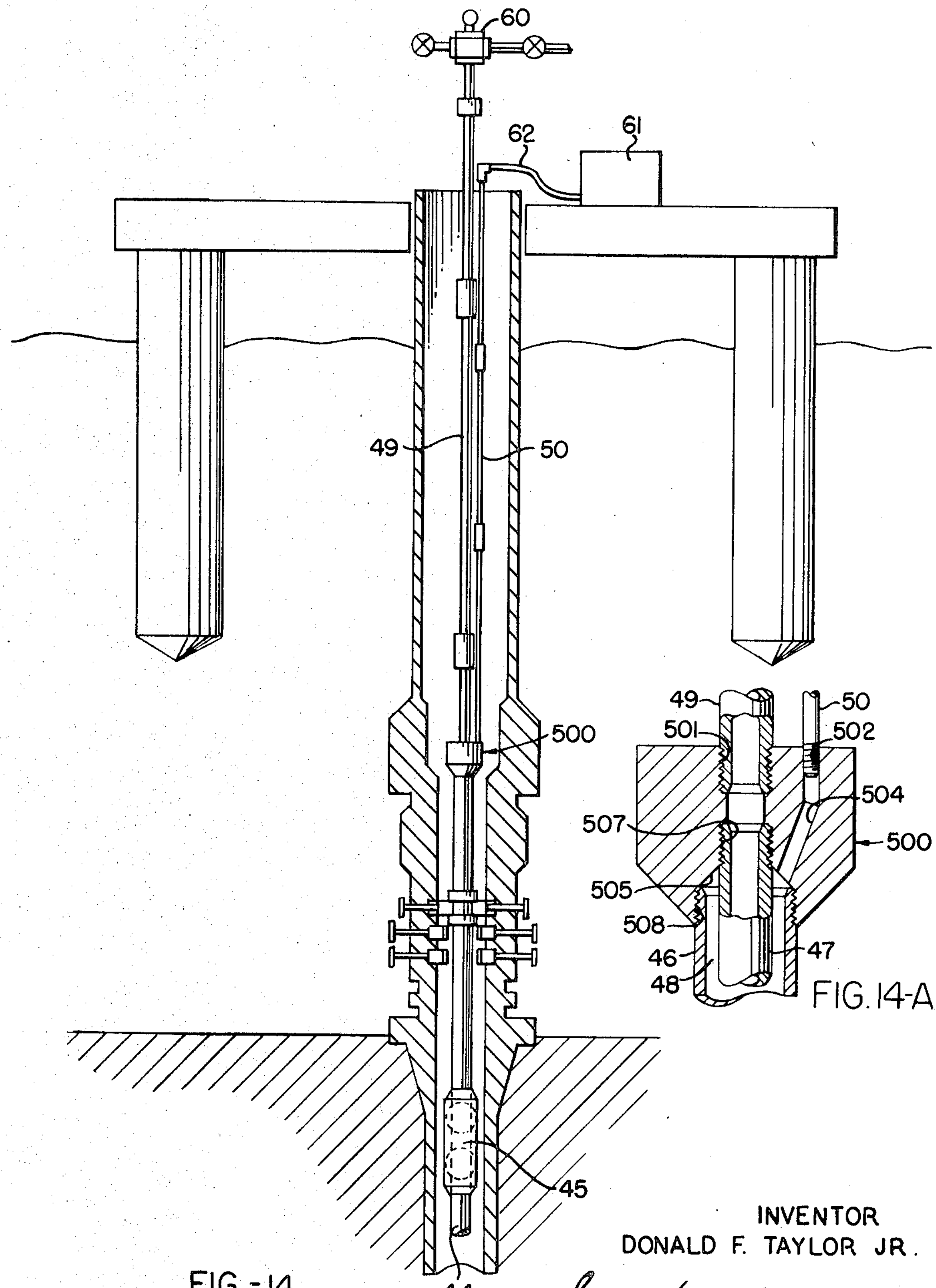

FIG.-14

FIG. 14-A

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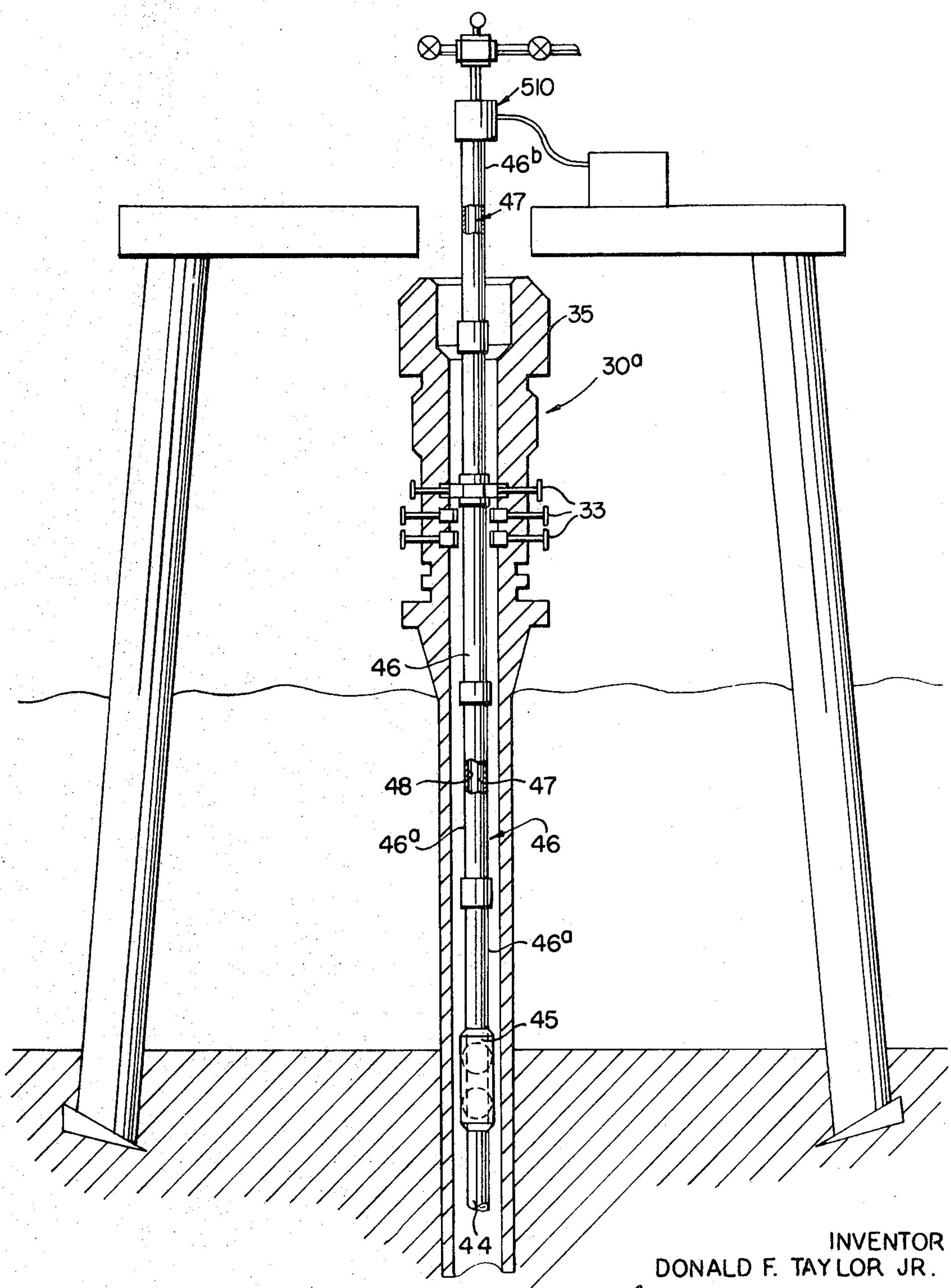

FIG.-16

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WELL TOOLS

This application is a division of Ser. No. 469,978 filed Feb. 8, 1968 now U.S. Pat. No. 3,411,576.

An object of this invention is to provide a new and improved flow conductor assembly, which is installable in the well installation employed during the drilling of a well, through which various operations may be performed, such as perforating, short time production testing, and the like.

Still another object is to provide a flow conductor assembly which is held in place in the well installation by a blowout preventer of the well installation which was used in the drilling of the well.

Still another object is to provide a flow conductor assembly having a flow conductor through which fluids may flow between the surface and the well which is provided with a valve located below the blowout preventer and which may be controlled from the surface.

A further object is to provide a flow conductor assembly in which the valve is biased toward its closed position and which is movable to open position by means controllable from the surface.

A still further object is to provide a flow conductor assembly having a flow passage through which a control fluid is conducted to the valve from the surface wherein the valve is moved to open position by increasing the pressure of the control fluid at the surface.

Still further object is to provide a flow conductor assembly which permits movement of well tools therethrough into and from the well.

Another object is to provide a well flow conductor assembly usable in a well installation employed in the drilling of a well below a body of water wherein the well installation provides a continuous passage from above the surface of the water into the well and wherein the valve of the flow conductor assembly is positioned near the ocean floor when the well installation is positioned in the well and being held by a blowout preventer which closes the continuous passage about the well flow conductor assembly.

Still another object is to provide a flow conductor assembly including a valve connectable to the top of a tubing which extends into the well and a pair of telescoped concentric flow conductors connected to the upper end of the valve, the inner flow conductor conducting fluid being in alignment and communication with the tubing when the valve is open and the telescoped conductors providing a passage therebetween through which control fluid from the surface is transmitted to the valve to open the valve.

Still another object is to provide a flow conductor installation wherein the outer flow conductor is provided with a means engageable by the blowout preventer of a well installation for holding the flow conductor assembly against movement in the well installation.

A further object is to provide a flow conductor assembly wherein a connector head is connected to the upper ends of the telescoped flow conductors and has passages communicating with the inner flow conductor and the control fluid passage wherein the connector head has means for detachably securing a large flow conductor thereto for communication with the inner flow conductor and a small control fluid flow conductor for communication with the passage provided by the telescoped conductors.

A still further object is to provide a latch mandrel for a flow conductor releasably engageable with a latch means of the flow conductor when it is inserted downwardly and placed in communication with the inner concentric flow conductor thereinto and which is not releasable thereon except upon rotation of the latch mandrel.

A still further object is to provide a latch mandrel and valve assembly for the use with a second flow conductor which is engageable with a latch means of the connector head wherein it is inserted into another passage of the connector head and placed into communication with the control fluid flow passage of the concentric conductors and which is releasable therefrom only upon rotation thereof.

Another object is to provide a new and improved guide usable with the latch mandrel for orienting the latch mandrel and the latch mandrel and valve assembly with the two passages of the connector head.

Still another object is to provide a flow conductor assembly having means a new and improved connector head usable in the flow conductor assembly which is provided with latch means engageable with latch mandrel to releasably secure the flow conductors inserted therein against nonrotational displacement therefrom.

An important object of the invention is to provide a valve having a housing in which a pair of balls provided with axial passages are mounted, each of which is separately biased toward its closed position and has an operator means for moving it to open position, the housing having means for simultaneously conducting control fluid under pressure to the two operator means to cause the balls to be moved to their open positions.

Still another object is to provide a valve wherein each operator means includes a piston and a piston member releasably secured to the piston, the piston member being biased upwardly to hold the ball in closed position, the ball being moved to open position when the pressure thereabove exceeds the pressure therebelow by a predetermined value sufficiently great to release the piston member from the piston and overcome the force biasing the piston member upwardly.

Still another object is to provide a valve wherein the housing is provided with a flow passage through which control fluid under pressure is transmitted to the piston to move the piston member and therefore the ball to its open position against the force exerted thereon by the means biasing the piston member.

A further object is to provide a new and improved guide for orienting successively a large flow conductor and a small flow conductor in alignment with the upper ends of the passages of a connector head.

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

FIG. 1 is a schematic illustration of a well installation with a flow conductor assembly embodying the invention extending therethrough;

FIG. 2 is an enlarged sectional schematic illustration showing an intermediate portion of the flow conductor assembly in position in the well installation;

FIG. 3 is a view similar to FIG. 2 being a continuation thereof showing a lower portion of the flow conductor assembly;

FIG. 4 is a vertical, partly sectional view of the upper portion of the valve of the flow conductor assembly;

FIG. 4A is a fragmentary enlarged view of a portion of the valve;

FIG. 4B is an enlarged fragmentary view of another portion of the valve;

FIG. 5 is a view similar to FIG. 4, being a continuation thereof showing an intermediate portion of the valve;

FIG. 6 is a view similar to FIG. 5, being a continuation thereof, showing the bottom portion of the valve;

FIG. 7 is an enlarged fragmentary sectional view of a portion of the valve;

FIG. 7–A is a sectional view taken on line 7–A–7–A FIG. 5;

FIG. 8 is a vertical sectional view of the connector head of the flow conductor assembly;

FIG. 9 is an enlarged sectional view taken on line 9–9 of FIG. 8;

FIG. 10 is a fragmentary side view of a latch mandrel connectable in one passage of the flow conductor assembly;

FIG. 11 is an enlarged fragmentary, vertical, sectional view of the valve of the connector head;

FIG. 12 is a vertical, partly sectional view of a latch mandrel and valve assembly which is connectable in another passage of the connector head;

FIG. 13 is a vertical, partly sectional, view of the guide and the connector head of the flow conductor assembly showing the guide mounted on the latch mandrel of a large flow conductor;

FIG. 14 is a schematic, partly sectional view showing a modified form of the flow conductor assembly in the well installation;

FIG. 14a is a fragmentary, partly sectional view of a modified connector head used in the flow conductor assembly of FIG. 14;

FIG. 15 is a vertical, partly sectional view of another modified form of the flow conductor assembly in the well installation;

FIG. 15–A is a vertical, partly sectional, view of a connector head of the flow conductor assembly illustrated in FIG. 15; and,

FIG. 16 is a vertical, partly sectional view of still another modified form of the flow conductor assembly in a well installation.

Referring now particularly to FIG. 1 of the drawing, the well installation 30 at the bottom of a body of water, which is used during the drilling of the well, includes a casing 31 which is secured in the usual manner to a casing head 32, a stack of blowout preventers 33 mounted on the casing head, a latch head 35 mounted on the uppermost blowout preventer and a riser tube 36 releasably connected to the upper end of the latch head and extending above the surface of the water and through an aperture in a floating work platform 37. This well installation provides a longitudinal continuous passage 38 from above the surface of the water to the well through which a flow conductor assembly 40 may extend and be supported adjacent the bottom of the body of water by means of one of the blowout preventers 33. The blowout preventers may be of any well known and suitable type and be manually operable by divers or may be remotely operated, as for example, hydraulically, in which event the suitable control fluid lines would extend therefrom to the work platform. Such blowout preventers have means for holding a flow conductor which extends therethrough against movement and for sealing therebetween. The flow conductor assembly includes a string of tubing 44 which extends to any desired depth in the well and which usually has a packer (not shown) for closing the annulus between the tubing and the casing above a producing formation, a valve 45 which controls flow of fluids through the string of tubing, and a pair of concentric conductors 46 and 47 which provide an annular passage 48 for the flow of control fluid for controlling operation of the valve 45 connected to their lower ends. The lower end of the inner conductor 47 is placed in communication with the tubing string 44 when the valve 45 is opened. The flow conductor assembly also includes surface flow conductors 49 and 50 and a connector head 51 connected to the upper ends of the concentric conductors. The lower ends of the surface conductors 49 and 50 are releasably connected to the connector head 51 which establishes communication between the large surface conductor 49 and the inner flow conductor 47 and between the small or control fluid conductor 50 and the annular passage 48.

When the flow conductors 49 and 50 are to be secured to the connector head which is already in the passage 38 below the surface of the water, a guide 55 is secured to the large flow conductor 49 and is employed to properly orient the large flow conductor relative to the connector head and also to orient the guide relative to the connector head so that it will be in proper position to guide the lower end of the small conductor properly to the connector head for connection thereto.

In use, after the drilling operations have been completed and while the drilling well installation 30 is still in place and it is desired to perform short time production testing operations on the well, the string of tubing is lowered in the well from the floating working platform 37 by the usual well known equipment and, sequentially, the valve 45 is connected to the upper end of the string of tubing, the concentric flow conductors 46 and 47 are connected to the upper end of the valve, the connector head is connected to the concentric flow conductors and, if desired, the large and small surface flow conductors are releasably connected to the connector head as the string of tubing is lowered into place through the passage 38 into the well.

When the string of tubing and the flow conductor assembly 40 are in desired location in the well installation, at least one of the blowout preventers is operated to engage the outer flow conductor 46 to hold it against upward or downward movement in the well installation 30 and also to seal therebetween. Suitable surface control equipment 60 is connected to the upper end of the large flow conductor 49 to control the flow therethrough and the string of tubing 44 and to permit introduction of well tools into and from the large conductor 49.

Control fluid under pressure is supplied to the upper end of the control fluid conductor 50 and the annular passage 48 between the concentric conductors from a suitable control manifold 61 through a conduit 62 to control operation of the valve 45. Tools may be run through the flow conductor assembly and the tubing string to perforate the casing at the location of the producing formation and, if desired, cementing operations and the like may also be performed by use of the flow control assembly and the tubing string. The valve 45 is closed and opened as required by such operations.

The production of well fluids from such earth formation may then be tested by permitting their flow upwardly through the string of tubing to the surface. The valve may be closed at any desired time by decreasing the fluid pressure which is transmitted thereto from the manifold 61.

If it is necessary to remove the conductors 49 and 50 and the riser pipe 36 from the latch head, as due to the occurrence of storm conditions at the location of the well, the valve 45 is closed and the pipes 49 and 50 are then detached from the connector head as by unscrewing them. The riser pipe is also detached from the latch head. The working platform itself may either be left anchored in place or removed prior to the arrival of the storm. The string of tubing, the valve, the concentric flow conductors and the connector head are now left supported in the well by the blowout preventer. Since the water conditions at the bottom of the body of water are always relatively quiet with little or no wave action, there is little likelihood that the portions of the flow conductor assembly left in the well will be damaged. The valve 45, which is below the blowout preventers, will close the upper end of the tubing in the event that the riser pipe and the flow conductor 49 and 50 are damaged or broken away from the connector and latch head, as in the event the work platform is struck by a vessel or a sudden storm or unpredicted earthquake wave occurs. The latch head being of very strong construction will in all likelihood not be broken away when the riser pipe is so detached or broken away from it.

When the storm ceases of if for any other reason it is desired to come back and reconnect the flow conductor 49 and 50 to the connector head in order to perform further or additional operations on the well, the floating working platform 37 is again positioned over the well head assembly, the riser pipe 36 is connected to the latch head 35 and preferably any water within the well head assembly above the blowout preventer stack is removed, as by pumping. The guide 55 is then mounted on the lowermost end of the large flow conductor 49 and is lowered through the riser pipe. The guide which includes a large tubular member 64 and a small tubular member 65 will not permit connection of the flow conductor 49 to the connector head 51 until the guide is so oriented relative to the connector head that its small tubular member 65 is properly positioned over the connector head to guide properly the small flow conductor 50 to the connector head. The large surface flow conductor is then connected to the connector head and subsequently the small flow conductor is lowered through the riser pipe and guided by the guide 55 to the connector head and again releasably attached thereto. Further operations then may be performed through the flow conductor assembly and the string of tubing, such as further production testing, cementing and the like.

The valve 45 includes an elongate tubular mandrel 100 which includes a top section 101 provided with internally threaded section 103 into which the lower end of the inner flow conductor 47 is threaded and an internally threaded section 102 in which the lower end of the outer flow conductor 46 is threaded.

The mandrel 100 also includes an upper cylinder section 137 whose upper end is threaded on the reduced lower end portion of the top mandrel section 101, an upper connector section 138 whose upper portion is threaded into the lower portion of the upper cylinder section 137, an upper operator section 139 whose upper reduced portion is threaded on the lower reduced portion of the upper connector section 138, a middle connector section 140 whose upper portion is telescoped into the upper operator section 139 and is threadedly secured into the lower end of said upper operator section, a lower cylinder section 141 whose upper end is threaded on the lower end of the middle connector section 140, a lower connector section 142 whose upper end telescopes into the lower cylinder section 141 and is threadedly secured thereto, a lower operator section 143 whose upper end is threaded on the reduced lower end portion of the lower connector section 142, and a bottom section 144 which extends into the lower end portion of the lower operator section and is threadedly connected therein. Each of the mandrel sections may be held against rotation relative to the other adjacent sections to which it is connected by means of set screws 145 and 146 which extend through end slots of one section into a threaded bore of the other. The upper and middle connector sections 138 and 142 have seal assemblies, which may include an O-ring 148 and a backup ring 149 positioned in external recesses in said sections and which seal between the connector sections and the mandrel sections into which they telescope. The middle connector section 140 also has a similar seal assembly which seals between it and the upper operator section 139, and the bottom mandrel section 144 has a similar seal assembly which seals between it and the lower operator section.

The top mandrel section 101 is provided with one or more vertical upwardly opening longitudinal passages 105 whose lower ends open through transverse bores 106 to an annular passage 107 between the mandrel 100 and an external sleeve 109 whose upper end portion is threaded on the reduced middle portion 110 of the top mandrel section. The upper end of the passage 107 is closed by a seal assembly 112, which engages the external surface 114 of the midportion of the top mandrel section below a downwardly facing annular shoulder 115 formed thereon and the internal surface 117 of the sleeve 109 above an upwardly facing shoulder 118 therein. The seal assembly may include an O-ring 113, a backup ring whose downward movement is limited by its engagement with the shoulder 118, a pair of backup rings on either side of the O-ring, and a thrust ring whose upward movement is limited by its engagement with the shoulder 115. The lower end of the annular passage 107 is similarly closed by a seal assembly 125 whose O-ring 126 engages the external surface 127 of the lower cylinder section 141 of the mandrel and the internal surface 128 of the sleeve below its internal annular shoulder 129. The seal assembly includes an upper backup ring 131 whose upward movement is limited by its engagement with the sleeve shoulder 129, a pair of backup rings on either side of the O-ring, and a thrust ring whose downward movement is limited by its engagement with the upwardly facing end surface or shoulder 135 of the seal assembly retainer member 136 threaded into the lower end of the sleeve 109.

The ball valve 150 is pivotally mounted in the lower operator mandrel section 139 by means of pins 151 whose outer portions are rigidly secured in suitable lateral bores 152 in the wall of the upper operator section 139 and whose inner portions extend into slots 153 of the ball. The engagement of the pivot pins 151 with the surfaces of the ball defining the slots which extend angularly relative to the central axis of the ball causes the ball to rotate substantially 90° from its open position wherein its axial passage 155 extends longitudinally relative to the mandrel and a closed position wherein its passage 155 extends transversely relative to the longitudinal axis of the mandrel when the ball valve is moved upwardly a predetermined distance in the housing. The valve is moved between its lower open position and its upper closed position by an operator assembly 160 which includes a piston 161, a tubular piston member 162 whose upper end is connected to the piston, a tubular housing 163, upper and lower annular seats 164 and 165 disposed above and below the ball, and a pair of cooperative upper and lower locking rings 166 and 167 which hold the ball and the seats against displacement from the housing.

The tubular piston 161 includes a tubular upper extension 171 which extends upwardly into the top mandrel section 101 and on which are mounted two seal assemblies 175 which seal between external surfaces 173 of the upper extension and the internal surface 174 of the top mandrel section. Each of the assemblies may include a plurality of pressure sensitive type packing rings for sealing in both upward and downward directions as shown. Downward movement of the upper seal assembly 175 is limited by the upwardly facing end shoulder 176 of a retainer ring 177 whose downward movement is limited by engagement of its internal downwardly facing annular shoulder 178 with top surfaces of a plurality of ring segments 182 whose inner portions extend into an annular recess 183 of the piston extension. Upward movement of the upper seal assembly 175 is limited by the bottom annular shoulder 186 of a packing retainer ring 185. The retainer ring 185 may be secured to the top end of the packing extension in any suitable manner, as by means of pins 187 which extend through suitable lateral bores of the retainer ring into the lateral bores of the piston extension. Upward movement of the lower packing assembly on the piston extension is prevented by a backup ring 179 whose top annular surface engages the downwardly facing annular surfaces of ring segments 182 which extend outwardly beyond the limits of recess 183. Downward movement of the lower packing assembly on the piston extension 171 is limited by the upwardly facing shoulder 180 of the piston extension 171.

The lower end of piston 161 has upper and lower packing or seal assemblies 191 and 192 mounted thereon above and below its external annular flange 193. The seal assembly 191 may include a plurality of packer rings 194, a backup ring 195 which engages the top annular shoulder 196 of the flange 193 to limit downward movement of the packer rings, and a retainer ring 198 which limits upward movement of the packer rings. The retainer ring is secured to the piston by suitable pins 199 which extend through lateral apertures of the retainer ring into lateral bores of the piston. The lower seal assembly 192 similarly may include a plurality of packer rings 201 whose backup ring 202 engages the downwardly facing annular shoulder 203 of the piston flange 193 to limit upward movement of the packer rings on the piston. Downward movement of the packer rings is limited by a retainer ring 205 secured to the piston by pins 207 which extend through suitable lateral apertures of the retainer ring into lateral bores of the piston.

The upper end of the tubular piston member 162 telescopes into the enlarged lower portion of the bore of the piston and its upward movement into the piston is limited by the engagement of its annular external shoulder 211 with the downwardly facing internal shoulder 212 of the piston. The piston member is held releasably against downward movement relative to the piston by a split snap ring 214 whose inner portions extend into an external annular recess 215 of the tubular piston member and whose outer portions extend into the internal annular recess 216 of the piston.

The snap ring has an upwardly and outwardly inclined outer cam surface 217 whose engagement with the annular shoulder 217*a* of the piston defining the lower end of the recess 218 when the piston member is forced downwardly relative to the piston causes the snap ring to contract and move inwardly into the recess 215 of the piston member and thus release the piston member for downward movement relative to the piston. The snap ring also has an upper external downwardly and outwardly inclined shoulder 217*b* whose camming engagement with the bottom end surface of the piston 161, as the piston member is telescoped upwardly into the piston, causes the snap ring to be moved resiliently inwardly into the recess 214 of the piston member. The snap ring moves resiliently outwardly into the piston recess 216 when it moves into alignment therewith.

The piston and the mandrel define an annular piston chamber 218 above the piston and below the bottom annular end surface 219 of the top mandrel section. The annular passage 107 communicates with the piston chamber 218 through one or more lateral ports 220 of the upper piston section 137 of the mandrel.

The piston is biased upwardly by a pair of springs 221 and 222 disposed about the piston member in an annular spring chamber 223 between the piston member and the upper piston section 137. The upper end portions of the springs abut the downwardly facing annular shoulders 224 and 225 respectively, of a spring retainer ring 227 rigidly secured to the piston member by a plurality of screws 228 threaded in the lateral bores 229 of the spring retainer and whose pin end portions extend into the apertures 231 of the tubular member. The lower ends of the springs engage the top annular shoulder 232 of the upper connector section 138.

Fluid may flow into and out of the spring chamber as the piston moves upwardly and downwardly in the mandrel through a plurality of ports 233 in the wal of the piston member.

The upper connector section 138 is provided with an internal annular downwardly opening recess 235 in which is disposed a seal assembly 236 which seals between the upper connector section and the tubular piston member below the ports 233 thereof. Upward movement of the seal assembly, which may include a plurality of packing rings 237 is limited by the downwardly facing annular shoulder 238 of the upper connector section and downward movement thereof is limited by an annular seal retainer ring 240 threaded in the lower enlarged end portion of the connector section. An O-ring 241 seals between the retainer ring and the upper connector section. The seal assembly 236 prevents upward flow of fluids into the spring passage and then inwardly into the tubular piston member when the ball 150 is in closed position.

The housing 163 has an upper annular portion 245 which is telescoped on the reduced lower portion 246 of the tubular piston members 162 and is rigidly secured thereto in seal tight relationship in any suitable manner, as by a weld 247. The upper annular seat 164 is disposed in the downwardly facing annular recess 250 of the housing and its upward movement in the housing is limited by the engagement of its top shoulder with an internal downwardly facing shoulder 252 of the housing. An O-ring 253 disposed in an upper external recess of the seat seals between the upper seat and the housing. The upper seat may have an annular seat ring 255 of a suitable hard surfaced low friction substance, such as is commercially available under the names "Hostaloy" and "Colmonoy," interposed between its internal annular arcuate surface 256 and the outer spherical surface of the ball 150. The seat ring may be bonded or otherwise suitably secured to the seat.

The housing has a plurality of dependent resilient collet fingers 260 which extend below the ball 150 and are provided with internal bosses 261 at their lower ends whose lower portions are received in an annular upwardly facing recess 262 provided by the lock rings 166 and 167. Outward movement of the lower ends of the collet fingers is limited by the engagement of the external surfaces of the bosses 261 with the internal annular shoulder 263 of the upwardly extending annular lock flange 266 of the lower locking ring 167. Upward movement of the collet fingers relative to the upper lock ring is limited by the engagement of the upper shoulders of their internal bosses with the downwardly facing annular shoulder 268 provided by the external annular flange 269 of the upper lock ring.

The two lock rings are secured to one another by a plurality of socket head cap screws 270 which extend upwardly through suitable apertures in the lower lock ring into the downwardly opening threaded bores 271 of the upper lock ring. Lock washers 272 are interposed between the heads of the cap screws and the downwardly facing shoulders provided by the downwardly opening bores 275 of the lower lock ring in which the heads of the cap screws are received.

Downward movement of the lower seat 165 is limited by the engagement of its bottom surfaces 278 with the top surface 279 of the upper lock ring 166. The lower seat has an internal upwardly facing annular arcuate surface 280 to which is bonded or otherwise suitably secured a seat ring 281 of a suitable low friction material which engages the spherical outer surface of the ball 150. The lower seat 165 is biased upwardly toward engagement with the ball by a plurality of springs 284 disposed in a plurality of downwardly opening circumferentially spaced bores 285 of the lower seat. The upper ends of the springs engage the downwardly facing surface defining the upper end of the bore and their lower end portions engage the top surface 279 of the upper lock ring. The upper and lower lock rings have pins 288 whose inner portions are secured in suitable lateral bores of the lock rings and whose outer portions extend outwardly into the longitudinal slots 289 between the collet fingers 260 to engage the collet fingers and prevent rotation of the lock rings relative to the housing 163. The pivot pins 151 also extend to the recesses of the ball through two of the longitudinal slots 289. It will be apparent that the upper and lower seats, the ball and the upper lock ring 166 may be inserted upwardly into the housing 163 between the collet fingers whose lower end portions flex resiliently outwardly to permit such upward movement of these components and then flex inwardly as the top internal shoulders 267 of their bosses 261 move below the lower shoulder 268 of the upper lock ring flange 269. The lower lock ring is then moved upwardly to telescope its lock flange 266 about the lower end portions of the collet finger bosses and is then secured to the upper lock ring by the cap screws 270 thus locking the collet fingers against outward movement.

Downward movement of the piston 162 and the housing is limited by the engagement of the inclined downwardly facing shoulder 299 of the lower lock ring 167 with the internal upwardly facing shoulder 290 of the middle connector section 140.

The lower ball 150*a* and its operatively and structurally associated elements are similar in structure and mode of operation to the ball 150 and its operatively and structurally associated elements and, accordingly, the elements associated with the lower ball have been provided with the same reference numerals, to which the subscript "a" has been added, as the corresponding elements operatively associated with the upper ball 150. Fluid may flow between the passage 107 and the piston chamber 218*a* above the piston 161*a* via the ports 220*a* of the lower piston section 141. Downward movement of the tubular piston 162*a* is limited by the engagement of the shoulder 299*a* of the lower lock ring with the shoulder 290*a* of the bottom mandrel section 144. The upward force exerted on the piston 162 by the springs 221 and 222 and the upward force exerted on the piston 162*a* by the springs 221*a* and 222*a* and static pressure of fluids in the conductor 46 acting upwardly through the ports 233 and 233*a* on the undersides of the pistons 161 and 161*a* are greater than the static pressure of the fluids in the conductor 46 and in the passage 48 between the conductors 46 and 47 acting downwardly on such pistons so that the pistons will move upwardly and rotate the balls to their closed positions when the fluid in the small surface flow conductor is not maintained under pressure.

In use, when it is desired to open the two ball valves, the fluid pressure in the passage 107 is increased, as by pumping from control manifold 61, and when the downward force exerted on the pistons 161 and 161*a* by the fluid pressure in the piston chambers 218 and 218*a* exceeds the total upward force exerted on the pistons by the springs 221, 222, and 221*a*, any upwardly acting pressure differentials across the balls and their pistons, and any frictional resistance present in the system due to these forces, the pistons will start to move downwardly. Continued pumping from manifold 61 will cause the pistons to continue to move downwardly until stopped by the engagement of the shoulders 289 and 289*a* of the lower lock rings 167 and 167*a* with the respective upwardly facing shoulders 299 and 299*a* of mandrel sections 140 and 144. Continued pumping from manifold 61 will produce an immediate pressure increase in the fluids being pumped and then may be seen on a pressure gauge in the fluid line 62 on the surface. The pressure required at the pistons 161 and 161*a* is approximately 10 percent greater than any well pressure acting to close the ball valves. During the downward movement of pistons within their limits of travel, the balls 150 and 150*a* rotate through substantially 90° from a closed position wherein their axial passages 155 and 155*a* are out of alignment with the axial passages of the housing, the tubular piston members, the pistons, and the mandrel, to positions wherein they are in alignment with these axial passages to permit fluid flow through the valve.

If the pressure in the passage 107 is decreased below the value at which its force holds the pistons in their lower positions, the force of the springs, and of any upwardly acting pressure differential acting across the pistons and balls, moves the pistons and the balls upwardly in the mandrel thus causing the balls to rotate through substantially 90° to positions wherein their axial passages 155 and 155*a* extend transversely relative to the longitudinal axis of the mandrel and the engagement of their outer surfaces with the seat members 255 and 255*a* then prevents upward flow of fluid through the mandrel.

Upward movement of the pistons 161 and 162 is limited by the engagement of the shoulders 294 and 294*a* of the housings 163 and 163*a* with the shoulders 295 and 295*a* of the packer nuts 240 and 240*a*, respectively. Any upward pressure differential existing across the balls now tends to hold them in sealing engagement with the seat members. During the upward and downward movement of the balls, the lower and upper seats 164 and 164*a* and 165 and 165*a* of the two balls guide the rotational movement of the ball valves.

The balls when they are in their closed positions may be moved to open positions either by increasing the pressure within the annular passage 107 in the manner described above or by increasing the pressure within the inner string of tubing 47, as by pumping thereinto at the surface and therefore in the passage through the tubular operator assembly 160 above the upper ball 150. When the pressure within the inner tubing is increased to such value that its force acting across the upper ball 150 and the upper piston 161 exceeds the force of the upwardly acting pressure differential existing across the ball 150, the force of springs 221 and 222 and the force of the snap ring 214, the ball valve is moved downwardly and pulls the piston member 162 downwardly therewith, the camming engagement of the external lower cam shoulder 217 of the snap ring with the bottom shoulder 217*a* of the piston camming the snap ring inwardly into the recess 215 to permit such downward movement of the piston member relative to the piston. The piston is held against downward movement since the pressure in the chamber 218 is now considerably smaller than the pressure below the piston acting upwardly on the piston through the ports 233 from the inner string 47. As more fluid is pumped into the inner string 47, the ball 150 is moved downwardly and at the same time is rotated to at least partially open position admitting fluid pressure to the passage through the lower tubular operator assembly 160*a* above the lower ball 150*wall* The ball 150*a* and the piston member 162*a* are then moved downwardly relative to the piston 160*a* and the ball 150*a* rotates to at least partially open position. Once the two balls are in at least partially open position, fluids may be pumped downwardly through the valve and into the tubing 44 which is connected to the lower end of the bottom mandrel section 144.

When the pumping is stopped and the pressure across the ball valves tends to equalize the springs 221*a* and 222*a* move the tubular valve member 162*a* and the ball 150*a* upwardly and the springs 221 and 222 move the tubular valve member 162 and the ball 150 upwardly back to the positions illustrated in FIGS. 4, 5 and 6 of the drawings. As the snap rings 214 and 214*a* move into alignment with the internal recesses 216 and 216*a* of their associated pistons 161 and 161*a*, the snap rings move resiliently outwardly thereinto to releasably hold the piston members releasably secured to the piston. The engagement of the upper cam shoulders of the snap rings with the bottom end shoulders of the pistons of course cams the snap rings inwardly into the external recesses 215 to permit such upward telescoping movement of the upper end portions of the piston members into the pistons.

It will be apparent that the two balls are mounted in longitudinally spaced relation within the valve mandrel and in the event one of the balls fails to function properly and close when it is required to do so, that the other will close. The valve embodying the invention is therefore used wherever it is essential that flow through a flow conductor be stopped when this is necessary, as for example, in well installations where failure of the valve to close when a predetermined condition arises may cause very costly damage.

It will further be seen that a common control fluid pressure will operate both balls and that preferably the forces exerted by the springs 221 and 222 and 221*a* and 222*a* on the two pistons are equal so that both balls will tend to open when the fluid pressure within the annular passage 107 increases to a first predetermined value and will close when such pressure drops below a predetermined value.

It will further be seen that the valve is of relatively simple economical and compact construction even though it is provided with two separate means for effecting closure of the valve for extreme reliability of performance of the valve.

Referring now particularly to FIG. 8, the connector head 51 includes a tubular latch housing 301 whose upper end is threaded into the enlarged lower portion 302 of the central passage 303 of a latch head 304. The latch head has an internal annular flange 305 which provides a downwardly facing annular stop shoulder 306, a lower upwardly and inwardly extending annular cam shoulder 307 and an upper upwardly and outwardly extending annular stop shoulder 308. The lower end of the latch housing is threaded in the enlarged upper portion 309 of a tubular connector sub 310. A tubular latch retainer 312 is mounted within the latch housing against longitudinal movement therein, its lower end being threaded in a retainer bushing 314 whose bottom external annular flange 315 is disposed below the annular lower end shoulder 316 of the latch housing and the annular upwardly facing shoulder 317 of the connector sub. The latch retainer has an external annular flange 319 at its upper end portion which is provided with a plurality of circumferentially spaced upwardly opening slots 320. The upper end of the external latch retainer flange is beveled or inclined upwardly and inwardly.

A latch 325 is mounted in the latch housing for limited longitudinal movement relative thereto and includes a base ring 326, a plurality of circumferentially spaced resilient collet or latch fingers 328 integral with and extending upwardly from the base ring and into the slots 320 of the external flange 319 of the latch mandrel. Each of the collet fingers is provided with internal longitudinally extending bosses 330 provided with thread teeth 331. The thread teeth have bottom surfaces 332 which extend substantially horizontally or perpendicularly to the longitudinal axis of the latch housing and with downwardly and inwardly extending upper shoulders or surfaces 333. Downward movement of the latch 325 is limited by the engagement of the bottom end surface of its base ring 326 with the annular top surface or shoulder 335 of the retainer bushing 314. The upper ends of the collet fingers are spaced below the cam shoulder 307 of the latch head when the latch 325 is in its lowermost position. When the latch head is moved upwardly in the latch housing, the upwardly and inwardly extending upper external cam shoulders 337 of the latch fingers move into engagement with the cam shoulder 307, and this camming engagement of the shoulders 337 and 307 will tend to cause the upper ends of the latch fingers to move inwardly. A seal assembly 340 is disposed in the connector sub and may include a plurality of packer rings 341 disposed between upper and lower adapter rings 342 and 343. Upward movement of the seal assembly is limited by the engagement of the top surface of the upper adapter ring with the bottom end surface of the retainer bushing 314 and its downward movement is limited by the engagement of the lower adapter ring with the upwardly facing annular shoulder 344 of the connector sub. The connector sub 310 is provided with an internal annular flange 346 which provides upper and lower stop shoulders 347 and 348. The upper end of the inner concentric flow conductor 47 is threaded in the reduced internally threaded portion 349 of the bore of the connector sub and the outer concentric flow conductor 46 is threaded in the lower enlarged internally threaded portion 350 of the connector sub. The connector sub has a lateral port 353 which opens to the bore of the connector sub through the shoulder 351 to the upper end of the annular passage 48 between the concentric flow conductors.

A latch mandrel 360 is connected to the lower end of the large flow conductor 49 to constitute its lower end portion by means of internal threads in its upper end portion. The lower end portion of the latch mandrel is telescopable downwardly through the central passage 303 of the latch head 304 into the latch housing and has external threads 362 which are engageable with the threads 331 of the latch fingers. The upper shoulders or surfaces 363 of the threads 362 extend substantially perpendicularly to the longitudinal axis and their lower surfaces 364 extend upwardly and outwardly. When the lower end of the latch mandrel is inserted through the passage 303 of the latch head the reduced portion 365 of the latch mandrel below the threads 362 moves past the latch finger threads and thereafter the lower shoulders 364 of the teeth of the latch mandrel engage the upper surfaces 333 of the teeth 331 of the latch fingers and cam the upper ends of the latch fingers outwardly to permit further downward movement of the latch mandrel. When the downward telescoping movement of the latch mandrel is arrested due to the engagement of its annular stop shoulder 367 with the upper stop shoulder 308 of the latch head, the latch mandrel teeth 362 are in threaded engagement with the teeth 331 of the latch fingers and the seal assembly 340 sealingly engages the reduced portion 365 of the latch mandrel to seal between the connector sub 310 and the latch mandrel 360. Due to the provision of the substantially horizontal bottom surfaces 332 of the latch finger teeth and similar top surfaces 363 of the latch mandrel teeth 362, upward nonrotational movement of the mandrel relative to the latch cannot now take place. Any upward movement of the latch mandrel will now cause the latch 325 to move upwardly and as the cam shoulders 337 of the latch fingers engage the internal cam shoulder 307 of the connector head, their camming engagement tends to force the upper ends of the latch fingers inwardly and prevents disengagement of the latch mandrel from the connector head except by rotation thereof relative to the connector head and therefor to the latch 325 which is held against rotation by the retainer 312 into whose slots 320 extend the internal bosses 330 of the latch fingers.

The latch head 304 has a vertical bore 370 radially spaced from its longitudinal axis in which is rigidly secured an elongate housing 371 which includes an upper latch section 372, an intermediate connector section 373 and a valve housing section 374. The connector section has an upper portion 376 which is threaded in the lower end of the latch housing section 372 and an external intermediate flange whose downwardly facing annular shoulder 379 engages an internal upwardly facing annular shoulder 380 of the connector head to limit downward movement of the connector section in the bore 370. The connector section has an externally threaded intermediate portion 382 which is secured to the internally threaded portion 383 of the latch head 304 below its shoulder 380.

A latch retainer 312*a* and a latch 325*a* mounted in the elongate housing are similar in structure and operation to the retainer 312 and the latch 325 and, accordingly, have been provided with the same reference characters, to which the subscript "a" has been added, as the corresponding elements of the latch retainer 312 and the latch 325, respectively. Downward movement of the latch 325*a* in the latch housing section 372 is limited by the engagement of its base ring 326*a* with the top end surface or shoulder 385 of the connector housing section 373. The lower externally threaded end portion of the retainer 312*a* is threaded in the enlarged threaded upper end portion of the central bore or passage 388 of the connector housing section. Upward movement of the latch 325*a* is limited by the engagement of the cam shoulders of its latch fingers 328*a* with the annular upwardly and inwardly extending cam shoulder 307*a* of the latch housing section 372. The connector housing section has an internal annular flange 390 which provides an upper stop shoulder 391 and a downwardly facing stop shoulder 392.

A seal assembly 394 is disposed in the bore 388 of the connector housing section below the flange shoulder 392 and may include a plurality of packing rings 395 disposed between a pair of upper and lower adapter rings 396 and 397. Upward movement of the seal assembly is limited by the engagement of the upper adapter ring with the stop shoulder 392 and its downward movement is limited by the engagement of the lower adapter ring with a retainer ring 398 whose upward movement in the bore 388 is limited by the engagement of its top surface with the downwardly facing annular shoulder 399 of the connector housing section. The top end surface of the valve housing section 374, which is threaded in the lower portion 400 of the connector housing section, limits downward movement of the retainer ring 398. The valve housing section 374 is provided with an external outer recess in its upper end portion in which an O-ring 401 is disposed and seals between the valve and connector housing sections.

A valve 402 is mounted in the valve housing section for controlling flow of fluids through the passage 388 and thus through the housing 371 and includes elongate tubular body 404 which is biased upwardly toward closed position by a spring 405 disposed about the valve body. The lower end portion of the spring bears against the bottom upwardly facing shoulder or surface 406 of the valve housing section 374 and its upper end portion bears against the bottom annular shoulder of an external annular flange 408 of the valve body.

The valve body has an upper reduced externally threaded end portion 410 on which is threaded the lower end portion of a check valve housing 411. An O-ring 413 disposed in an external annular recess of the valve body seals between the check valve housing and the valve body. A check valve 412 mounted in the housing is biased downwardly into engagement with the annular seat surface 414 of the valve body by a spring 415. The stem 416 of the check valve extends upwardly of the check valve housing through an aperture on its top. The spring bears against an annular upwardly facing shoulder of the check valve and a downwardly facing shoulder of the check valve housing. The check valve when in its lower closed position in seated engagement with the seat 414 prevents flow from the lateral ports 417 of the check valve housing into the upper portion of the central passage 418 of the valve body above the lateral ports 419 which communicate with the passage 418 and which extend through the flange 408 thereof. The engagement of the upper surface of the flange 408 with the ring 398 limits upward movement of the valve body in the housing. When the valve 402 is in its upper position in the body, the seal assembly 394 sealingly engages the check valve housing 411 and thus closes the housing passage to flow of fluids therethrough.

The downwardly opening port 422 in the bottom of the valve housing section 374 is in communication with the port 353 of the connector sub 310 through a conduit 424 whose opposite ends are connected to the valve housing section and the connector sub by means of suitable fittings or connectors 425 and 426 threaded into the outer threaded portions of the ports 422 and 363. The check valve 412 when in its upper position will of course permit flow of fluids upwardly therethrough from the passage 418 when the pressure in the housing section below the seal assembly rises to permit escape of fluids from the housing and thus from the passage 48.

A latch mandrel and valve assembly 430 (FIG. 12) connectable to the lower end of the small surface flow conductor 50 by a connector guide 431, is telescopable downwardly into the upper end of the housing 371 and includes a latch mandrel 432 provided with external threads 433 whose lower upwardly and outwardly inclined surfaces 434 are adapted to engage the upper downwardly and inwardly inclined surfaces or shoulders 333*a* of the teeth 331*a* and cam the resilient latch fingers 328*a* outwardly to permit downward movement of the threads relative to the teeth and whose substantially horizontally extending shoulders 435 adapted to engage the substantially horizontally extending bottom shoulders or surfaces 332*a* of the teeth 331*a* to prevent upward movement of the latch mandrel relative to the latch 325*a*. The upper ends of the latch fingers 328*a* are cammed resiliently outwardly during downward movement of the threads 433 therepast and then move resiliently inwardly to engage the threads 433 to prevent upward nonrotational movement of the assembly 430.

A valve housing 438, threaded on the lower reduced end portion 439 of the latch mandrel 432, has a reduced lower portion 441 which is engageable by the seal assembly 394 and a downwardly facing stop shoulder 440 which is engageable with the stop shoulder 391 of the flange 390 of the connector 373 to limit downward movement of the latch mandrel and valve assembly in the housing 371. A valve 442 slidably mounted in the housing 438 has an external annular recess in which is disposed an O-ring 444 which sealingly engages with the internal seal surface 445 of the valve housing 438 when the valve is in its lower closed position wherein its downward movement is stopped by the engagement of its downwardly facing annular shoulder 447 with the internal upwardly facing annular shoulder 448 of the housing 438. The valve is biased to its lower position by a spring 449 whose lower end engages the top annular shoulder of an external annular flange 451 of the valve and whose upper end portion engages the downwardly facing annular end surface or shoulder 452 of the latch mandrel 432. The spring extends about a tubular upper extension 454 of the valve. The flange 451 is provided with longitudinal slots 455 and the tubular extension is provided with lateral ports 456 opening to the slots to facilitate flow through the valve housing when the valve is in its open position.

The valve has a downwardly extending reduced or rod portion 458 whose bottom end is adapted to engage the top end of the stem 416 of the check valve 412 as the tubular body 432 is telescoped downwardly into the elongate housing 371 and after the reduced lower end portion 441 of the valve housing has moved into sealing engagement with at least the upper portion of the seal assembly 394 so that very little fluid which might be present in the passage 388 of the elongate housing 371 above the check valve housing 411 will be permitted to flow downwardly. Since the spring 449 which biases the valve 442 downwardly is weaker than the spring 405 which biases the valve 402 upwardly, the valve 442 will be moved upwardly to its open position before the lower end surface of the valve housing 438 engages the top surface of the check valve housing 411 to permit upward flow of fluid which may be trapped in the passage 388 between the lower end of the valve housing 438 and the check valve housing 411.

The large and small vertical tubular members 64 and 65 of the guide 55 are rigidly connected to one another by a bottom plate 451, an intermediate plate 452 and an inclined top plate 453. The large tubular member extends through the aligned apertures 455, 456 and 457 of the plates with the lower end portion of the large tubular member extending below the lower bottom plate 451 and with its top surface coplanar with the top surface of the inclined top plate. The small tubular member 65 similarly extends through aligned apertures 459, 460 and 461 of the bottom, middle and top plates with its bottom surface being coplanar with the bottom surface of the bottom plate and with its top surface being coplanar with the top surface of the inclined top plate.

Vertical plates 464 and 465 extend radially outwardly from the large and small tubular members between the top and intermediate plates respectively and vertical plates 466 and 467 whose bottom edges rest on the bottom plate extend radially outwardly from the large and small tubular member respectively. These components of the guide are secured to one another by welding.

The guide is releasably securable to the latch mandrel 360 by one or more pins 470 threaded in suitable lateral bores 471 of the large tubular member 64 whose inner portions are receivable in the annular external recess 474 of the latch mandrel 460. The latch mandrel 360 also has a pair of vertical external slots 475 in which the pins are receivable and which open upwardly to the recess 474.

Upward movement of the guide on the latch mandrel is limited by the engagement of the pins with the upwardly facing surfaces 477 of the latch mandrel defining the lower ends of the slots and downward movement of the guide on the latch mandrel is limited by the engagement of the pins with the downwardly facing annular shoulder 478 defining the upper end of the latch mandrel recess 474.

When the large flow conductor 49 is to be connected to the connector head 51 which is already in place in the latch head 35 of the well installation 30, the latch mandrel 360 is secured to the lower end of the large flow conductor and inserted into the large tubular member 64 of the inner guide, and the pins 470 are then rotated to move their end portions inwardly into the recess 474 of the outer concentric conductor 46. The guide is then supported on the latch mandrel as the large flow conductor is lowered downwardly through the riser pipe 36. The guide now holds the large flow conductor centered within the riser pipe so that it will be aligned vertically with the passage 303 of the latch head 304. If the small tubular member 65 of the guide is not properly aligned with the upper latch section 372 of the elongate housing 371 of the connector head, downward movement of the guide is arrested by the engagement of the top end shoulder of the elongate housing with the bottom plate 451 of the guide. The large flow conductor and the latch mandrel can then continue downward movement relative to the guide and to the connector head until the pins 470 engage the shoulder 478 of the latch mandrel. At this time the latch mandrel is in the position illustrated in FIG. 13 relative to the connector head with its threads 362 located above the connector head so that the latch mandrel cannot be connected to the connector head 51. The large flow conductor is then raised and rotated until the pins 472 are received in the upper ends of the slots 475 of the latch mandrel. Rotation of the large pipe is continued until the small tubular 372 moves into vertical alignment with the latch section whereupon the guide moves by gravity downwardly until its downward movement is arrested by the engagement of the bottom end surface of the large tubular member 64 with the top surface of the latch head 304 or by the engagement of the pins 470 with the latch mandrel shoulder 478. The latch mandrel can then move downwardly through the passage 303 and its threads 362 engage the teeth 331 of the bosses 330 of the fingers of the latch 325. The downward movement of the latch mandrel and therefore of the large flow conductor 49 is then arrested due to the engagement of the latch mandrel shoulder 367 with the shoulder 308 of the latch head 304.

It will thus be seen that the guide is used both to align the latch mandrel and large flow conductor with the passage 303 of the latch head 304 of the connector head and also to properly orient the small tubular member 65 of the guide with the elongate housing 371 of the connector head so that when the latch mandrel and valve assembly 430 connected to the lower end of the small flow conductor 50 are thereafter lowered through the riser pipe, the inclined plate 453 will guide the lower end of the latch mandrel and valve assembly into the upper end of the small tubular member 65 and therefore into alignment with the upper end of the upper latch section of the elongate housing 371. The latch mandrel and valve assembly will then telescope into the upper end of the elongate housing and be secured thereto by the engagement of the threads 433 thereof with the teeth 331*a* of its latch 325*a*. As the valve housing 438 moves downwardly through the passage 388, the bottom end of its valve rod 458 engages the top end of the stem 416 of the check valve 412 and the valve 442 is moved to open position as the valve housing continues to move downwardly. The bottom end of the valve housing then engages the top end of the check valve housing whereupon the continued downward movement of the valve housing moves the valve 402 downwardly against the resistance of the spring 405. As the check valve housing moves out of sealing engagement with the seal assembly 394, the reduced end portion 441 of the valve housing moves into engagement with the seal assembly. Communication is now established between the lower end of the passage 388 and the central longitudinal passage of the latch mandrel and valve assembly 430.

Such downward movement of the latch mandrel and valve assembly 430 continues until the shoulder 440 of the valve housing 438 engages the internal shoulder 391 of the connector sub. At this time the threads 433 of the latch mandrel are in full engagement with the threads 331*a* of the latch 325*a* and this engagement of the latch mandrel threads and the latch threads now prevents nonrotational upward movement of the latch mandrel from the elongate housing 371. The latch mandrel may then be disconnected only by rotating the latch mandrel to unscrew its threads out of engagement with the thread teeth of the latch fingers of the latch 325*a*.

In use, after the well has been drilled and the well installation 30 which has been used in drilling the well, including the drilling phase stack of blowout preventers 33, is still in place, the string of tubing 44 is made up and lowered into the well installation 30 through the riser pipe 36 and the latch head 35. As the tubing string is lowered into the well installation the upper end of the string of tubing is threaded into the lower threaded portion 294 of the bottom section 144 of the mandrel 100 of the valve 45, and the lower ends of the inner and outer concentric conductors 47 and 46 are threaded into the threaded portions 103 and 102, respectively, of the top section 101 of the mandrel and their upper ends are threaded in the internally threaded portions 349 and 350, respectively, of the connector sub 310 of the connector head 51. The large flow conductor 49 is then releasably secured to the connector head by the latch mandrel 360 which is secured to its lower end and similarly the small or control fluid conductor 50 is secured to the connector head by means of the latch mandrel and valve assembly 430 which is secured to its lower end by the guide connector 431. A suitable fluid, such as a light oil, is introduced into the passage 105 of the valve 45, the passage 48 provided by the concentric flow conductors, the tube 425 and the small flow conductor 50 as these components are connected to one another. This assembly of the tubing string 44, the valve 45, the concentric conductors 46 and 47, the connector head 51 and the large and small flow conductors 49 and 50 is lowered to a position wherein the external annular recess 500 of the outer concentric flow conductor 46 is aligned with one of the blowout preventers 33. Such blowout preventer 33*a* may be any suitable type, as for example the type illustrated on Pages 1134 through 1140 of the Composite Catalogue of Oil Field Equipment and Services, 1964—65 Edition, published by World Oil, Houston, Texas, which has a pair of rams 501 and 502 which are movable toward each other and each is provided with resilient seal elements 503. The rams are adapted to engage the top and bottom shoulders 504 and 505 respectively of the outer concentric conductor 46 defining the recess 500 when in operative engagement with the outer conductor to prevent either upward or downward movement of the outer concentric flow conductor 46. Others of the blowout preventers 33, such as the blowout preventer 33*b*, may be of the type illustrated on Pages 2575—2579 of the Composite Catalogue, which employ a contractor piston 510 to urge an annular sealing element or packing 511 into sealing engagement with a flow conductor, such as the outer flow conductor 46 to seal therebetween and close the passage 38. The blowout preventers are now operated to close the annular passage or annulus 38 and also hold the outer flow conductor against longitudinal movement.

Any desired production testing operations may now be performed using the well installation 30 previously used to drill the well. For example, various well tools may be moved downwardly through the large flow conductor 49, after the valve 45 has been opened by maintaining the pressure of the control fluid by means of the manifold 81 and the conduit 62 connected to the upper end of the control conductor 50. The rate of flow and volume of flow of the well fluids into the well through perforations in the casing may then be tested by permitting them to flow upwardly through the string of tubing to the surface. If it is desired or necessary to pump fluids, such as cement, acid or the like, into the well through the string of tubing, the balls of the ball valve may be maintained in open position by maintaining proper fluid pressure from the manifold 61 to the valve 45 or, if such pressure is not available, by pumping downwardly into the large flow conductor into the passages of the operator assemblies 160 and 160*a* of the ball valve 45 in the manner described above.

If it is necessary or desirable to disconnect the flow conductors 49 and 50 from the connector head and the riser pipe 36 from the latch head 35 due to the occurrence of the storm conditions, before any such desired operations have been completed, the pressure manifold is operated to relieve or remove the pressure in the small flow conductor 50, which causes the valve 45 to close. The large flow conductor 49 is rotated to cause the threads 362 of its latch mandrel 360 to unscrew from the thread teeth 331 of the latch 325 of the connector head, and then similarly the small flow conductor 50 is rotated to cause the teeth 433 of its latch mandrel 432 to disengage from the teeth 331*a* of the latch 325*a*. As the latch mandrel and valve assembly 430 on the lower end of the small flow conductor is moved upwardly from the elongate housing 371 of the connector head, the valve body 404 moves upwardly to closed position so that no salt water may then flow downwardly thereinto. Once the two flow conductors 49 and 50 are removed from the well installation, the riser pipe may also be disconnected from the latch head 35.

The tubing 44 is thus left supported in the well by the blowout preventers. The valve now prevents any water from flowing into the tubing and prevents any of the well fluids from flowing upwardly out of the tubing.

If it is thereafter desired to reconnect the large and small flow conductors to the connector head in order that any such interrupted operations may be completed or others initiated, the latch head 360 is inserted through the large tubular member 64 of the guide 55, and the pins 470 are then rotated to move their inner end portions into the annular recess 474 of the latch mandrel 360. The pins are preferably moved into the slots 475 so that during the lowering of the latch mandrel and the large flow conductor 49, the guide is in its lowermost position on the latch mandrel. The guide 55 holds the large flow conductor centralized within the riser pipe 36 during the lowering thereof through the riser pipe to the connector head and holds the latch mandrel in position wherein its lower end is aligned with the passage 303 of the connector head 51 and will enter thereinto. If the small tubular member 65 is not aligned with the upper latch section 372 of the elongate housing 371 of the connector head 51, the bottom plate 451 of the guide engages the top of the latch section and downward movement of the guide is now arrested. Continued downward movement of the large flow conductor and the latch mandrel 360 will then cause the lower reduced portion 365 of the latch mandrel to enter into the passage 303 of the latch head 304 of the connector head 351. The engagement of the pins 470 with the top shoulder 478 of the latch mandrel defining the upper end of the recess 474 then stops further downward movement of the latch mandrel before its threads 362 enter into the passage 303 and into engagement with the thread teeth 331 of the latch fingers of the latch 325. An upward force then imparted to the large flow conductor causes it to move upwardly relative to the guide. The large flow conductor is rotated as it is moved upwardly to cause the inner ends of the pins to be received in the upper ends of the slots 475. Once the pins are received in the slots, rotation of the large flow conductor will also cause rotation of the guide and, as the guide is rotated and its small tubular member 65 moves over and into alignment with the elongate housing 371, the elongate housing will no longer support the guide and the guide will drop down, the small tubular member 65 telescoping over the upper latch section 372. The guide is then supported on the latch head 304 of the connector head by engagement of the bottom and shoulder of its large tubular member 64 therewith or is then supported on this latch mandrel 360 by the engagement of the inner portions of its pins 470 with the shoulder 478 of the latch head 360 defining the upper end of the recess 474.

The large flow conductor is then lowered and the threads 362 of the latch mandrel engage the teeth 331 of the latch 325 so that the large flow conductor and latch mandrel is then rigidly connected to the latch head against upward nonrotational movement. At this time the guide rests on the latch head 304 due to the engagement of the bottom end shoulder of the large tubular member 64 with the latch head.

The latch mandrel and valve assembly 430 is then connected to the lower end of the small flow conductor 50 and is lowered through the riser pipe. The small flow conductor is preferably filled with a suitable fluid, such as light oil, after the latch mandrel and valve housing assembly is connected to its lower end. When the lower end of the valve housing 438 moves into engagement with the top inclined plate 453 of the guide at any location above the upper end of the small tubular member 65, the top plate guides the valve housing toward the upper end of the small tubular member and when it moves into alignment therewith, the latch mandrel and valve assembly moves downwardly therethrough and is guided thereby into the central 388 of the elongate housing 371. As the latch mandrel and valve assembly t0 downwardly through the elongate housing 371, the valve 442 is in the valve housing 438 is opened when it moves into engagement with the valve stem 416 of the check valve 412 and the reduced lower end portion 441 of the valve housing moves into sealing engagement with the seal assembly 394 and then moves the valve body 404 downwardly so that the check valve housing 411 moves out of sealing engagement with the seal assembly 394. Fluid communication is therefore now established between the lower end of the small flow conductor 50 and the annular passage 48 provided by the concentric flow conductors 46 and 47 and therefore with the passage 107 of the valve 45 through the valve housing section 404 and the tube 424.

Any desired well operations can now again be performed, the valve 45 being opened and closed as required by controlling the fluid pressure transmitted through the small flow conductor 50 to the valve 45.

If it is thereafter again desired to detach the large and small surface conductors 49 and 50 from the connector head, the small flow conductor is first rotated to unscrew the threads 433 of its latch mandrel 432 from the thread teeth 331a of the latch 325a. After the small flow conductor has been removed from the well, the large flow conductor is rotated to disengage the teeth 362 of its latch mandrel 360 from the teeth 331 of the latch 325 whereupon the large flow conductor 49 may be removed to the surface. As the large flow conductor and latch mandrel 360 move upwardly from the connector head the pins 470 engage either the bottom shoulder 479 defining the lower end of the annular recess 474 thereof or the shoulders 477 defining the lower ends of the slots 475. The guide is thus moved upwardly with the latch mandrel to the surface.

It will be apparent that once the string of tubing 44, the valve 45 and the concentric flow conductors 46 and 47 are positioned in the well and held by the blowout preventers 33, the large and small surface flow conductors may readily disconnected therefrom and reconnected thereto as required leaving the valve positioned below the blowout preventers, and the ball valve keeps the upper end of the string of tubing closed to flow of fluids therethrough when the small flow conductor is not connected to the connector head. The blowout preventers of course close the passage 38 of the well installation 30 about the outer concentric flow conductor 46.

Referring now particularly to FIG. 14 and 14a, the large and small flow conductors may be connected to the inner and outer concentric flow conductors 47 and 46 by means of a connector head 509. The lower end of the large flow conductor 49 is threaded into the upper internally threaded portion 501 of the connector head and the lower end of the small flow conductor 50 is threaded in the upper threaded portion 502 of a passage 504 of the connector head which opens to the interior of the head at the internal annular shoulder 505 thereof between the threaded portions 507 and 508. The inner concentric flow conductor 47 has its upper end threaded in the threaded portion 507 of the head and the outer concentric conductor 46 has its upper end threaded in the lower threaded portion 508 of the head. Control fluid may flow into the annular space 48 between the concentric conductors through the small flow conductor and the passage 504 of the head and thence to the valve 45.

It will be apparent that in the event storm conditions arise or it is necessary to quickly disconnect the surface flow conductors 49 and 50 from the head 509, the conductors 49 and 50 must be unscrewed from the connector head, and thereafter it will be necessary to pull the head 509, the concentric flow conductors and the string of tubing to the surface to enable the flow conductors 49 and 50 to be threaded into the head.

Referring now to FIG. 15, the concentric flow conductors 46 and 47 may have additional sections 46a and 47a, respectively, connected thereto to extend to the surface with the uppermost sections 46a and 47a being connected to a head 510. The topmost section of the outer flow conductor 46 is threaded in the lower threaded portion 511 of the head and the uppermost section of the inner concentric flow conductor 47 is threaded in the threaded portion 513 of the head. The large flow conductor 49 is threaded in the upper threaded portion 514 of the head and the conduit from the manifold is threaded in the outer threaded portion 515 of the passage 516 which opens to the annular passage between the inner and outer concentric flow conductors. The control fluid is thus transmitted to the valve 45 through the annular passage 48 of the concentric flow conductors which extends above the working platform.

Referring now to FIG. 16, if the well installation 30a has its stack of blowout preventers 33 above the surface of the water, the platform being permanently secured to the earth below the water, the outer flow conductor 46 provided with an annular recess 500 may be connected to the valve 45 by a plurality of sections 46a and to the head 510 by one or more sections 46b. Similarly, the inner flow conductor 47 may be comprised by a plurality of sections connected by suitable couplings. The inner and outer flow conductors, the ball valve 45, and the string of tubing 44 will of course be held by the blowout preventers 33 and the control fluid from the manifold will be transmitted to and from the valve through the concentric annular passage 48 between the two flow conductors.

It will be apparent that in each of the installations described, the valve is positioned at a location near the bottom of the body of water so that if any damage occurs to the installation above the well, the valve will automatically close, or "fail safe," to prevent flow of well fluids through the string of tubing.

It will now be apparent that a new and improved apparatus has been illustrated and described for performing various operations in a well which utilize the blowout preventers of the equipment which was used during the drilling of the well to support a string of tubing and a valve which control the flow of fluids through the string of tubing.

It will further be seen that the apparatus includes flow conductor means which comprises inner and outer concentric flow conductors which provide an annular passage for the flow of control fluid to and from the valve and that the outer flow conductor above the valve is held by a blowout preventer.

It will further be seen that the annular passage provided by the concentric flow conductors may extend to the surface if desired, as in the case of the installations illustrated in FIGS. 15 and 16, or a small conduit 50, as in the case of the well installations illustrated in FIGS. 1 and 14, may be provided to communicate with the upper end of the annular passage.

It will further be seen that the flow conductors 49 and 50 may be detachably secured by means of a connector head 31 connected to the concentric flow conductors above the blowout preventers so that the upper portions of the conductors which permit flow of fluids through the string of tubing and permit movement of well tools therethrough and of the control fluid may be easily disconnected therefrom and reconnected thereto.

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

I claim:

1. A valve including: a tubular housing having a longitudinal flow passage therethrough; a pair of longitudinally spaced valve means in said housing coacting with each other for individually closing said longitudinal passage to fluid flow therethrough; means resiliently biasing each of said pair of valve means to a position individually closing said housing flow passage; said housing having spaced means at its upper end for connecting said housing to the lower ends of a pair of upper flow conductors and means at its lower end for connecting said housing to the upper end of a third flow conductor therebelow whereby fluid may flow through said housing through said flow passage from the third flow conductor to one of the pair of upper conductors; said housing having passage means for conducting control fluid to each of said pair of valve means from the other of said pair of upper fluid conductors for moving said pair of valve means against the force of said biasing means to open position to permit flow through said housing flow passage from said third flow conductor to said one of said pair of upper flow conductors.

2. A valve including: a tubular housing having a longitudinal passage therethrough; a pair of longitudinally spaced valve means in said housing for individually closing said longitudinal passage to fluid flow therethrough, said housing having spaced connecting means at its upper end for connecting said housing to the lower ends of a pair of upper flow conductors and connecting means at its lower end for connecting said housing to the upper end of a third flow conductor therebelow whereby fluid may flow through said housing passage from said third flow conductor to one of said connecting means and to one of said upper pair of flow conductors connected therewith; said valve means including biasing means biasing each of the valve means to closed position and fluid pressure responsive means for moving each of the valve means to open position against the resistance of said biasing means, said housing having control fluid passage means opening upwardly at its upper end to the other of said connecting means for conducting control fluid pressure from the other of said pair of upper flow conductors to said pressure responsive means of said pair of valve means for opening said valve means.

3. A valve including: a tubular housing having a longitudinal flow passage therethrough; a pair of longitudinally spaced valve means in said housing coacting with each other for individually closing said longitudinal passage to fluid flow therethrough, said housing having spaced means at its upper end for connecting said housing to the lower ends of a pair of upper flow conductors and means at its lower end for connecting said housing to the upper end of a third flow conductor therebelow whereby fluid may flow through said housing from the third flow conductor to one of the pair of upper conductors; said housing having passage means for conducting control fluid to said valve means from the other of said pair of upper fluid conductors for moving said pair of valve means to open position to permit flow from said third flow conductor to said one of said pair of upper flow conductors, wherein said valve means includes: a tubular piston, and a tubular piston member longitudinally movable in said housing, said piston and said piston member having longitudinal passage means therethrough; coengageable means on said piston and said piston member limiting movement of said piston member relative to said piston; a ball including a flow passage mounted in said longitudinal passage of said housing for movement between positions opening and closing said longitudinal passage of said housing; and means operatively associated with said piston member and ball for moving said ball between said open and closed positions upon predetermined longitudinal movement of said piston member in said housing; said piston member being movable relative to said housing to cause said ball to move to said open position when said piston member is in its upper position and the control fluid pressure in said control fluid passage means of said housing above said piston means is increased to a predetermined value to move said ball to open position.

4. The valve of claim 1, wherein each of said valve means includes: a tubular piston member; a ball having a flow passage therethrough mounted in said longitudinal passage of said housing, said ball and said piston member having coengageable means for moving said ball between open and closed positions in said longitudinal passage of said housing; means operatively associated with said piston member and said ball and with said biasing means for causing said ball be biased to move with said piston member to said closed position wherein said ball prevents fluid flow through said housing; said piston being exposed to control fluid pressure from said housing control fluid passage means for moving said valve against the force of said housing means to an open position wherein said ball permits flow through said flow passage of said housing.

5. A valve including: a housing having a longitudinal flow passage therethrough; spaced means at the upper end of said housing for connecting a pair of flow conductors to said housing; means at the lower end of said housing for connecting a third flow conductor to said housing; a pair of longitudinally spaced tubular piston means having a longitudinal flow passage therethrough communicating with the flow passage of the housing and longitudinally movable in said passage and each having external annular flange means thereon, each of said pair of piston means and said housing defining separate annular chamber means therebetween above said flange means of each of said piston means; seal means sealing between each of said piston means and said housing above and below said chamber means; means on said housing providing a fluid passage opening to each of said annular chamber means and to one of said spaced connecting means at the upper end of said housing for conducting fluid pressure from the flow conductor connected with said one connecting means to each of said chamber means; said flange means of each of said tubular piston means being exposed to fluid pressure in said annular chamber means in which each of said flange means is disposed for downward movement of said piston means by said fluid pressure; resilient means biasing each of said piston means upwardly in said housing opposite the force of the fluid pressure in said annular chamber means; a pair of ball closure members rotatably mounted in said housing and each having a flow passage therethrough disposed to communicate with the longitudinal passage of one of said piston means when in one position and movable to another position closing said longitudinal passage of said one of said piston means; means operatively connecting each of said ball closure members separately with one of said piston means; said ball closure members, said piston means and said housing having coengageable means for moving said ball closure members between closed positions and open positions upon longitudinal movement of the piston

means in the housing, whereby said ball closure members are each moved to and held in open positions by fluid pressure in said chamber means acting on said flange means of said piston means and are each moved to closed positions by said resilient biasing means when said fluid pressure acting on said flange means of said piston means is sufficiently reduced or relieved.

6. A valve including: a tubular housing having a flow passage extending longitudinally therethrough; a pair of longitudinally spaced separate valve means in said housing each separately biased to a position closing said flow passage against fluid flow therethrough; separate fluid pressure responsive means operatively connected with each of said valve means for moving said valve means to a position opening said flow passage to flow therethrough; upper connector means on the upper end of said housing for connecting said housing to the lower ends of a pair of upper flow conductors, and connector means at the lower end of said housing for connecting said housing to the upper end of a third flow conductor, one of said upper connector means and said lower connector means communicating with the flow passage of the housing whereby fluid may flow through said housing from the third flow conductor to one of the pair of upper flow conductors; said housing having passage means therein communicating with the other upper connector means and with said valve means for conducting control fluid from the other of said pair of upper flow conductors to said fluid pressure responsive means of each of said valve means for moving said pair of valve means to open position to permit flow from said third flow conductor to said one of said pair of upper flow conductor.

7. A valve of the character set forth in claim 6 wherein: each of said fluid pressure responsive means operatively connected with said valve means comprises a pair of separate piston means provided in said tubular housing operably each connected with one of said valve means and exposed to control fluid pressure from said passage means of said housing whereby said pair of valve means is operated by the pressure of the control fluid supplied to said piston means through said passage means to move the valve means to open position.

8. A valve of the character set forth in claim 6 wherein: a pair of separate resilient means is provided in said housing each coacting with one of said valve means for biasing said valve means to closed position upon relief of control fluid pressure acting on said piston means to close said valve means to prevent flow from the third flow conductor to said one of said upper connector means.

9. A valve of the character set forth in claim 7 wherein: said housing has guide means at its upper end having openings formed therein for guiding said one of said upper flow conductors to said one upper connector means at the upper end of said housing for releasably connecting said one of said upper flow conductors to said valve housing; said guide means also having guide means for said other of said pair of upper flow conductors for guiding said other of said pair of flow conductors to said other upper connector means of said housing for releasable connection therewith.

10. A valve including: a tubular housing having a longitudinal flow passage therethrough; a pair of longitudinally spaced rotary ball valve means in said housing each having a flow passage therethrough, said ball valve means being each rotatable in said housing to a position individually closing said longitudinal flow passage to fluid flow therethrough; a pair of connector means on said housing at the upper end thereof for connecting said housing to the lower ends of a pair of upper flow conductors; connector means at the lower end of said housing for connecting said housing to the upper end of a third flow conductor; said lower connector means and one of said upper connector means communicating with said housing flow passage whereby fluid may flow through said housing and said spaced ball valve means from said third flow conductor to one of said upper pair of flow conductors; resilient means in said housing coacting with each of said pair of ball valve means for biasing said ball valve means to closed position; fluid pressure responsive means in said housing operatively connected with each of said ball valve means and responsive to fluid pressure for moving each of said ball valve means to open position against the resistance of said resilient biasing means; said housing having passage means therein communicating with the other of said upper connector means at the upper end of said housing and with said pressure responsive means for conducting control fluid under pressure from the other of said pair of upper flow conductors to said pressure responsive means for moving each of said ball valve means to open position against the force of said resilient biasing means to open the housing flow passage to flow therethrough.

11. A valve of the character set forth in claim 10 wherein said pressure responsive means comprises a pair of piston means in said valve housing each separately operatively connected with one of said ball valve means and exposed to the pressure of said control fluid from said passage means to be actuated by pressure of such control fluid to move said ball valve means to open position.

12. A valve of the character set forth in claim 11 wherein said resilient means comprises a pair of spaced springs each operatively associated with one of said piston means for biasing said piston means to a position in which the ball valve means with which it is connected is moved to closed position.

13. A device of the character set forth in claim 10 wherein means is provided in said valve for conducting fluid pressure of the fluids flowing through the valve to each of said piston means to act on said piston means in coaction with said resilient means to move said ball valve means to closed position.

14. A device of the character set forth in claim 9 wherein each of said pair of ball valve means comprises a separate ball valve closure member and said pressure responsive means comprises a pair of separate operator pistons, and each said ball valve closure member is releasably connected with a separate one of said operator pistons and said connection is releasable under a predetermined force applied to said ball valve closure member, whereby fluid pressure from said one of said upper flow conductors may be applied to said ball valve closure members in sequence to move said ball valve closure members to a position permitting flow therethrough to the pipe below the valve.

15. A device of the character set forth in claim 13 wherein said means for conducting fluid pressure to said operator piston also when said valve closure members are in closed position serves to conduct the pressure of the fluids downstream of said valve closure members to said piston means to aid said resilient means in biasing said closure members closed.