Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

Original Filed June 10, 1965 11 Sheets-Sheet 1

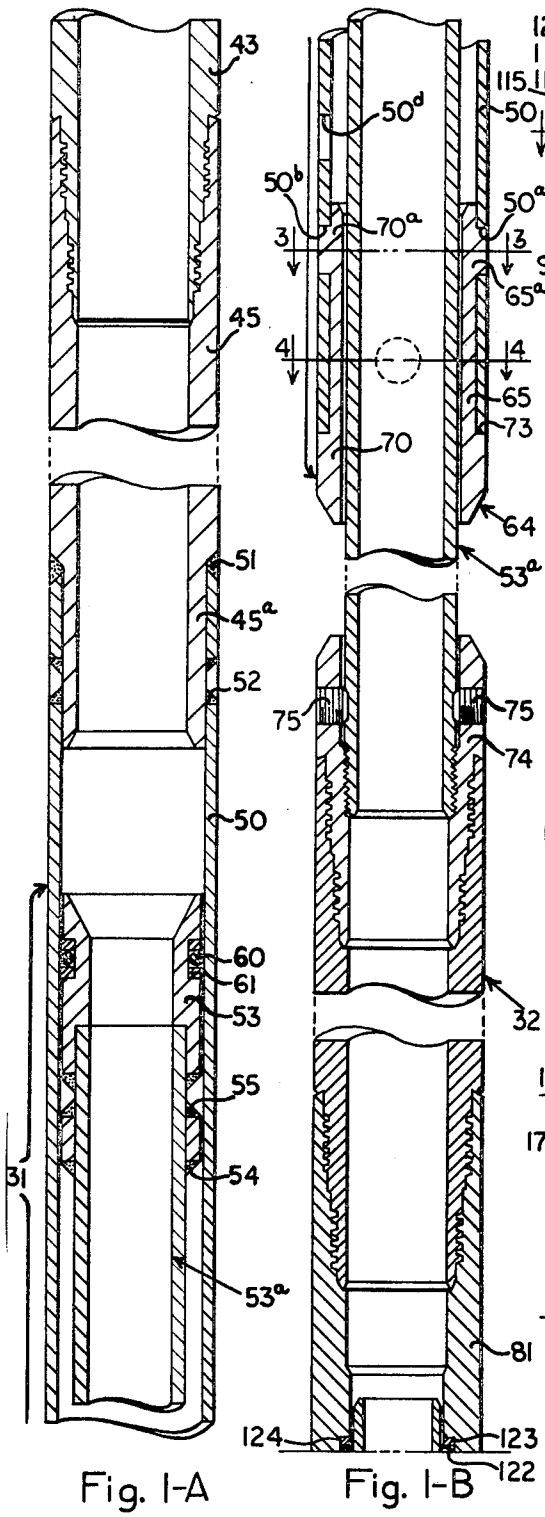


Fig. 1-A

Fig. 1-B

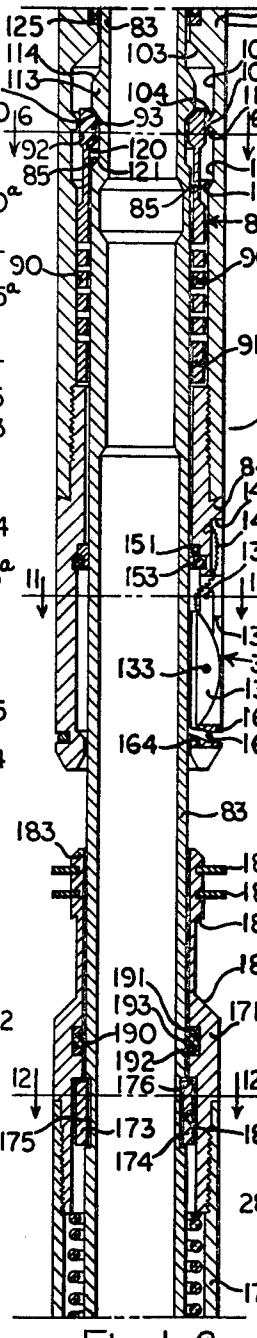


Fig. 1-C

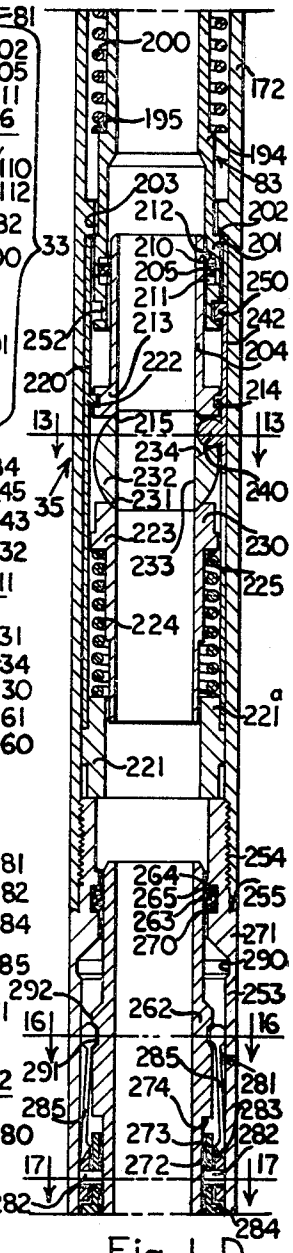


Fig. 1-D

INVENTOR
JOHN V. FREDD

BY Kenyon Ackley and Walter J. Jayne
ATTORNEY

Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

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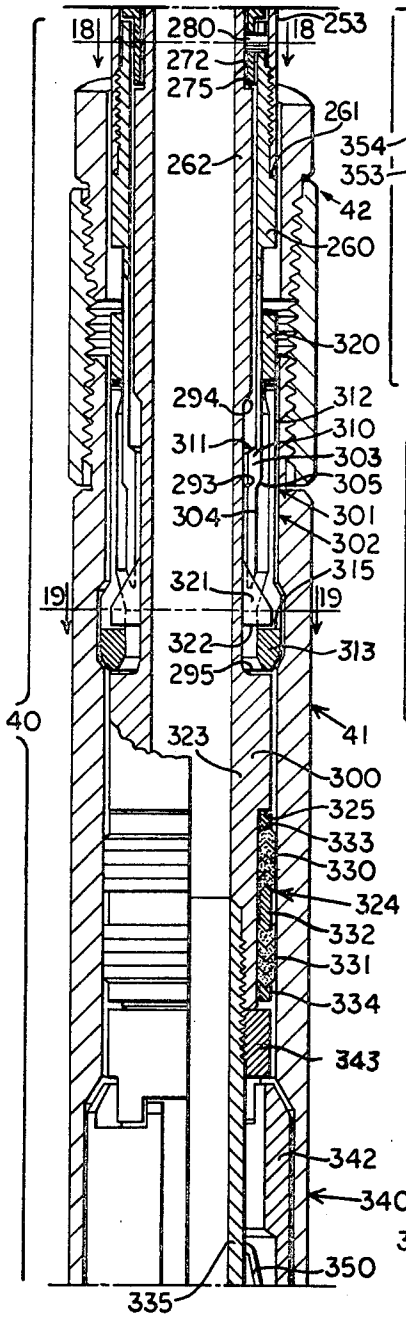


Fig. 1-E

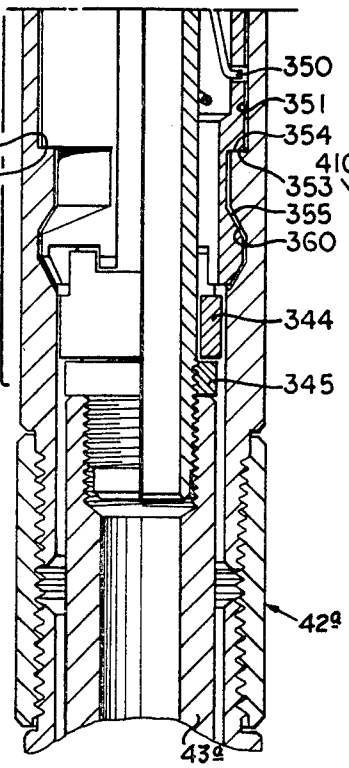


Fig. 1-F

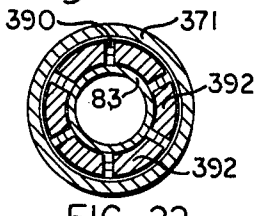


FIG.-22

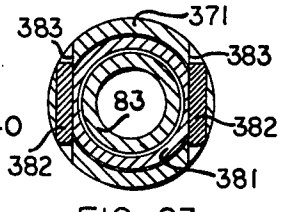


FIG.-23

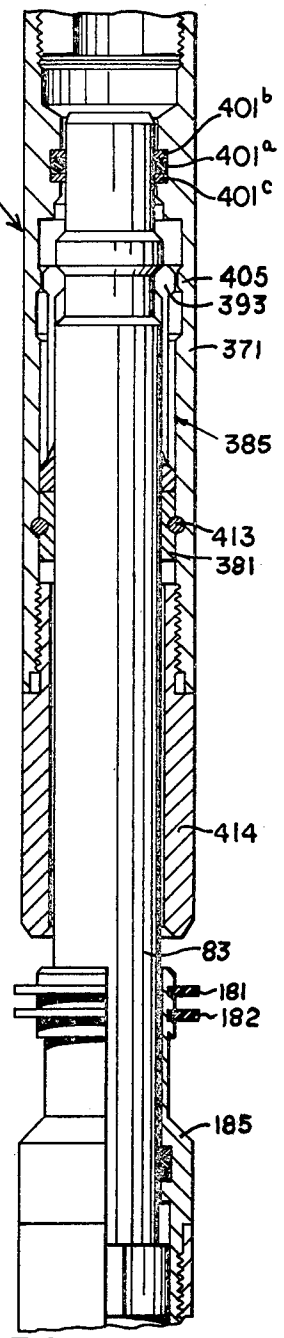


FIG.-26

INVENTOR
JOHN V. FREDD

BY Eyestinger Ackley and Walter J. Jayne

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Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

Original Filed June 10, 1965 11 Sheets-Sheet 3

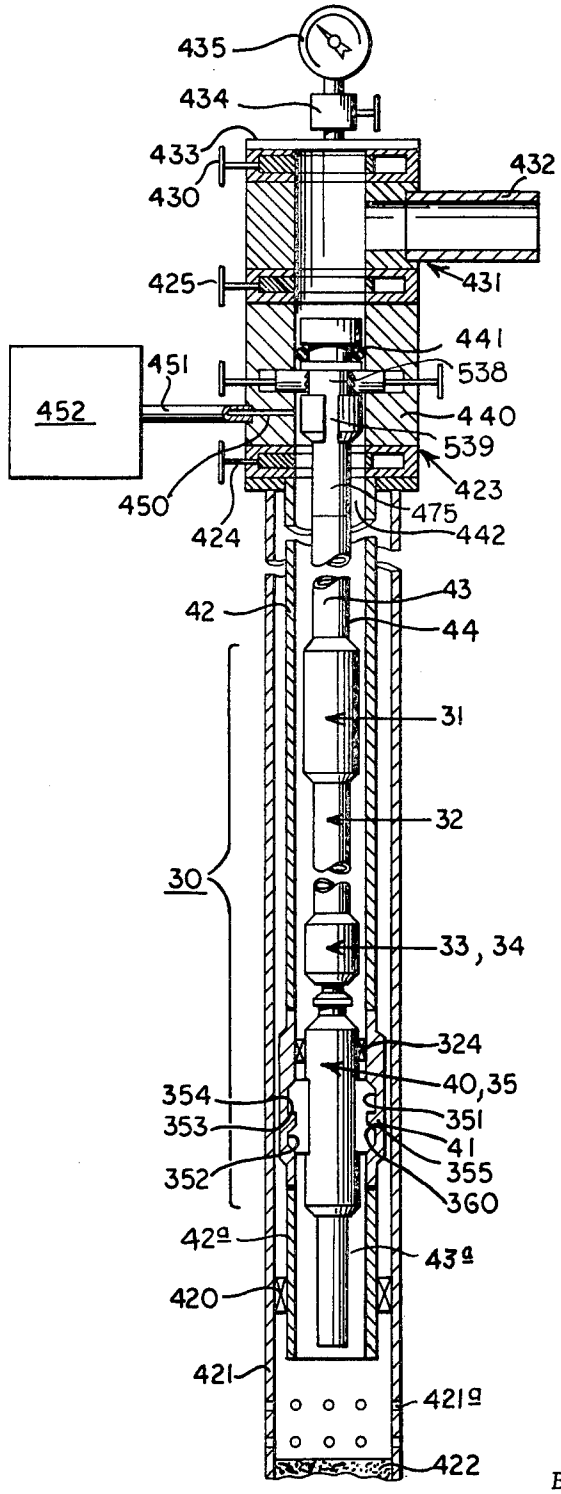


FIG.-2

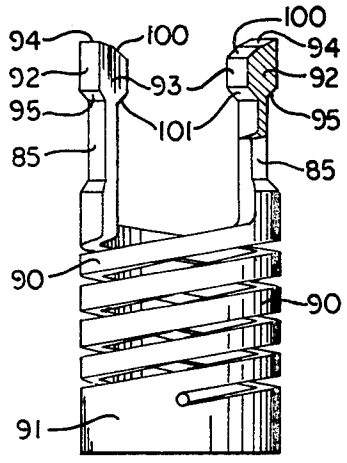


FIG.-7

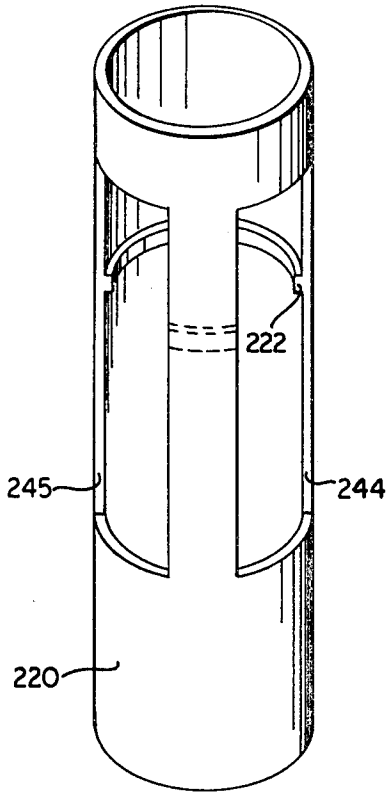


FIG.-14

INVENTOR
JOHN V. FREDD

BY Eastman, Ackley and Walter J. Jayne

ATTORNEY

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WELL TOOLS

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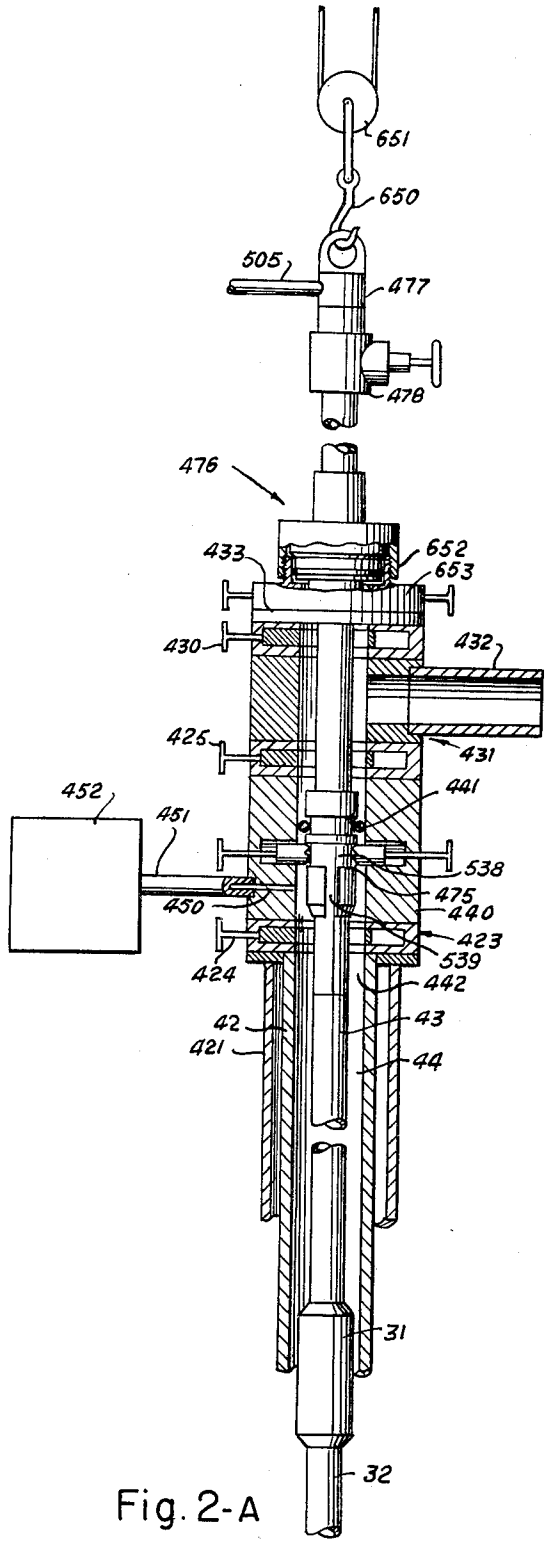


Fig. 2-A

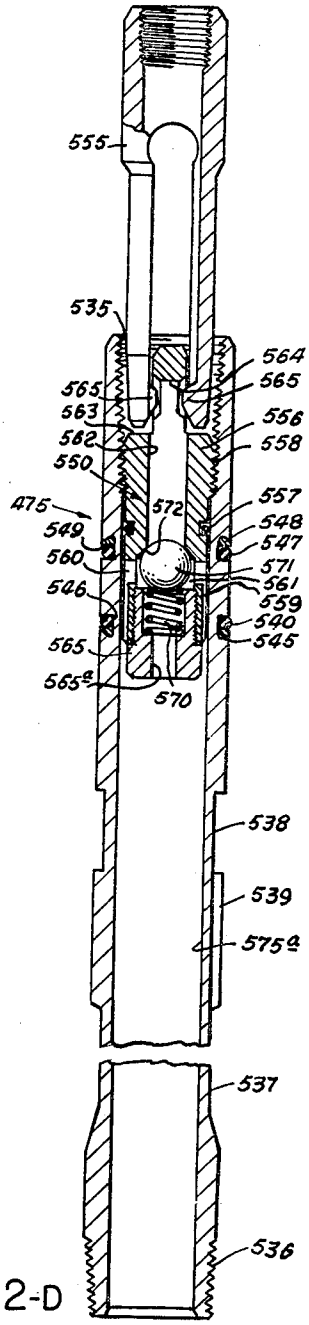


Fig. 2-D

INVENTOR
John V. Fredd
BY Eastings Ackley and Walter J. Jayne
ATTORNEYS

Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

Original Filed June 10, 1965 11 Sheets-Sheet 5

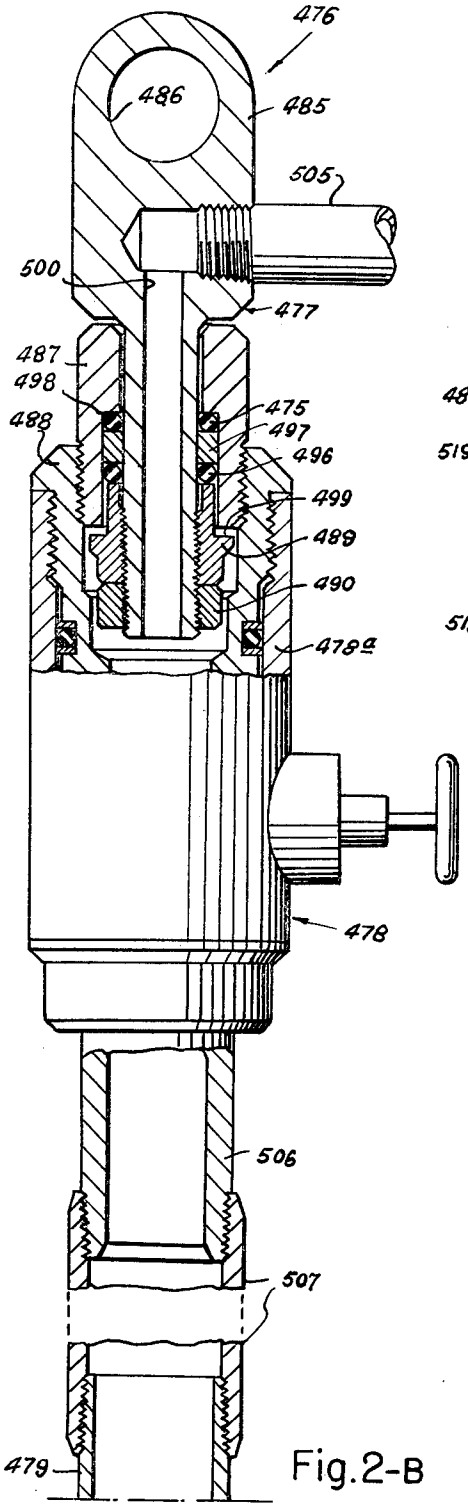


Fig. 2-B

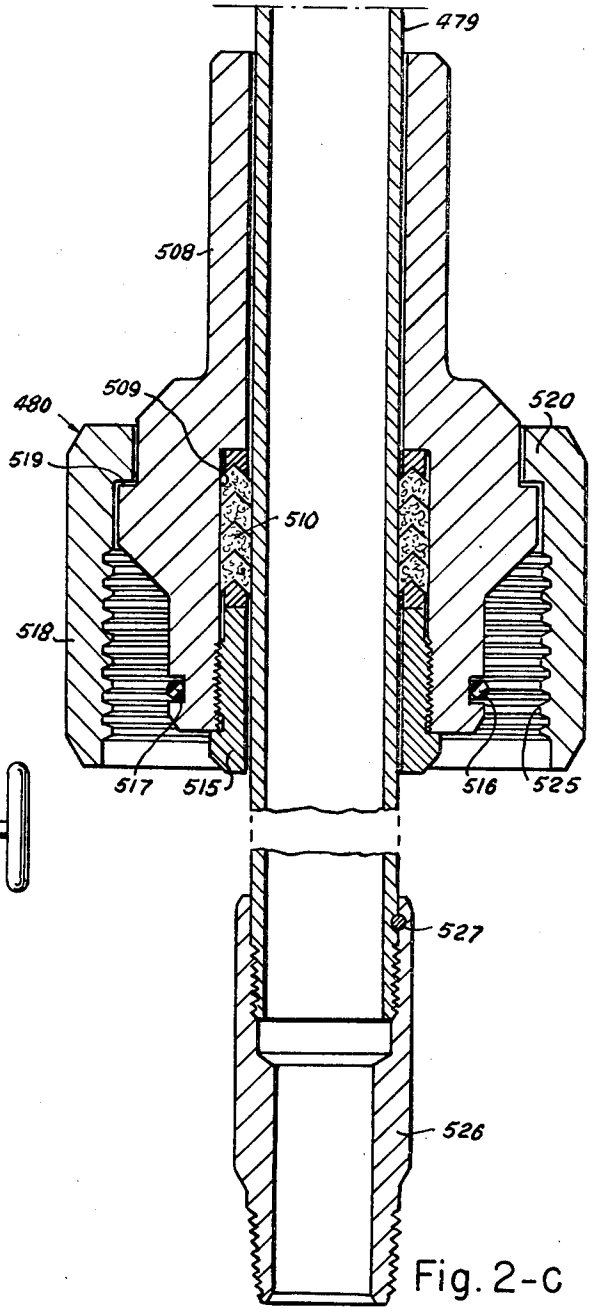


Fig. 2-C

INVENTOR
John V. Fredd

BY Eastings Ackley and Walter J. Jaynes
ATTORNEYS

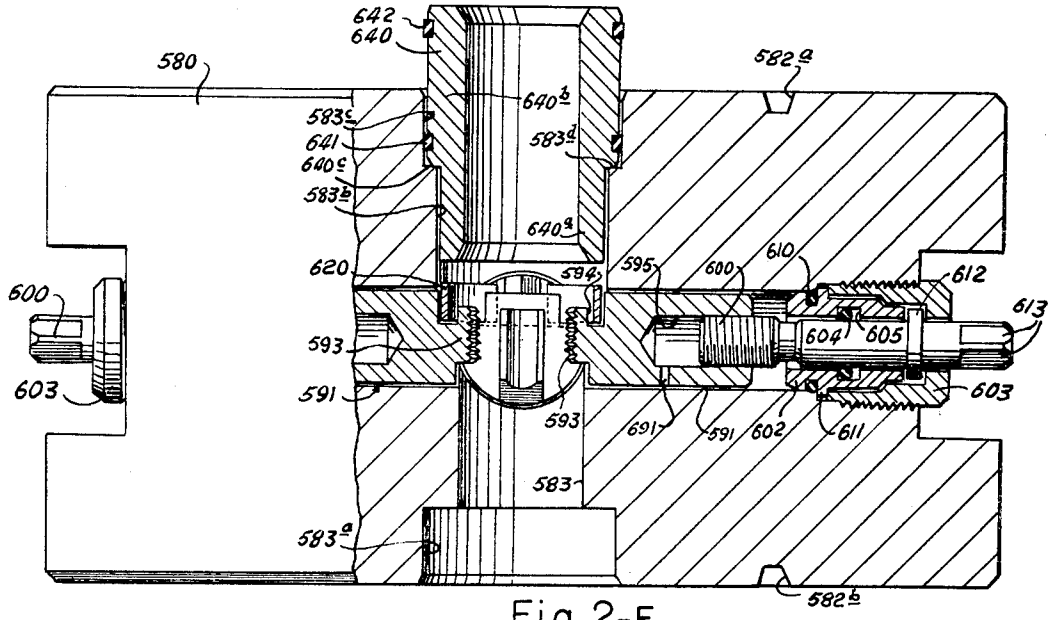


Fig. 2-F

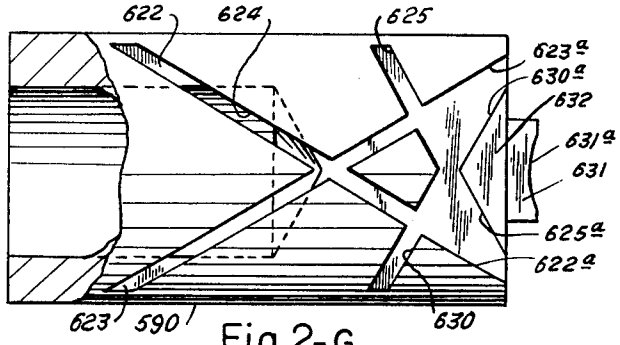


Fig. 2-G

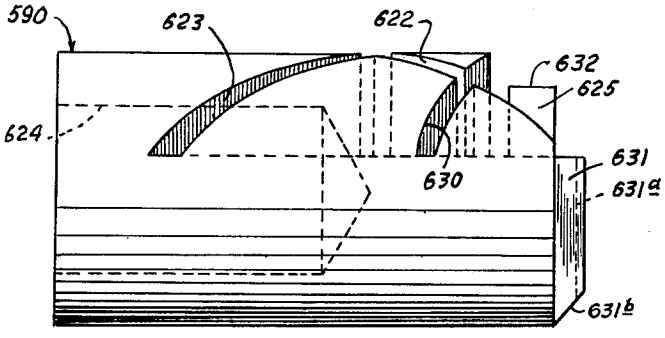


Fig. 2-H

INVENTOR
John V. Fredd

BY Cushman, Darby & Cushman and Walter J. Jason
ATTORNEYS

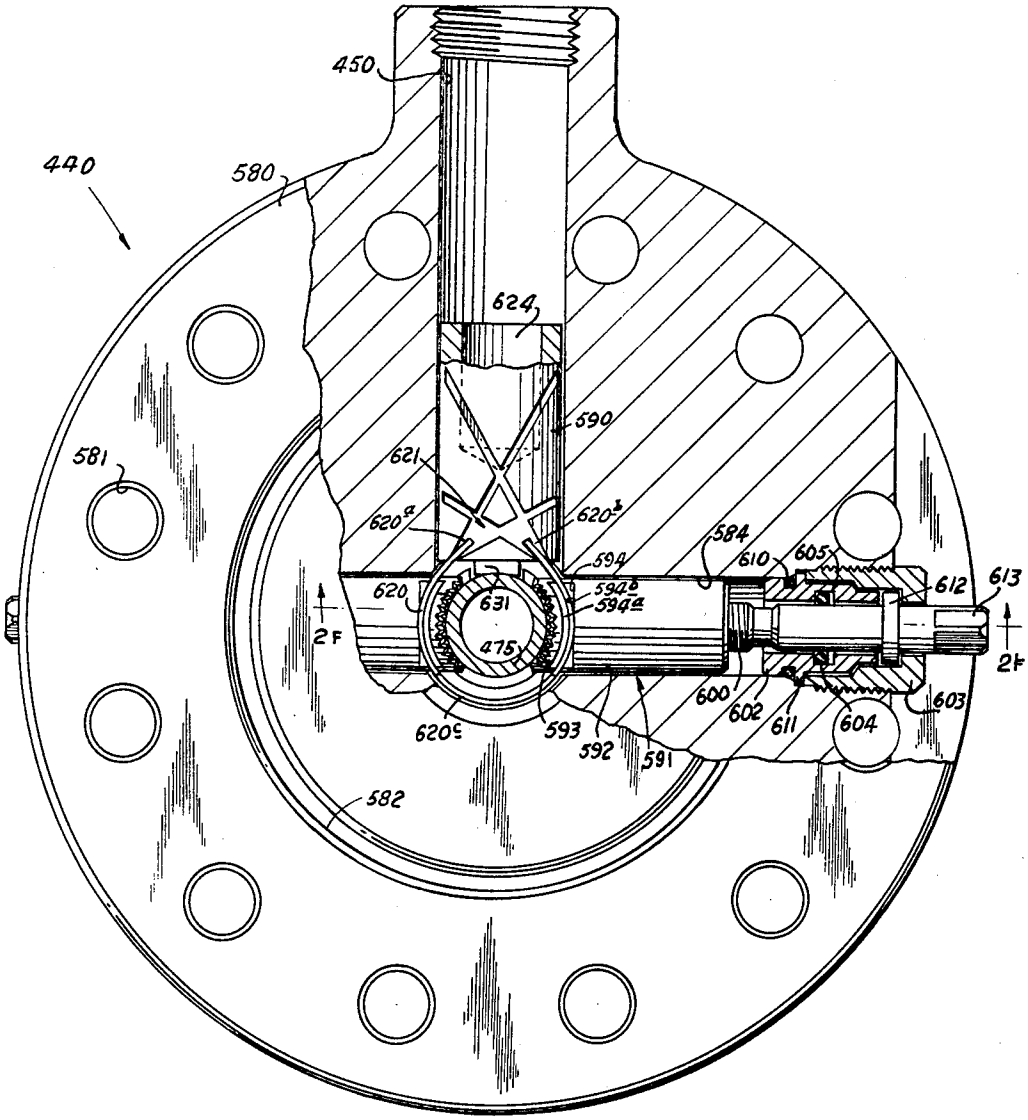


Fig. 2-E

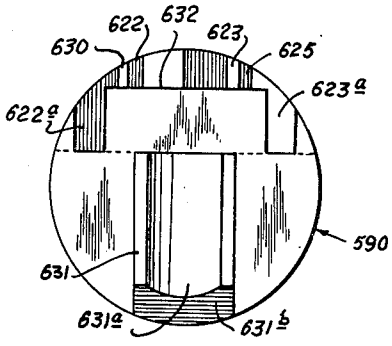


Fig. 2-I

INVENTOR
John V. Fredd

BY Estastings Ackley and Walter J. Jagmin
ATTORNEYS

Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

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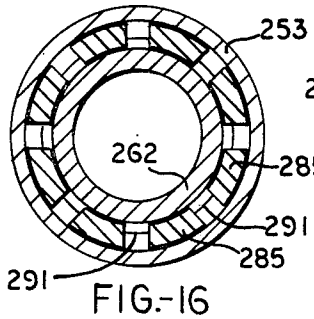


FIG.-16

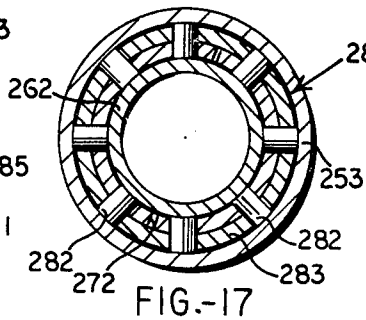


FIG.-17

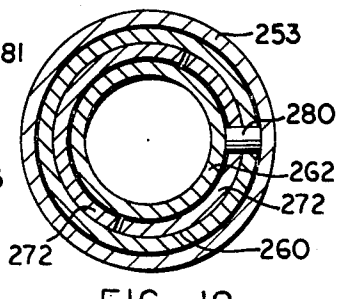


FIG.-18

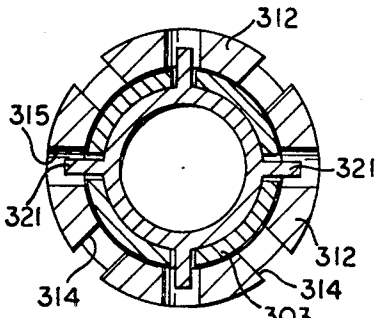


FIG.-19

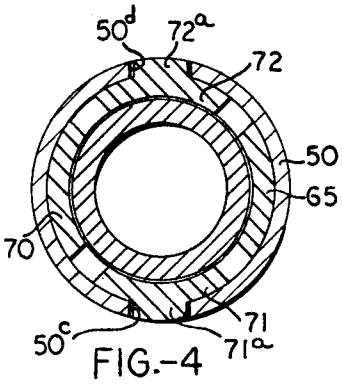


FIG.-4

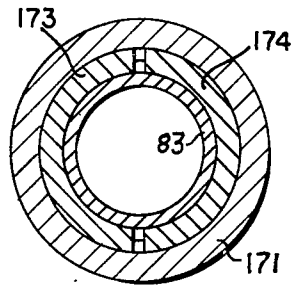


FIG.-12

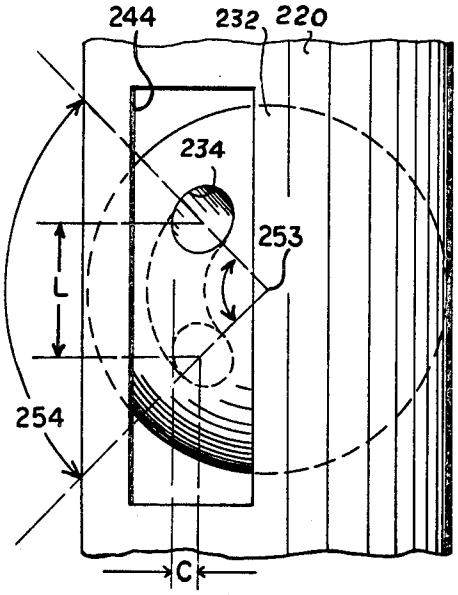


FIG.-15-B

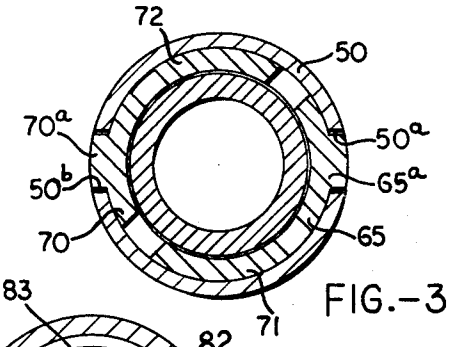


FIG.-3

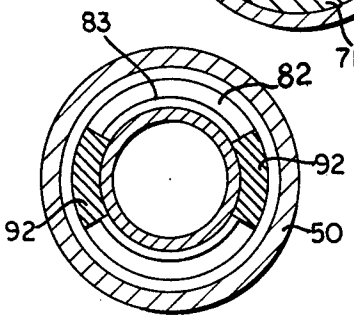


FIG.-6

INVENTOR
JOHN V. FREDD

BY Estastings Ackley and Walter J. Jaym ATTORNEY

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WELL TOOLS

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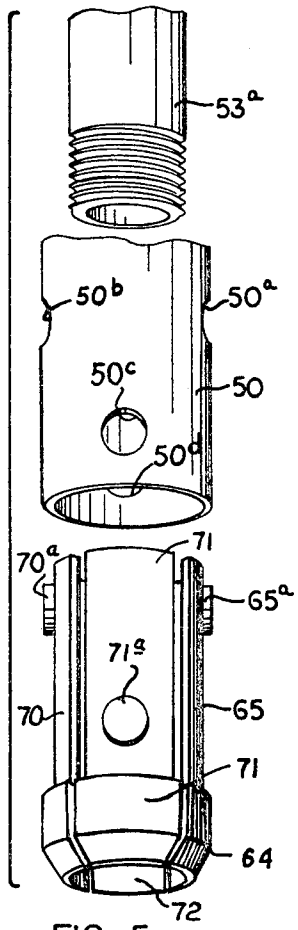


FIG.-5

INVENTOR
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Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

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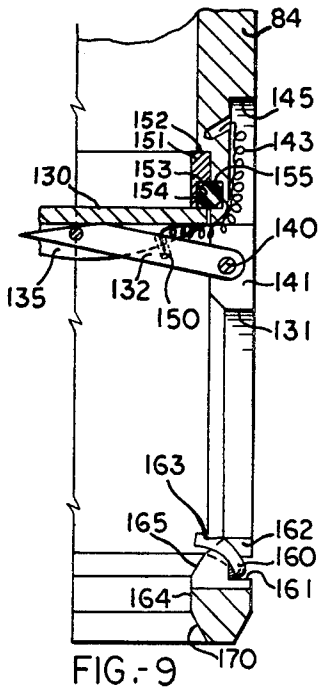


FIG.-9

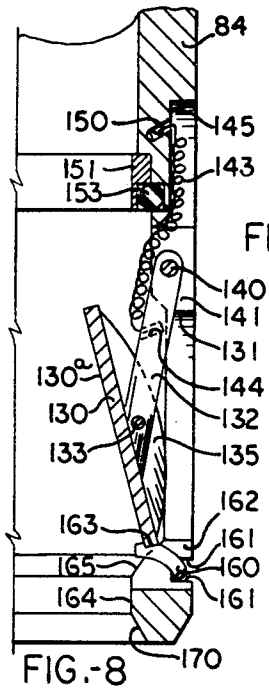


FIG.-8

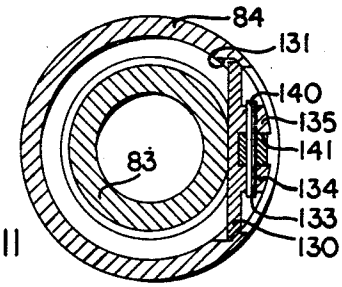


FIG.-11

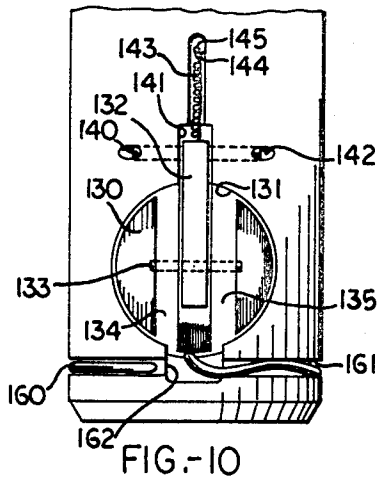


FIG.-10

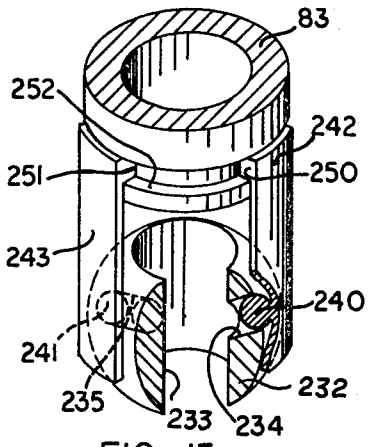


FIG.-15

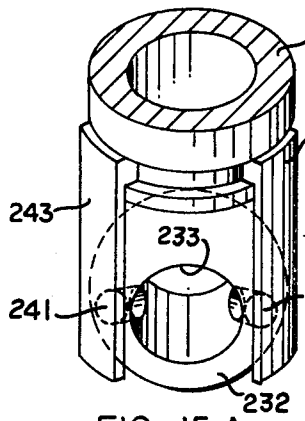


FIG.-15-A

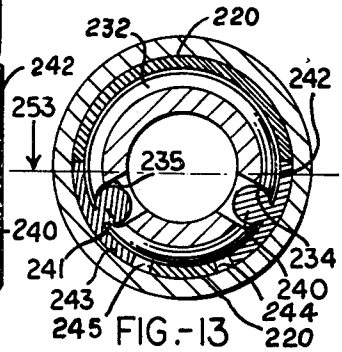


FIG.-13

INVENTOR

JOHN V. FREDD

BY Gustastings Ackley and Walter J. Jaynes

ATTORNEY

Feb. 10, 1970 J. V. FREDD 3,494,417

WELL TOOLS

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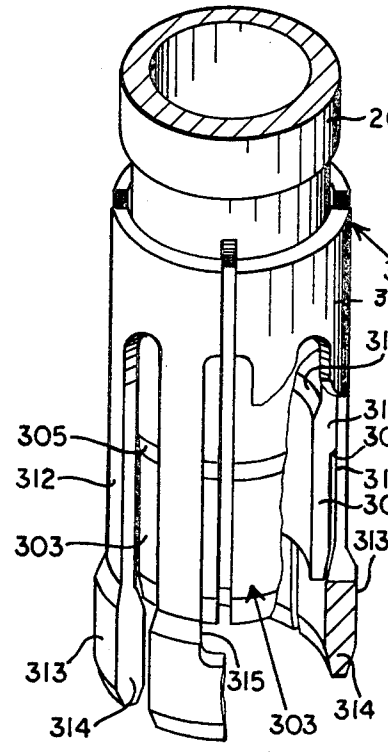


FIG.-20

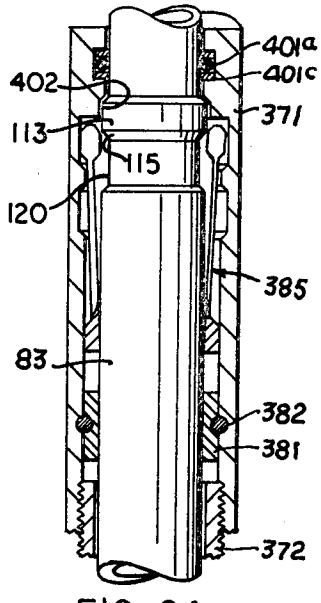


FIG.-24

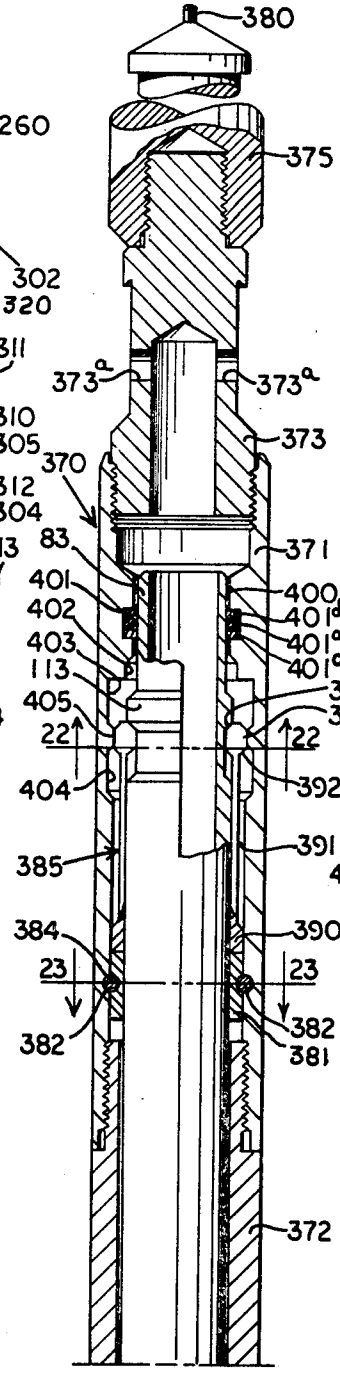


FIG.-21

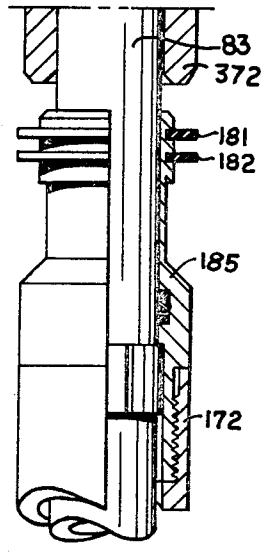


FIG.21A

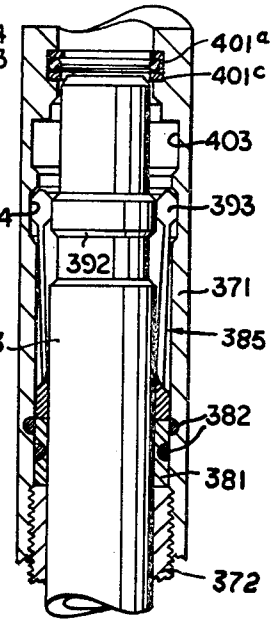


FIG.-25

INVENTOR

JOHN V. FREDD

BY Hastings Ackley and Walter J. Jayne

ATTORNEY

United States Patent Office

3,494,417
Patented Feb. 10, 1970

3,494,417

WELL TOOLS

John V. Fredd, Dallas, Tex., assignor to Otis Engineering Corporation, Dallas, Tex., a corporation of Delaware

Continuation of application Ser. No. 462,800, June 10, 1965. This application Jan. 29, 1968, Ser. No. 703,519

Int. Cl. E21b *43/00*

U.S. Cl. 166—73 15 Claims

ABSTRACT OF THE DISCLOSURE

A well fluid flow control system having a subsurface safety valve actuated to a closed position by a columnar weight forming a part of the flow conductor and having pressure responsive means for maintaining said columnar weight in a position holding the valve open under predetermined conditions, said pressure responsive means being responsive to predetermined flow conditions to release the columnar weight to close the valve, whereby the valve is adapted for use at great depths in the well flow conductor. A hanger system for the subsurface valve for supporting the tubing string of the flow conductor in the well bore in a manner permitting fluid pressure to be applied from the surface into the annular space within the well bore exteriorly of the flow conductor through the hanger assembly.

This invention relates to well tools and more particularly relates to well flow control systems.

This application is a continuation of my co-pending application Ser. No. 462,800, filed June 10, 1965, now abandoned.

One object of this invention is to provide a new and improved flow control system for controlling fluid flow through a flow conductor responsive to a predetermined change in one or more variables which may be related to or independent of the conditions within the conductor.

It is another object of the invention to provide a new and improved safety valve system for use in a flow conductor of a well.

It is a further object of the invention to provide a flow control system including a subsurface valve which may be used in a well conductor at any desired depth.

It is a still further object of the invention to provide a fluid flow control system including a subsurface valve which is not limited in use to a particular depth and thus may be installed in a flow conductor below the depth at which paraffin normally forms in the conductor.

It is another object of the invention to provide a fluid flow control system for controlling fluid flow through a well conductor which does not include a small hydraulic line between the surface control elements of the system and the subsurface valve operable in response to such control elements.

It is a further object of the invention to provide a fluid flow control system including a subsurface valve biased toward a closed position by a weight column which is counterbalanced to hold the valve in open position by surface controlled fluid pressure in an annular flow passage around and separate from the flow passage in which the valve is dispensed and through which the fluid controlled by the device flows.

It is an additional object of the invention to provide a fluid flow control system including a subsurface valve which is weight biased toward a closed position and held in an open position by a pressure medium controllable in response to variations in one or more conditions which are independent of the controlled fluid flow through the device.

It is a still further object of the invention to provide a fluid flow control system including a surface controlled subsurface valve which may be landed in a nipple of a well conductor without removing the conductor from the well.

It is another object of the invention to provide a fluid flow control system including a subsurface valve having a full bore passageway extending therethrough whereby various well tools may be passed through the section of the flow conductor containing the subsurface valve.

It is an additional object of the invention to provide a fluid flow control system including a subsurface valve which may be installed in a flow conductor utilizing a minimum of surface equipment.

It is a further object of the invention to provide a fluid flow control system including a tool for running in and positioning the subsurface valve included in the system.

It is an additional object of the invention to provide a fluid flow control system which includes a tool for removing the subsurface valve which forms a principal component of the system.

It is another object of the invention to provide a fluid flow control system including a polished joint for positioning a subsurface valve and connecting an inner tubing string within a well bore while holding fluid pressure within the tubing string.

It is a further object of the invention to provide a fluid flow control system including a tubing hanger assembly for supporting a string of inner tubing within a well bore while permitting fluid pressure to be applied from the surface into an annular space within the well bore around the tubing string.

It is an additional object of the invention to provide a surface positioned tubing string hanger assembly having radially movable clamp rams and a radially movable lug ram through which fluid pressure is applied to an annular space within the well bore around the inner tubing string supported by the hanger.

The invention is therefore directed to a well fluid flow control system having a tubular weight member forming a part of the flow conductor and movable longitudinally relative to the flow conductor thereabove for actuating a valve between open and closed positions, said weight member being moved to a position holding the valve open by pressure responsive means exposed to fluid pressure in the well bore exteriorly of the flow conductor and the valve; and a hanger system for supporting the tubing string or flow conductor in the well in a manner permitting fluid pressure to be applied from the surface to the pressure responsive means.

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:

FIGURES 1–A through 1–F together constitute a longitudinal view partially in section and partially in elevation of the surface flow control valve employed in the system of the invention;

FIGURE 2 is a diagrammatic representation partially in section and partially in elevation of the flow control system with the subsurface valve installed in operational position and connected to a surface control unit included in the system;

FIGURE 2–A is a diagrammatic representation partially in elevation and partially in section illustrating the well head portion of the system shown in FIGURE 2 at an intermediate stage in the process of landing and securing the subsurface valve and inner tubing string;

FIGURES 2–B and 2–C taken together constitute a longitudinal view partially in section and partially in elevation of the polished point assembly utilized in the procedure of landing and securing of the inner tubing string in the well bore;

FIGURE 2–D is a longitudinal view partially in section and partially in elevation illustrating the hanger sub used in supporting the inner tubing string from the hanger assembly and including a back pressure valve assembly together with its running tool;

FIGURE 2–F is a top view partially in section and partially in elevation of the tubing string hanger assembly showing the hanger sub in section locked within the assembly;

FIGURE 2–F is a side view partially in section and partially in elevation of the hanger assembly of FIGURE 2–E with that portion in section being viewed along the line **2F—2F** of FIGURE 2–E;

FIGURE 2–G is an enlarged top view partially in elevation and partially in section of the lug ram used in the hanger assembly of FIGURE 2–E;

FIGURE 2–H is a side view in elevation of the lug ram of FIGURE 2–G; and,

FIGURE 2–I is a right end view in elevation of the lug ram of FIGURE 2–H;

FIGURE 3 is a sectional view taken along the line **3—3** of FIGURE 1–B;

FIGURE 4 is a sectional view taken along the line **4—4** of FIGURE 1–B;

FIGURE 5 is an exploded perspective view of the retainer assembly used in the telescoping joint to hold the upper end of the weight section within the lower end of the inner tubing string;

FIGURE 6 is a sectional view taken along the line **6—6** of FIGURE 1–C;

FIGURE 7 is a perspective view of the detent collent used in the connection to the upper end of the subsurface valve;

FIGURE 8 is an enlarged fragmentary longitudinal view partially in section and partially in elevation of the flapper valve at hte lower end of the coupling between the weight section and the upper end of the subsurface valve, showing the flapper valve latched in the open position as when running the weight section and tubing string into the well;

FIGURE 9 is a view similar to FIGURE 8, showing the flapper valve in closed position as when withdrawing the weight section and tubing string from the well;

FIGURE 10 is a fragmentary view in elevation of the lower end of the weight section showing the back side of the flapper valve when the valve is in the open position and the weight section is engaged over the upper end of the subsurface valve unit illustrated in FIGURE 1–C;

FIGURE 11 is an enlarged sectional view taken along the line **11—11** of FIGURES 1 and 1–C;

FIGURE 12 is a sectional view along the line **12—12** of FIGURE 1–C;

FIGURE 13 is a sectional view along the line **13—13** of FIGURE 1–D;

FIGURE 14 is a view in perspective of the sleeve which encases the ball valve;

FIGURE 15 is a view in perspective of the ball valve, its operator member, and the operator tube, showing the valve in open position;

FIGURE 15–A is a view in perspective illustrating the ball valve, its operator members, and the operator tube with the ball valve in closed position;

FIGURE 15–B is an enlarged, fragmentary, diagrammatic view of the valve sleeve of FIGURE 14 with the ball valve in position within the sleeve and the operator members removed showing one of the windows in the sleeve and illustrating the arcuate path followed by one of the operator holes of the ball valve as the ball valve moves between the open and closed positions;

FIGURE 16 is a sectional view along the line **16—16** of FIGURE 1–D;

FIGURE 17 is a sectional view along the line **17—17** of FIGURE 1–D;

FIGURE 18 is a sectional view taken along the line **18—18** of FIGURE 1–E;

FIGURE 19 is a sectional view along the line **19—19** of FIGURE 1–E;

FIGURE 20 is an exploded view in perspective illustrating the lower end of the lock sleeve and the primary collect lock of the lock mandrel assembly used in securing the subsurface valve in a nipple in the tubing of a well;

FIGURES 21 and 21–A taken together constitute a longitudinal view partially in section and partially in elevation of the running tool used to position the subsurface valve within a well bore, showing the tool engaged over the upper end of the operator tube of the valve unit;

FIGURE 22 is a sectional view along the line **22—22** of FIGURE 21;

FIGURE 23 is a sectional view along the line **23—23** of FIGURE 21;

FIGURE 24 is a fragmentary view partially in section and partially in elevation of the running tool showing the position of the collect of the tool as the tool is being latched over the upper end of the operator tube of the subsurface valve unit;

FIGURE 25 is a longitudinal, fragmentary view, in section and elevation showing the running tool collect position and shear pins severed as the tool is lifted from the operator tube of the subsurface valve unit after setting the unit in a well bore; and,

FIGURE 26 is a longitudinal view partially in section and partially in elevation of the pulling tool for removing the subsurface valve from a well bore, showing the tool installed over the upper end of the operator tube of the subsurface valve.

A fluid flow control system is accordance with the invention is illustrated in FIGURE 2. The well is equipped, either initially or when installing the system, with a tubing string, such as the outer tubing string **42**, provided with a landing nipple **41** in which the subsurface valve assembly **30** is landed and removably secured. The outer tubing string extension **42*a*** extends downwardly through a well packer **420** which is any suitable form of packer which will seal the annular space between the outer tubing string and the casing **421** of the well. Also, the tubular extension **43*a*** on the lower end of the subsurface valve may extend downwardly to any desired depth with- or below the tubing extension **42*a***. The well bore may be plugged back by cement or other suitable material at **422** while the casing is perforated as at **421*a*** above the cement plug to permit formation fluids to flow into the well bore below the packer **420**. The outer tubing string **42** and the inner tubing string **43** are supported at the surface from the well head assembly **423** which may include a first master valve **424**, a second master valve **425**, and a swab valve **430**. Between the second master valve and the swab valve a T or cross-connection **431** is connected to permit the securing of a flow line **432** leading to conventional surface equipment such as a separator and a tank battery, not shown, for handling the fluids produced from the well. The upper end of the swab valve is closed by a flange **433** through which a conventional needle valve **434** and a pressure gauge **435** are secured to permit a determination of the pressure within the well head assembly. The inner tubing string **43** extending to the subsurface valve is supported from the hanger assembly **440** positioned in the well head between the first and second master valves. The hanger assembly is illustrated in detail in FIGURES 2–E through 2–I.

The inner tubing string is secured to and supported from a hanger sub **475**, shown in FIGURE 2–D, which is

removably engaged in the hanger assembly. The clamp rams **591** of the hanger assembly engage an annular recess **538** on the hanger sub to hold the hanger sub and inner tubing string against longitudinal movement. The longitudinal slot **539** below and connecting with the recess **538** of the hanger sub receives a lug **631** on a ram **590**, see FIGURE 2–E, to hold the hanger sub against rotation at the position shown in FIGURE 2–A during handling of the inner tubing string in the procedure of installing the flow control system. The hanger assembly and hanger sub, as will be explained in greater detail hereinafter, are provided with means for forming the seal **441** closing off the upper end of the annular space **44** between the inner and outer tubing strings. A lateral flow passage **450** extends through the hanger assembly into the annular space **44** to allow fluid pressure to be applied through the conduit **451** from the pressure source **452** to provide the required fluid pressure within the annular space around the subsurface valve for supporting the valve in an open position by holding the weight column in an upward position, as explained in more detail hereinafter. The fluid pressure source **452** is arranged to function responsive to the operational conditions which are monitored and used as the bases for control of the fluid flow control system. For example, it may be desired that the subsurface valve be closed when the pressure within the well head or the flow line **432** exceeds a predetermined maximum. In such event the pressure is monitored by any suitable means so that when the pressure exceeds the predetermined maximum the pressure source **452** is then deactivated permitting the pressure within the annular space **44** to drop allowing the weight column of the subsurface valve to close the valve shutting off flow through the inner tubing string. When the flow control system of the invention is used in connection with an off-shore well having a platform or other well head structure which might be severely damaged by a ship or a barge, the pressure source **452** may be used in conjunction with a detection system for deactivating the pressure source to shut in the well in response to a severe blow sustained by the well platform which might damage or knock off the well head.

A principal component of the fluid flow control system is the subsurface valve assembly **30** illustrated in detail in the FIGURES 1–A through 1–F and 3 through 26. The subsurface valve assembly includes a telescoping joint **31**, a weight or floating section **32**, a detent assembly **33**, a flapper valve assembly **34**, the ball valve assembly **35**, and a lock mandrel assembly **40**. The lock mandrel assembly secures the ball valve assembly within the landing nipple **41** which is a part of outer tubing string **42** through which an inner tubing string **43** extends. The telescoping joint forms a longitudinally slidable connection between the inner tubing string **43** and the floating section so that the floating section may be raised and lowered relative to the inner tubing string to open and close the ball valve. The floating section is supported in an upward position to hold the ball valve opened by a pressure differential between the pressure in the annular space **44** between the inner tubing string **42** and the outer tubing string **43** and the pressure in the flow stream in the tubing string **43**. The weight of the floating section biases the ball valve toward a closed position while the pressure of a fluid in the annulus between the inner and outer tubing strings biases the floating section in an upward position to hold the valve open. A decrease in pressure of the fluid biasing the floating section upwardly releases the floating section to impose its weight on the ball valve closing the valve irrespective of and independent of the ambient pressure around the ball valve and weight sections mechanism.

In FIGURES 1–A through 1–F, the ball valve is illustrated in open position and the lock mandrel assembly located within the landing nipple but not yet locked in the nipple against upward movement. Referring to FIGURE 1–A, the bottom section of the inner tubing string **43** is threaded to the tubing joint **45** which is suitably secured at the reduced end section **45***a* to the upper end of the tubular body **50** of the telescoping sections. The connection between the section **45** and the body **50** is made by welding the upper end of the body around the tubing joint at **51** and also by welding the members together through a plurality of circumferentially spaced holes **52** formed around the body.

An annular piston head **53** is slidably disposed within the body **50** and secured on the upper end of the piston rod **53***a* by an annular weld at **54** and welds between the floating section and the piston head through a plurality of circumferentially spaced holes **55** extending through the piston head. A port **50***d* through the body **50** permits the movement of fluids into and out of the body as the piston head reciprocates in the body. The O-ring **60** disposed in the annular recess **61** of the piston head between the back-up rings **62** and **63** seals between the piston head and the inner wall of the body **50**. As will be discussed in more detail hereinafter, the action of fluid under pressure beneath the annular piston head **53** biases the floating section upwardly to maintain the safety valve in open position.

The lower portion of the telescoping joint **31** includes an annular retainer assembly **64** engaged in the lower end of the body section **50** to hold the piston head within the body. By so limiting the downward movement of the piston head relative to the body by means of the stop assembly, the body may be lifted until the upper end of the stop assembly engages the lower end of the piston head at the weld **54** to raise the floating section and the ball assembly. The stop assembly, as represented in FIGURSE 1–B, 3, 4, and 5, is segmented to facililtate insertion of the assembly into the body. The assembly consists of the cylindrical segments **65** and **70** having upper outwardly projecting lugs **65***a* and **70***a*, respectively, as seen in FIGURES 1–B, 3, and 5, and of the cylindrical segments **71** and **72** having the lower outwardly projecting lugs **71***a* and **72***a*, respectively, as shown in FIGURES 4 and 5. The segments **65** and **70** are held in the body by engagement of the lugs **65***a* and **60***a* and the upper holes **50***a* and **50***b*, respectively, while the segments **71** and **72** are retained in the body by engagement of the lugs **71***a* and **72***a*, respectively, in the lower holes **50***c* and **50***d*, respectively, of the body. Each of the segments is enlarged around its lower end forming an upwardly facing shoulder **73** extending around the assembly engaging the lower end of the body **50**. Since the function of the stop assembly is to limit the downward travel of the piston head within the body **50**, the several segments of the assembly are loosely fitted with respect to each other and around the floating section to facilitate their insertion into the body.

The piston rod **53***a* is threaded at the lower end into the coupling **74**, which is locked to the piston rod by a plurality of the socket set screws **75** radially positioned around the coupling engaging the piston rod as illustrated in FIGURE 1–B. The coupling **74** is threaded into the upper end of the weight section **32** comprising a a variable number of the tubular members depending upon the weight required at the operating depth of the valve. The lower end of the weight section is threaded to the detent section body **81** shown in FIGURES 1–B and 1–C. A detent collet **82** is loosely positioned within the body **81** to releasably connect the body to the upper end of the ball valve operator tube **83**. The collet is held in the body by engagement of the lower end of the collet with the upper end of the flapper valve body or cage **84** threaded into the lower end of the body **81**. As shown in FIGURE 7, the collet includes the collet fingers **85** formed on the spring section **90** which extend from a base ring **91**, thereby allowing the collet fingers to flex both laterally and longitudinally. Each of the collet fin-

gers has an outer boss **92** and an inner boss **93**. The outer bosses extend from the upper ends or shoulders **94** to the lower upwardly and outwardly inclined shoulders **95**. The inner bosses **93** are defined by the inwardly convergent upper and lower internal shoulders **100** and **101**. Referring to FIGURE 1–C, the body **81** has an upper internal annular locking recess **102** between an upper internal annular shoulder **103** and the lower internal annular shoulder **104** of an inwardly extending annular flange **105**. The lower internal annular locking recess **110** is formed within the body **81** between the downwardly sloping internal annular bottom shoulder **111** of the flange **105** and the upwardly facing internal annular shoulder **112**. The valve operator tube is provided with an external annular locking flange **113** between the external annular shoulders **114** and **115**. An external annular locking recess **120** extends on the tube **83** between the shoulder **115** and the external upwardly facing annular shoulder **121**. The collet fingers cooperate with the recesses and flanges on both the operator tube and within the body **81** for connecting and disconnecting the lower end of the weight section and the upper end of the operator tube, as will be explained in more detail hereinafter.

The O-ring **122** is fitted within the recess **123** in the body **81** between the back-up rings **124** and **125** to seal between the inner wall of the body and the outer wall of the operator tube.

As shown in FIGURE 1–C, the flapper valve assembly **34** is mounted on the valve cage **84**. Referring to FIGURES 8–11, the flapper valve **130** is supported for movement between the full open position illustrated in FIGURE 1–C when the valve is disposed within the circular opening **131** extending through the body **84** and the closed position illustrated in FIGURE 9. The valve is pivotally supported on an arm **132** by a pin **133** extending through the arm and the parallel spaced longitudinal flanges **134** and **135** formed on the back side of the flapper valve. The arm **132**, whose upper end extends into the vertical slot **140** of the valve cage is pivotally connected to the valve cage by a pin **141** which extends through the tangentially oriented hole **142** in the valve body. The flapper valve is biased toward the closed position by a spring **143** extending from a hole **144** in the arm through the longitudinal slot **145** to the hole **150** in the valve cage. The opposite ends of the spring are secured in the holes **144** and **150** in a suitable manner, as by friction fit or the like. When the valve is in closed position, as in FIGURE 9, it seats against the valve seat **151** fitted in the recess **152** of the valve body. The O-ring seal **153** disposed in the annular recesses **154** of the valve seat and **155** of the valve body seals between the valve body and the valve seat. When the inner tubing string including the flapper valve assembly is being run downwardly into a well bore over the upper end of the operator tube, the flapper valve is held in open position by a latch spring **160** disposed in an external annular slot **161** of the valve body. The latch end of the latch spring extends through the slot **162** in the valve body to releasably engage the lower edge of the flapper valve, as illustrated in FIGURE 8, to hold the valve in open position while the tubing string is being run downwardly through the well bore and over the upper end of the valve operator tube. The notch **163** in the spring is shaped so that when the valve cage **84** moves over the operator tube **83**, the outer surface of the tube will engage the inner face **130***a* of the flapper valve to displace the valve into the opening **131** and disengage the notch **163** of the lower rim of the valve. Movement of the flapper valve from the position of FIGURE 8 to the vertical position of FIGure 1–C release the spring from the valve rim. When the flapper valve assembly is over the valve operator tube, the external surface of the tube holds the flapper valve in the full open outward position within the opening **131** of the body as shown in FIGURE 1–C. The spring **143** biases the flapper valve toward the closed position of FIGURE 9 due to the pulling force exerted by the spring between the valve body and the valve arm **132**. Thus, when the flapper valve assembly is lifted from over the safety valve operator tube, the spring **143** pulls the flapper valve to the closed position. The lower end of the valve cage **84** is provided with the extending internal annular flange **164** having an upper sloping shoulder **165** and lower sloping shoulder **170** to facilitate movement of the valve body over the valve operator tube.

Referring to FIGURE 1–C, the valve operator tube **83** extends through the head member **171** which is threaded into the upper end of the valve housing **172**. The operator tube is coupled with the head member by the split ring segments **173** and **174**, see FIGURE 12, disposed in the cooperating external annular recess **175** around the operator tube and the internal annular recess **180** within the head member. The recess **180** extends to the lower end of the head member and thus is substantially longer than the recess **174** thereby permitting longitudinal movement of the operator tube relative to the head member while limiting the upward movement of the operator tube so that the head member is lifted by the split rings when the tube is raised to engage the split rings with annular shoulder **176** of the head member defining the upper end of the recess **180**.

The external annular flexible rings **181** and **182** mounted on the upper enlarged head are engageable with the internal surfaces of the external tubing string **41** to form a sand barrier therebetween which prevents sand from accumulating around the lower portions of the latch device by migrating downwardly around the head member of the valve. An external annular downwardly sloping flange **184** is formed on the head member at the lower end of the head **183** and an upwardly facing external annular flange **185** is formed around the head member below the flange **184**. The O-ring **190** is positioned between back-up rings **191** and **192** in internal annular recess **193** within the head member to seal between the inner wall of the head member and the operator tube.

Referring to FIGURES 1–C and 1–D, the valve operator tube **183** extends downwardly into the valve housing **172** with an enlarged section **194** of the operator tube providing an upwardly facing shoulder **195**. A spring **200** disposed around the operator tube engages the lower end of the head member **171** and the shoulder **195** and biases the operator tube in a downward direction. The enlarged bottom section **201**, of the operator tube provides an upwardly facing external annular shoulder **202** which engages the bottom annular shoulder of the internal annular flange **203** of the valve housing to limit upward movement of the operator tube relative to the valve housing.

An upper tubular seat **204** has an upper portion slidably disposed within the lower end of the operator tube. An O-ring **205** positioned between the back-up rings **210** and **211** in the internal annular recess **212** within the lower end of the operator tube **83** seals between the valve seat and the internal surface of the tube. An external annular flange **213** is formed around the lower end of the valve seat and provided with an external annular recess **214**. An annular downwardly facing valve seat surface **215** is formed on the lower end of the valve seat **204**. An internal annular sleeve **220**, see FIGURES 1–D and 14, is disposed within the valve housing **172** between the flange **203** and the lower valve seat guide **221**. An internal annular flange **222** of the sleeve is received in the recess **214** around the upper valve seat locking the upper valve seat against longitudinal movement within the valve housing. The sleeve is of a resilient substance and deforms outwardly as the upper valve seat is telescoped downwardly thereinto and the external flange **213** thereof moves past the internal flange **222** until the flange **222** moves into alignment with the recess **214**. This assembly

of the upper valve seat with the sleeve is, of course, performed prior to their insertion into the valve housing **172**. A lower valve seat **223** is biased upwardly by a spring **224** disposed around the lower valve seat and between the upper end of the valve seat guide and the lower external annular shoulder **225** of the upper enlarged portion **230** of the lower valve seat. An internal annular upwardly facing seat surface **231** is formed on the upper end of the lower valve seat.

A ball valve **232** disposed betweeen the valve seat surfaces **215** and **231** has a flow passage **233** to permit fluid flow through the subsurface valve assembly when the ball valve is in the open position illustrated in FIGURE 1–D. The upper valve seat is held against upward movement by engagement with the flange **222** while the lower valve seat is biased upwardly by the spring **224** causing the ball valve always to be held in engagement with its upper and lower seats.

The ball valve is provided with operator holes **234** and **235**, see FIGURE 13, which receive the operator knobs **240** and **241** formed on the operator members **242** and **243**, respectively. As best illustrated in FIGURE 14, the operator members **242** and **243** are disposed in the longitudinal windows or slots **244** and **245** formed in the sleeve **220**. The slots **244** and **245** are each sufficiently longer and wider than the operator members to permit the necessary longitudinal and circumferential or lateral movement of the operator members to rotate the ball valve between open and closed positions. The operator members **242** and **243** are, respectively, provided at their upper ends with the internal flanges **250** and **251** which are slidably received in the external annular groove **252** of the operator tube **83** so that longitudinal movement of the operator tube will raise and lower the operator members to rotate the ball valve. Longitudinal reciprocation of the operator members by the operator tube causes the operator knobs to rotate the ball valve between open and closed positions about the axis **253** as represented in FIGURES 13 and 15–B. The ball valve is rotated between open and closed positions through the angle **254** which is an angle of substantially 90 degrees. During the movement of the ball valve, the operator holes **234** and **235** move a distance L longitudinally and a distance C circumferentially as represented in the FIGURE 15–B. To move the ball valve between open and closed positions, the operator members must move longitudinally the distance L while the operator knob on each of the operator members must follow the arcuate path illustrated in the dotted line portion of the FIGURE 15–B, thus causing the operator members to each move circumferentially the distance C. The flanges **250** and **251** fit sufficiently loosely within the recess **252** to permit this circumferential movement of the operator members as they are moved longitudinally to rotate the ball valve. In order for the operator members to move the distance C circumferentially, their flanges must slide in the recess **252** and in so doing, each of the two operator members moves the distance C toward the other member and then away the same distance to rotate the ball valve through the required 90 degrees for moving the ball valve between closed and open position. Each of the operator members will move laterally or circumferentially around the recess through an arc of approximately 10 degrees while rotating the ball between the open and closed positions. Each of the operator holes moves through an arc of approximately 15 degrees while the ball rotates between its closed and open positions. The shorter arcs of movement of the operator knobs are due to the facts that when the ball is in its fully open and fully closed positions, the knobs are in outer positions in the operator holes; and they move farther inwardly into the operator holes as the ball approaches and reaches a middle position during its movement between its fully open and fully closed positions and then again move to their outer positions in the operator holes as the ball moves from its middle position toward its fully open or fully closed position. Thus, the operator members will converge toward each other and move away from each other a total of twenty degrees during the rotation of the ball valve. It will therefore be obvious that each of the windows **244** and **245** must be wider than the widths of the operator members by substantially 10 degrees of arc or a circumferential distance C and they must be longer than the operator members by the longitudinal distance L in order to contain the operator members and permit their combined longitudinal and circumferential movement during the rotation of the ball valve.

As the ball valve is rotated by the operator members, its longitudinal position within the valve housing remains fixed since the ball valve is biased into sealing engagement with the fixed upper valve seat by the force of the spring **224** which urges the lower valve seat upwardly against the ball valve.

The lower valve seat guide **221**, which fits within the lower end of the sleeve **220** along an upper reduced section **221***a*, is held against downward movement by the upper end of the secondary collet housing **253** threaded into the lower end of the valve housing **172**. The upper end section **254** of the housing **253** is reduced in diameter providing the upwardly facing external annular shoulder **255** against which the lower end of the valve housing rests providing a substantially smooth external surface along the connection between the valve housing and the secondary collet housing. The collet housing is threaded on the primary collet lock sleeve **260** as shown in FIGURE 1–E with the lower end of the housing engaging the upwardly facing annular shoulder **261** of the lock sleeve. A collet lock mandrel **262** is positioned within the secondary collet housing **253** and the collet lock sleeve **260** as shown in FIGURES 1–D and 1–E with the O-ring **263** positioned in the internal annular recess **264** within the housing **253** between the back-up rings **265** and **270** to seal between the external surface of the upper end of the lock mandrel and the interal annular boss **271** within the housing. An annular split sleeve **272** is disposed around the lock mandrel **262** within the external annular recess **273** of the lock mandrel with upward movement of the sleeve relative to the lock mandrel being limited by the annular shoulder **274** at the upper end of the recess and downward movement of the split sleeve relative to the mandrel being limited by the annular shoulder **275** at the lower end of the recess. As illustrated in FIGURES 1–E and 18, the split sleeve fits within the upper end of the lock sleeve **260** to which the split sleeve is secured by a shear pin **280** which releasably engages the split sleeve and lock sleeve. Referring to FIGURES 1–D and 17, a secondary collet **281** is secured around the split sleeve **272** by a plurality of shear pins **282** which extend through the base ring **283** of the collet into the split sleeve. An external annular flange **284** around the split sleeve in engagable with the lower end of the base ring of the secondary collet and with the upper end of the collet lock sleeve **260**. The collet fingers **285** of the secondary collet serve to releasably connect the housing **253** with the lock mandrel **262**, the collet fingers being receivable in the internal annular recess **290** within the housing and the external annular recess **291** of the lock mandrel. An annular locking surface **292** is formed around the lock mandrel above the locking recess **291**.

As shown in FIGURE 1–E, the lock mandrel **262** is reduced along the intermediate section **293** with the reduced section extending from a sloping downwardly facing annular shoulder **294** to a lower external annular should **295**, which is at the upper end of the enlarged bottom section **300** of the lock mandrel. A primary collet assembly **301** is disposed around the lock mandrel with the major portion of the assembly extending along the reduced portion **293**. Referring to FIGURES

1–E, 19 and 20, the primary collet assembly, which functions to lock the ball valve assembly **35** against upward movement within the landing nipple **41**, includes the primary collet **302**, which is loosely fitted about the lock mandrel and the locking fingers **303** which are formed on and extended downwardly from the lock sleeve **260** around the lock mandrel within the collet. When the device is in locked position within the landing nipple, the locking fingers hold the primary collet in locked position within the nipple. The FIGURES 19 and 20 best illustrate the relationship of the locking fingers with the primary collet. Each of the locking fingers **303** has a thin lower end section **304** extending downwardly from the sloping shoulder **305** formed on the thicker central portion **310** of the locking finger. An internal upwardly facing sloping shoulder **311** is formed on the upper end of each of the enlarged central sections of the locking fingers. The enlarged central section and the lower thin section of the locking fingers are positioned around the reduced section **293** of the locking mandrel so that the shoulder **294** on the locking mandrel and the shoulder **311** on the locking fingers are engageable with each other.

The primary collet **302** includes a plurality of downwardly extending collet fingers **312**, each having an outer locking surface or boss **313** which is engageable in the locking recess of the landing nipple. Between each of the collet fingers is a downwardly opening slot **314** while each of the fingers is provided with a slot **315** which opens upwardly through the base ring **320** of the collet. A plurality of radially extending fins **321** are formed around the lock mandrel **262** along the reduced section **293**. Each of the fins extends into one of the slots **315** formed in each of the collet fingers **312** to hold the collet in the downward position shown in FIGURE 1–E. As best shown in FIGURE 19, each of the locking fingers **303** is positioned behind a slot **314** overlapping the inside surface of half of one of the locking fingers and half of the other locking finger adjacent to the slot. Each of the locking fingers may engage half of the inside surface of two adjacent collet fingers. The locking fingers coact with each other to lock the collet fingers **312** in the landing nipple.

The lock mandrel **262** is reduced along a lower section **323** around which is disposed the packing assembly **324** which is held against upward movement by the downwardly facing annular should **325** on the mandrel. The packing assembly comprises a V-shaped packing **330** and **331** confined between the male adaptor **332** and the female adaptors **333** and **334**.

The lock mandrel **262** is threaded on the lower end to a locator mandrel **335** which supports the selector key assembly **340** which locates the flow control device at the correct position for locking within the desired landing nipple. The selector keys **341** and **342** are supported on the mandrel between the key nut **343** threaded on the mandrel at the lower end of the lock mandrel and the key retainer **344** supported on the mandrel below the keys by the threaded nut **345**. The selector keys are biased outwardly by springs **350** engaged between the mandrel and the keys. The keys engage the complementary shaped annular key grooves **351** and **352** within the landing nipple so that the engagement of the downwardly facing selector key shoulders **353** with the upwardly facing landing nipple shoulder **354** prevents downward movement of the device through the landing nipple. The upwardly and inwardly sloping surfaces **355** and the complementary surface **360** within the landing nipple permit upward movement of the device. As explained in more detail in U.S. Patent No. 2,798,559 issued to J. V. Fredd, July 9, 1957, the selector keys perform a locating function permitting the valve assembly to be moved through a tubing string until it arrives at a landing nipple having key grooves corresponding to the configuration of the outer surface of the selector keys.

Referring to FIGURE 21, the running tool **370** is shown locked on the operator tube **83** for lowering the valve assembly downwardly through a well bore to the position for locking the assembly within the landing nipple **41**. The running tool includes a tubular body **371** threaded at the lower end on a sleeve-like skirt **372** and at the upper end to a head member **373** which has an upper reduced threaded section **374** for the engagement of a support member **375** suspended from a wire line **380**. The ports **373***a* in the head member allow fluid flow between the central flow passage through the tool and the exterior so that the tool may be lowered and raised in a fluid filled hole. A retainer ring **381** is secured within the housing above and spaced apart from the skirt by the tangential shear pins **382** which are engaged through the tangential holes **383** through the housing and the tangential semicircular recesses **384** on opposite sides of the retainer ring.

The collet assembly **385** is loosely disposed within the housing above the retainer ring. The collet assembly includes a base ring **390** from which extend a plurality of collet fingers **391** each having a collet head **392** with an outwardly extending boss **393** and an inwardly extending boss **394**.

The housing **371** is reduced in internal diameter along a section **400** which is provided with an internal annular seal recess **401** containing an O-ring **401***a* between the back-up rings **401***b* and **401***c*. An internal recess **402** is formed in the housing for receiving the shoulder **114** and the upper portion of the locking flange **113** around the operator tube **83**. An upper annular locking recess **403** and a lower annular locking recess **404** are formed within the housing separated from each other by the internal annular locking flange **405**.

The structure of the pulling tool **410** in FIGURE 26 is substantially identical to the running tool with minor exceptions which will be explained and thus all of the identical parts and features of the tool have been given the same reference numerals. The shear pins **413** are identical in size to the shear pins **382** and differ therefrom only in the material of which they are constructed so that their shear strength will be greater. The shear pins **413** generally will be formed of steel or bronze as contrasted with a softer metal such as aluminum which may be used in the shear pins **382**. Also, only one shear pin **382** may be used whereas normally two of the shear pins **413** will be employed. The skirt **414** threaded into the lower end of the housing differs from the skirt **372** in the length of the portion of the skirt below the housing since the longitudinal position of the operator tube is lower when removing the flow control device from a well bore as contrasted with its position when running the device into a well bore. In all other respects the same basic tool may be employed for both running and pulling with the proper skirt and shear pins being installed depending upon the function that the tool is to serve.

The polished joint assembly **476** used in installing and removing the weight section and telescoping joint of the subsurface valve and the inner tubing string is illustrated in detail in FIGURES 2–B and 2–C. The polished joint assembly generally comprises a support swivel **477**, a valve **478**, an elongated, polished, slidable, tubular joint **479**, and a stuffing box **480** through which the polished joint is slidable. The neck **485** of the swivel is provided with a hole **486** to receive a supporting hook as shown in FIG. 2–A during installation or removal of the subsurface valve. The swivel neck extends in rotatable relationship through the bushing **487** which is threaded into the connecting member **488** engaged with the upper end of the body **478***a* of the valve **478**. A thrust bearing **489** is threaded on the lower end of the swivel neck and locked by the nut **490**. The O-rings **495** and **496**, separated by the ring **497**, are confined between the upper end of the

bearing **489** and the downwardly facing shoulder **498** within the bushing. When the polished joint assembly is suspended as in FIGURE 2–A and weight is placed on the bearing, the swivel neck is pulled upwardly forcing the upper end of the bearing closer to the shoulder **498** causing the O-rings to expand to seal between the bushing and the swivel neck. Upward movement of the swivel neck relative to the bushing is limited by engagement of the bearing surface **499** of the bearing **489** with the lower end of the bushing. A flow passage **500** extends through the swivel neck communicating with the conduit **505** connected into the neck to permit fluid flow into and out of the upper end of the polished joint assembly. The polished joint **479** is secured to the reduced lower end portion **506** of the valve body **478***a* by the coupling **507**. The valve **478** may be any suitable form of valve such as a ball valve which will close off fluid flow or regulate the fluid flow through the body **478***a* below the connecting member **488** and thus through the polished joint assembly.

The stuffing box **480** includes a body member **508** having a downwardly opening annular recess **509** in which the packing **510** is held by the retainer ring **515** threaded into the lower end of the body. The lower end of the body **508** is reduced and provided with an external annular recess **516** in which an O-ring **517** is fitted. A coupling **518** is loosely fitted around the body **508** and held against downward movement over the body by the upwardly facing external annular shoulder **519** of the body member **508** which is engageable with the internal flange **520** on the coupling. The coupling is provided with the internal threads **525** for connection over an upwardly extending externally threaded flange **652** on the upper face of a suitable blowout preventer **653**, with the inner surface of the flange of the blowout preventer fitting around the reduced lower portion of the body **508**. The O-ring **517** seals between the body and the inner surface of the blowout preventer flange. A coupling **526** is threaded on the lower end of the polished joint **479** and held against rotation relative to the joint by the shear pin **527**.

The polished joint **479** generally will be from 15 to 18 feet in length to permit the longitudinally maneuverability for landing and locking the tubing string in the well bore. The joint **479** is slidable through the stuffing box with downward movement of the member being limited by engagement of the lower end of the coupling **507** with the upper end of the body **508** and upward movement of the tubular member being similarly limited by the engagement of the upper end of the coupling **526** with the lower end of the retainer ring **515**. The external surface of the joint **479** is sufficiently smooth or polished that the packing **510** forms a seal with the joint as it slides through the stuffing box. The configuration of the elements of the packing cause the packing to expand into tighter relationship both with the inner wall of the recess **509** and with the external surface of the joint **479** when the packing is subjected to a pressure from below between the retainer ring and the surface of the joint.

The hanger sub **475**, as shown in FIGURE 2–D, is a tubular member which may be landed and locked within the hanger assembly **440** to support the inner tubing string **43** within the well bore. The sub is engageable on the lower end of the polished joint assembly for handling the tubing string in carrying out certain steps of installation and removal of the tubing string. The internal threads **535** at the upper end of the sub are engageable with the lower threaded end of the coupling **526** on the lower end of the polished joint assembly while the external threads **536** at the lower end of the sub permit connection with the upper end of a tubing string. The sub is reduced in diameter along a lower section **537** below and spaced apart from an external annular recess **538**. A longitudinal slot **539** is cut into the surface of the sub extending from the reduced section **537** upwardly into the recess **538**. An O-ring **540** and a back-up ring **545** are positioned in a lower external annular recess **546** and an O-ring **547** and a back-up ring **548** are similarly positioned in an upper external annular recess **549** around the sub.

A back-pressure valve assembly **550** is engageable in the upper end of the hanger sub to permit downward flow through the sub while preventing upward flow. The back-pressure valve may be threaded into and removed from the sub by means of the two pronged collet **555**. The body **556** of the back-pressure valve is provided with an external O-ring seal **557** around the body below the external threads **558**. The body is reduced in diameter along a lower end section **559** below the radial ports **560** connecting into the valve chamber **561** at the lower end of the longitudinal flow passage **562**. The back pressure valve body is reduced in diameter above the shoulder **563** and provided with a laterally extending slot **564** which permits fluid flow into the upper end of the bore **562** and receives the inwardly extending collet finger bosses **565** so that the collet may grip the body of the valve and rotate the body for threading it into and out of the hanger sub. A spring retainer **565** having a bore **565***a* is threaded into the lower end of the valve body to support the spring **570** and the ball valve **571**. A downwardly facing annular valve seat **572** is formed around the bore **562** to permit the ball valve to close off upward flow into the bore. Flow from above the ball valve causes the ball to move downwardly against the resistance of the spring allowing fluid to flow around the ball through the chamber **561** and the ports **560** downwardly around the reduced lower end section of the valve body into the bore **575***a* through the hanger sub. The biasing effect of the spring **570** maintains the ball on seat **572** together with an upwardly acting pressure differential across the ball to prevent upward flow through the valve so that the valve will hold a back pressure within a tubing string supported from the hanger sub. The back-pressure valve is inserted by the collet to the position shown in FIGURE 2–B only when certain operational conditions require the holding of a back pressure within the tubing string to which the hanger sub may be engaged.

The hanger assembly **440** includes a body **580** which is formed in the shape of a cylindrical segment having a plurality of radially positioned, axially extending bores **581** which permit the master valves **424** and **425** to be bolted to the bottom and top faces of the body. The body **580** may be formed from a standard type flange used in certain oil field production tools so that the hanger assembly may be secured with standard types of master valves having similar flange bodies. The seal recesses **582***a* and **582***b* are formed in the upper and lower faces, respectively, of the body to receive ring type seals to seal between the hanger assembly body and the adjacent bodies of the master valves. A radiallly extending bore **450** opens into an axial central bore **583** through the body. The radial bores **584** and **585** extend along a common axis perpendicular to the radial bore **450** and the axial bore **583** and intersecting the axial bore. The lug ram **590** in the bore **450** and the clamp rams **591** in the bores **584** and **585** cooperate to support the hanger sub and hold the sub against rotation in the hanger assembly. The outer end of the bore **450** is connectable with the conduit **451** as shown in the FIGURES 2 and 2A.

The clamp ram assemblies **591** in the bores **584** and **585** are identical in structure. The clamp ram **592** of each clamp ram assembly is provided at its inner end with an arcuate toothed section **593**, the length of which permits the toothed surface to be received within the annular recess **538** of the hanger sub **475** to provide vertical support to the sub within the hanger assembly. A locking spring slot **594** extends laterally across the clamp ram near the inward end thereof. The internally threaded bore **595** extends into the ram from the outward end to receive the jack screw **600** for moving the clamp ram in the bore **584** into and out of locking relationship with the hanger sub. A lateral vent port **601** extends through the clamp ram into the inward end of the bore **595** to allow entry

and exhaust of fluid from the bore **595** as the jack screw is rotated relative to the clamp ram. The jack screw is rotatably positioned through a packing gland **602** and the gland nut **603**. An O-ring **604** and a back-up ring **605** are fitted within the packing gland around the jack screw to seal between the jack screw and the gland. An O-ring **610** around the packing gland seals between the gland the surface of the bore **584**. The packing gland is held against inward movement by the annular flange **611** formed around the gland. A bearing flange **612** is formed around the jack screw fitted within the gland nut at the outward end of the gland to hold the jack screw against movement along its longitudinal axis while being rotated to move the clamp ram into and out of locking position. The outward end of the jack screw is provided with the flat surfaces **613** to permit engagement of a wrench with the jack screw for rotating the screw.

The lug ram **590** is retained within the bore **450** in the position illustrated in FIGURE 2–E by the spring **620** which encircles the bore **583** of the hanger assembly body passing through the recesses **594** at the inward ends of the clamp rams. The end portions **620***a* and **620***b* of the spring are received in the slot system **621** formed along the top of the lug ram. The mid portion **620***c* of the spring is wider than the end portion along the dimension parallel to the axis of the bore **583** to increase the strength of the spring.

The configuration of the lug ram is best understood by reference to the enlarged FIGURES 2–G through 2–I. The slot sytem **621** serves a dual function of providing fluid communication through a portion of the ram while also cooperating with the spring **620** to move the ram inwardly and outwardly within the bore **450**. The unusual configuration of the slot system is largely a result of machining expediency to achieve the two objectives of the system to provide the needed fluid flow paths and the necessary camming surfaces against which the spring acts to move the lug ram. The elongated slots **622** and **623** provide fluid communication through the ram from the inward end of the ram into its bore **624** which extends into the ram over about one half the length of the ram, as illustrated. The slots **622** and **623** also provide the cam surfaces **622***a* and **623***a*. The shorter slots **625** and **630** provide the cam surfaces **625***a* and **630***a*, respectively. A lug **631** having an arcuate inner face **631***a* is formed on the inward end of the lug ram to cooperate with the longitudinal slot **539** in the hanger sub to hold the hanger sub against rotation within the hanger assembly. The lower end of the lug **631** slopes upwardly and outwardly along the surface **631***b*. It will be readily understood that the slot system in the lug ram, due to the cylindrical configuration of the ram can be cut with standard milling tools by basically cutting the two long and two short slots previously described. The long slots **622** and **623** intersect the bore **624** to provide communication through the length of the ram. Obviously, the bore **624** can not extend entirely through the ram because of the need for material to form the lug **631** on the inward end of the ram. The triangular segment of the ram, two sides of which form the surfaces **625***a* and **630***a*, in cut off along its top forming the flat surface **632**.

The lug ram is moved into and out of locking position within the bore **450** by the action of the ends **620***a* and **620***b* of the spring which are expanded and contracted by the movement of the clamp rams within the bores **584** and **585**. In the position illustrated in FIGURE 2–E the lug ram is held inwardly by the spring so that the lug **631** is engaged in the longitudinal recess **539** of the hanger sub **475**. The lug ram is retracted sufficiently to disengage the lug from the longitudinal recess of the hanger sub by retracting the clamp rams **591** by rotation of the jack screws. As the clamp rams retract, the surfaces **594***a* of the clamp rams defining the inner sides of their slots **594** engage the inner surfaces of the portions of the spring **620** extending through these slots and, as both of the clamp rams are retracted or drawn away from the hanger sub, the spring is spread apart moving its end portions **620***a* and **620***b* away from each other. The spring end **620***b* acts against the surface **623***a* while the spring end **620***a* acts against the surface **622***a* of the lug ram causing the ram to be moved downwardly until the lug **631** is no longer engaged in the recess **539**. When the clamp rams are moved inwardly in the bores **584** and **585** the back faces **594***b* of the slots **594** engage the outer surface of the section of the spring **620** through each of the rams causing the end portions **620***a* and **620***b* of the spring to be moved closer together. As the spring end portions move closer together the inner surfaces of the spring end portions act against the cam surfaces **625***a* and **530***a* of the lug ram to cam the lug ram inwardly so that the lug **631** will be biased inwardly and may be received in the longitudinal recess **539** of the hanger sub.

A further important feature of the slot and spring arrangement as shown in connection with the lug ram is that due to the generous tolerance in the slot **594** between the inner and outer surfaces **594***a* and **594***b* defining the slots, the clamp rams **591** may be retracted sufficiently to withdraw the inward ends of the rams from the annular recess **538** of the hanger while the lug **631** is biased inwardly by the spring so that the hanger sub may be rotated and moved longitudinally until the lug is snapped by the spring ends into locking position in the slot **539**. In other words, the spring will permit the lug ram to be held outwardly with the lug **631** being engaged with the outer surface of the hanger sub at a location on either side or above or below the slot **539** and the hanger sub **475** may be rotated and moved longitudinally while hunting for the proper position and when such position is reached the spring biased lug ram will snap inwardly with the lug properly moving into the slot **539** to hold the sub against rotation while the polished joint assembly is threaded into or out of the upper end of the sub.

Referring to FIGURE 2-F, the axial bore **583** through the body **580** of the hanger assembly is enlarged along a lower section **583***a*, is enlarged along an intermediate section **583***b*, and is still further enlarged along an upper section **583***c* with an upwardly facing shoulder **583***d* being formed at the juncture of the sections **583***b* and **583***c*. A seal sub **640** is supported within the bore **583** to provide a sealing surface engaged by the O-rings **540** and **547** of the hanger sub when the hanger sub is locked in its proper position within the hanger assembly. The seal sub is reduced in diameter along a lower section **640***a* to fit within the section **583***b* of the bore through the body **580**. The upper section of the seal sub **640***b* is enlarged to fit within the section **583***c* of the bore. The external annular shoulder **640***c* around the seal sub seats on the shoulder **583***d* within the bore. The lower ring seal **641** and the upper ring seal **642** are engaged in annular recesses around the seal sub. The lower ring seal seals between the body **580** and the seal sub in the bore **583***c*. The upper ring seal seals within the bore of the master valve **425** around the seal sub.

The flow control system is installed in the well bore in several steps during each of which one or more of the above described components of the system is engaged in carrying out the step. The landing nipple **41** is installed in the outer tubing string **42** either upon initial completion of the well or subsequent thereto in order to permit landing and locking of the subsurface valve assembly **30**. The lock mandrel assembly **40** and the valve assembly **35** are landed and locked in place as a unit within the tubing string, followed by the detent assembly **33** and the flapper valve assembly **34**, the floating weight section **32**, and the telescoping joint. The detent assembly, the flapper valve assembly, the weight section, and the telescoping joint are lowered as a unit on the lower end of the inner tubing string **43** and engaged with the valve assembly by latching the detent assembly over the upper end of the operator tube **83** of the valve assembly.

A well in connection with which the flow control system of the invention is to be installed must be equipped with the landing nipple **41** to provide the means for landing and locking the subsurface valve assembly in position within the well bore. The landing nipple may have been installed in the tubing string **42** upon initial completion of the well. If, however, the landing nipple was not so installed, standard oil field procedures are used to pull the tubing string, connect the landing nipple in the string at the proper position, and run the string back into the well and secure it in position as illustrated in FIGURE 2. The well head **423** is made up with the necessary units for installation and operation of the flow control system. The well head includes the first and second master valves **424** and **425** on either side of the hanger assembly **440** which is provided with the previously described means or hanger sub **475** for hanging and packing off the inner tubing string **43** and connecting the fluid pressure conduit **451**. The first and second master valves are suitable commercially available valves having the standard flanges permitting interconnection with the body **580** of the hanger assembly. The pressure source **452** is conected into the hanger assembly **440** through the conduit **451**. If the well in which the system is being installed is one which is already producing and has a landing nipple **41** within its tubing string, it is not necessary to "kill the well"; i.e., fill the well with liquid sufficiently heavy to stop it from producing, in order to carry out the installation procedure. It is, of course, necessary that flow through the well be temporarily suspended to permit properly equipping the well head. This may be done by use of conventional wireline equipment to install a plug choke as illustrated at page 3737 of the Composite Catalogue of Oil Field Equipment Services 1964–65 edition, published by World Oil, Houston, Tex. With flow temporarily suspended in the well, or if the well is not flowing and thus does not require the plug choke, the well head is equipped with the first and second master valves and the hanger assembly above described. The well head also includes the T connection **431** on top of which is installed the swab valve **430**.

If the flow control system is being installed in a well which is being initially completed the well should be brought in, tested, and allowed to clean up prior to the steps of installing the subsurface valve. If desired the tubing can be loaded, that is, filled with a liquid, to lower the shut-in pressure of the well but every effort should be made to eliminate trapping dirty or corrosive fluids in the annulus **44** when landing and locking the inner tubing string on the subsurface valve.

To prepare the well head for installation of the subsurface valve assembly **35** and the lock mandrel **40** conventional wireline equipment is made up on the well head with the equipment being secured on top of the swab valve **430** after the flange **433** has been removed. Such wireline equipment includes a lubricator, a stuffing box, and other related apparatus as illustrated and described at page 3741 of the Composite Catalogue of Oil Field Equipment and Services, supra.

If a plug choke is in the landing nipple it must be removed before the valve assembly and lock mandrel can be landed. The tubing should be filled with water or oil and raised to shut-in pressure after which the plug choke is retrieved by standard wireline procedure.

In order to prepare the valve assembly and lock mandrel for insertion into the lubricator from which they are lowered to the landing nipple they are first interconnected in the relationship illustrated in FIGURES 1–D and 1–E by threading the head **271** into the lower end of the housing **172**. The running tool **370** is employed on the valve assembly for actually lowering the valve assembly and lock mandrel through the well bore. In assembly of the lock mandrel, the collet **281** and related members are positioned as shown with the shear pins **280** and **282** installed to hold the units in the relationship where the collet fingers **285** are engaged in the locking recess **291** around the collet lock mandrel **262**. Also the collet lock fingers **303** are held by the shear pin **280** in the relationship shown in FIGURE 1–E while running the devices into the well. The running tool **370** is latched over the operator tube **83** of the valve assembly as shown in FIGURE 21. The running tool is placed over the upper end of the valve operator tube with the operator tube moving into the running tool to the position shown in FIGURE 24 where the locking flange **113** moves into contact with the internal recess **402** with the locking flange camming the collet heads **392** outwardly into the annular recess **403** to allow the locking flange to pass to the position shown where the collet finger heads will move past the shoulder **115** on the lower end of the locking flange. The collet assembly **385** is loosely fitted within the housing **371** and around the operator tube so that the collet assembly may move upwardly with the operator tube to the position where the collet heads will move outwardly into the recess **403**. With the relationship between the valve operator tube and the running tool shown in FIGURE 24, the collet finger heads are positioned to where they may be cammed inwardly to engage the shoulder **115**. The running tool is lifted so that the internal annular flange **404** engages the bosses **393** on the collet finger heads to force the heads inwardly around the operator tube into the locking recess **120** with the upper ends of the collet finger heads engaging the shoulder **115** to support the operator tube and thus permit the valve assembly and lock mandrel assembly to hang from the running tool on the collet fingers. The running tool is lifted with the flange **405** moving into alignment with the bosses **393** on the collet finger heads to hold the collet finger heads in the recess **120** of the operator tube as illustrated in FIGURE 21. The spring **200** biases the operator tube downwardly and, therefore, the ball valve **232** toward a closed position. When the lock mandrel and valve assemblies are suspended from the running tool, the lock mandrel and the valve housing **172** are urged downwardly by their weight in opposition to the biasing force of the spring. This weight may be sufficient to hold the valve housing downwardly relative to the operator tube to keep the ball valve in the open position so that fluid may flow freely through it as the lock mandrel and valve are lowered into position in the tubing string. In the event, however, that the spring **200** is so strong that the weight of the lock mandrel assembly and the safety valve housing will not hold the ball valve in open position, the skirt **372** on the running tool is of sufficient length that its lower end will engage the upper end of the head **183** on the head member of the valve housing so that the operator tube of the valve is held upwardly relative to the valve housing at a position which will maintain the ball valve at least partially open to the degree necessary to allow well fluids to flow through the valve as it is lowered through the tubing string.

The lock mandrel and valve are lowered from the lubricator through the tubing string **42** until the lock mandrel reaches the landing nipple **41**. The landing nipple **41** may be one of several in the tubing string, particularly if a plurality of valves are to be installed in the string. Whether the landing nipple **41** is one of several or the only landing nipple in the string, the key grooves **351** and **352** of the landing nipple conform to the shape of the selector keys **341** and **342** so that when the lock mandrel reaches the landing nipple **41**, the selector keys will be expanded by the springs **350** into the key grooves with the landing nipple shoulder **354** engaging the selector key shoulders **353** to provide support for the lock mandrel and prevent its further movement downwardly. The selector keys thus provide a means for locating the lock mandrel in the proper landing nipple and give vertical support to the lock mandrel.

During the lowering of the lock mandrel and valve assembly through the tubing string, the well fluids in the tubing string move through the central flow passage ex-

tending through the mandrel and valve upwardly into the running tool and outwardly from the running tool through the lateral ports **373***a* back into the tubing string so that any piston effect from the lowering of the assemblies through the tubing string which might hinder their free movement is minimized.

When the lock mandrel is positioned in the landing nipple as above described, jarring impacts are applied to the upper end of the head member **171** by a suitable jar, not shown, incorporated in the wire line to the string. Jars useful in wire line tool strings are discussed on pages 3742–43 of the Composite Catalogue of Oil Field Equipment and Services, supra. The force from the jar is applied by the lower end of the skirt **372** of the running tool to the upper end of the head member with the force being transmitted downwardly through the valve housing **172** and the housing **253** to the collet lock sleeve **260** which is interlocked with the collet assembly **281** by the shear pin **280**. The selector keys are holding the lock mandrel against downward movement within the landing nipple and thus the collet lock mandrel **262** cannot move downwardly by virtue of its connection through the key nut **343** and locator mandrel **335** which are directly supported by the selector keys. With the lock mandrel **262** held against downward movement, the sleeve **272** is also held against downward movement by its engagement with the shoulder **275** on the lock mandrel. The inner end of the shear pin **280** is engaged in the sleeve **272** and thus a downward force by the jar which tends to push the collet lock sleeve **260** downwardly will shear the shear pin **280** freeing the collet lock sleeve to move downwardly inserting the locking fingers **303** on the lower end of the collet sleeve behind the primary collet fingers **312** to hold the collet fingers outwardly so that the outer locking surfaces **313** are held in the locking recess **40***a* of the landing nipple. The locking fingers wedge the collet fingers by virtue of their position behind the collet fingers in an expanded relationship which prevents the lock mandrel from being lifted upwardly and so long as the locking fingers remain in this position behind the collet fingers, the lock mandrel cannot be lifted. As the housings **172** and **253** are lowered in order to lower the locking fingers, the locking recess **290** within the housing **253** moves downwardly until it is in alignment with the heads of the collet fingers **285** which then spring outwardly into the locking recess. The normal position of the collet fingers **285** is outward so that they readily spring into the locking recess when it is in alignment with them. Any force tending to lift the valve assembly and the locking mandrel raises the housing **253**. The engagement of the collet fingers **285** in the locking recess **290** causes a lifting force on the collet **281**, which, through its base ring, is secured by the plurality of shear pins **282** to the sleeve **272**. The upper end of the sleeve **272** upon upward movement engages the shoulder **274** around the lock mandrel **262** since the lock mandrel is locked against upward movement by the collet fingers **312**. Any effort to move the housing **253** upwardly will apply a force to the collet fingers **285**, which, through the shear pins **282** and the sleeve **272**, acts against the shoulder **274** of the lock mandrel **262** to hold the housing **253** and thus the entire valve on the lock mandrel. When the housing **253** moves upwardly after the collet fingers are engaged in the locking recess **290** sufficiently to place the upper end of the sleeve **272** against the shoulder **274**, the collet fingers heads are in alignment with the external locking flange **292** around the lock mandrel **262** so that the collet fingers are locked in the locking recess **290** by the flange **292** and cannot be sprung inwardly by this upward movement of the housing **253**. Thus, since the lock mandrel **262** is held downwardly and the locking flange **292** holds the collet fingers **285** in locking engagement with the locking recess **290**, the collet fingers provide the latching mechanism between the lock mandrel and the housing. As will be explained hereinafter, the valve assembly may be removed from the lock mandrel by shearing the pins **282**.

After the lock mandrel and valve assemblies are latched in the landing nipple as described above the running tool may be removed from the operator tube of the valve. The tool is lifted upwardly with sufficient force to shear the pins **383** engaged between the housing and the retainer ring **381**. Since the retainer ring is held against upward movement by the collet which is engaging the locking recess of the safety valve operator tube, the upward force on the housing of the running tool causes the shearing of the pins to free the housing to move upwardly until the upper end of the skirt **372** engages the lower end of the retainer ring at which position the lower locking recess **404** is in alignment with the heads **392** on the collet fingers **391**. Lifting the housing of the running tool causes the retainer ring to lift the collet with the shoulder **115** on the operator tube camming the collet fingers outwardly into the recess **404** so that the collet fingers will release from the operator tube to permit the running tool to be lifted from over the operator tube thus releasing the running tool from the valve so that the wireline tool string may be removed from the well bore.

After the running tool is disengaged from the valve assembly it is withdrawn by the wire line into the lubricator from which it is removed in a conventional manner. The pressure within the outer tubing string **42** is bled off through the needle valve on the lubricator, not shown, and the master valve **424** is closed.

When the running tool is removed from the ball valve assembly, the ball valve is moved to closed position by the spring **200** engaging the shoulder **195** on the operator tube of the valve forcing the operator tube downwardly causing the operator members **242** and **243** engaged in the recess **252** to be forced downwardly to rotate the valve to the closed position.

With the valve closed and the pressure within the outer tubing string bled off as indicated above, the operation of running in and landing the inner tubing string and the telescoping joint my begin. Conventional pipe handling equipment capable of handling the inner tubing string with the weight section and telescoping joint are utilized to lower these elements through the outer tubing string and engage them on the ball valve assembly.

The master valve **424** is closed, the wireline apparatus down through the including the wireline valve is removed, and a suitable blowout preventer **653** having a flange **652** connectable to the coupling **518** of the polished joint assembly is installed on the swab valve.

The detent assembly, the weight section, and the telescoping joint are assembled in the relationship best illustrated in FIGURES 1–A through 1–C.

The flapper valve **230** is latched in the open position illustrated in FIGURE 1–C by engagement of the notched spring **160** with the lower edge of the flapper valve to hold the valve open so that the detent assembly may be placed over the upper end of the operator tube **83**. In view of the length of the tubular members involved, the detent, weight, and telescoping sections will require assembly as the different portions are lowered into the well bore. For example, the weight section **32** may be several hundred feet in length. The detent assembly **33** with the flapper valve latched in open position is engaged on the lowermost section of the weight section and the detent assembly is lowered into the well bore as the weight section is assembled together in the conventional manner of running tubing into a well bore. When the desired length of weight section has been assembled and supported in the well bore it is followed by the telescoping section which is secured with the weight section as shown in FIGURES 1–A and 1–B with the telescoping section being lowered into the well bore by the inner tubing string **43**. During the lowering of the detent assembly and weight section the weight of the units extends the telescoping section to its maximum length with the shoulder formed by the weld

54 at the lower end of the piston head engaging the upper end of the retainer assembly 64 so that the retainer assembly holds the piston within the tubular section 50 and supports the weight section and detent assembly.

The tubing string is lowered until the detent assembly is a short distance above the upper end of the operator tube of the valve assembly 35. The inner tubing string is "spaced out" or its length is adjusted with tubing "pup joints," which are short pipe joints about two feet in length used to provide latitude in forming a tubing string of the desired length. The spacing out is based on a calculated determination of the length of the inner tubing string required: to allow the detent assembly to be latched over the upper end of the operator tube; to place the telescoping joint at an intermediate travel point leaving it space to move upwardly and downwardly; and to allow the polished joint 476 to lift the tubing string for disengaging the detent assembly from the valve. In other words, the distance from the top of the operator tube to the hanger assembly 440 is determined by any conventional means and the length of the required tubing string is calculated to allow the telescoping joint to be at an intermediate point allowing some upward and downward movement and also permitting the polished joint 476 to lift the telescoping joint to its fully expanded position and pull the detent assembly off the top of the valve assembly so that the tubing string and detent assembly may be removed from the ball valve assembly. Since the polished joint assembly has a slidable section 479 of fifteen to eighteen feet in length, some latitude is permitted in the determination of the required length for the inner tubing string. When the tubing is spaced out and supported from the hanger sub and polished joint it is preferred that the detent assembly be several feet above the upper end of the valve assembly. When the spacing out procedure is completed, the upper end of the upermost inner tubing section is engaged on the threads 536 on the lower end of the hanger sub 475. The back pressure valve assembly 550 is removed from the hanger sub and the sub is connected with the lower end of the coupling 526 on the polished joint assembly. The valve 478 of the polished joint assembly is closed. At this time the stuffing box 480 should be in a downward position on the polished joint 479 with the lower end of the retainer nut 515 engaging or in close proximity to the upper end of the coupling 526. The polished joint assembly is suported during this procedure from the hook 650 suspended from the pulley 651 of the pipe handling equipment, not shown. The polish joint assembly is lowered sufficiently to permit the coupling 518 to be threaded on the flange 652 of the blow-out preventer 653. At this stage in the procedure the lower end of the flapper valve body 84 should be several feet above the upper end of the operator tube 83 of the valve assembly.

The outer and inner tubing strings are now filled with a reasonably clean liquid such as water or oil, if available, by opening the valve 478 in the polished joint and introducing the liquid through the conduit 505 whereby the liquid will flow through the flow passage 500 in the swivel downwardly through the polished joint assembly and the hanger sub into the inner tubing string from which it flows from the lower end of the string into the outer end of the tubing 42, filling both the annular space 44 between the tubing string and the inner tubing string. If the shut-in pressure is high, water may be preferred since it will be heavier than oil. Also, water probably will be more readily available. A hydraulic pump pumping the liquid through the conduit 505 is employed to raise the pressure within the tubing strings to the well shut-in pressure so that when the subsurface valve is opened during the installation procedure the pressures above and below the valve will be balanced to prevent fluid surges caused by the well pressure which might damage the equipment and possibly cause a blowout of the well. The hook 650 is now lowered allowing the polished joint 479 to slide through the stuffing box 480, lowering the inner tubing string until the lower end of the weight section is over the upper end of the operator tube and secured thereto by the detent assembly 33. When engaging the lower end of the weight section over the upper end of the operator tube, the inner tubing string is lowered until the detent assembly and the flapper valve slide over the upper end of the operator tube with the spring 160 being disengaged from the lower edge of the flapper valve as the valve passes over the locking flange 113. The flapper valve is then free and slides along the outer surface of the operator tube. The flapper valve housing and the detent assembly pass downwardly over the operator tube with the collet 82 which is loosely fitted within the body 81 engaging the upper shoulder 114 on the operator tube holding the collet upwardly until the recess 102 of the body is aligned with the heads of the collet fingers so that the shoulder 114 may cam the collet finger heads outwardly into the recess 102 as the shoulder 103 within the body forces the collet finger heads downwardly. The collet finger heads pass the locking flange 113 to snap inwardly around the lower shoulder 115 of the locking flange. When the collet has been latched over the locking flange of the operator tube and the shoulders 103 and 114 are engaged, the weight of the weight section will be supported on the valve which in turn is supported from the lock mandrel 40 latched in the landing nipple 41. As soon as the detent assembly latches over the upper end of the valve operator tube and the weight section becomes supported on the valve, the telescoping section may contract with the tubular section 50 sliding downwardly over the piston rod 53*a* and the piston head 53 moving farther into the tubular section. The latching on of the detent assembly to the operator tube should be readily detectable at the surface due to the reduction in the apparent weight of the tubing string when the support of the weight section is placed on the operator tube. As soon as the detent assembly is engaged on the upper end of the operator tube, the tubing string is lifted with the upper end of the retainer assembly 64 engaging the lower end of the piston 53 at the weld 54 to place a slight strain on the detent assembly to determine if it is properly latched. The lifting of the tubing string will raise the housing 81 of the detent assembly causing the inner locking flange 105 to move into alignment with the outer bosses 92 of the collet fingers 85 retaining the collet fingers in the locking recess 120 so that the collet remains engaged with the operator tube while the lower end of the collet is lifted by the upper end of the flapper valve housing 84. The lifting of the collet raises the operator tube moving the ball safety valve 232 to the open position illustrated in FIGURE 1–D. Since the tubing strings are liquid filled and pressured to the well shut-in pressure, the ball valve is safely opened to test the valve operation. The operator tube is preferably raised and lowered several times to test the valve function.

With the inner tubing string now securely attached on the operator tube of the valve assembly the pressure is bled off the liquid in the tubing strings to test the subsurface valve 30 under the well shut-in pressure. The inner tubing string is bled off through the valve 478 while the outer tubing string is bled off through the device 451 and the pressure source unit 452. At this point in the procedure the weight of the weight section is resting on the operator tube of the subsurface valve and if the valve is functioning properly the weight section should bias the valve to the closed position and hold the valve closed when the pressure within the tubing strings is bled off and therefore no flow should occur through the ball valve at this time. The valve 478 in the polished joint assembly is now closed and the polished joint is raised and lowered sliding through the stuffing box to raise and lower the inner tubing string to open and close the ball valve against the shut-in pressure. During this testing of the mechanical

functioning of the subsurface valve assembly, care must be exercised that the valve of the polished rod assembly is not opened at any time while the subsurface valve is being held open by the upward position of the inner tubing string since the liquid within the inner tubing string might be blown from the string by the well pressure while the ball valve is being mechanically held open by the upward position of the tubing string.

After it has been determined that the subsurface valve assembly is functioning properly, the inner tubing string is landed and secured within the hanger assembly **440**. The polished joint is lowered to position the hanger sub **475** within the hanger assembly at an elevation which will place the annular recess **538** slightly above the clamp rams **591** and the jack screws **600** are rotated moving the clamp rams inwardly toward the hanger sub. The clamp rams may be moved until it is determined that the inward ends are engaging the hanger sub at which time the jack screws are backed off to retract the clamp rams approximately the distance equal to the depth of the slots **594** between the faces **594***a* and **594***b* so that the toothed inward ends of the clamp rams are disengaged from the hanger sub while the spring ends **620***a* and **620***b* are contracted sufficiently to bias the lug ram inwardly with the lug **631** engaging the outer surface of the hanger sub. As has been previously explained, the inward movement of the clamp rams causes the faces **594***b* of the slots **594** to engage the spring segments in the slots to force the spring ends toward each other. As the spring ends move toward each other the inner surface of each of the ends engage the surfaces **625***a* and **630***a* within the slot system of the lug ram camming the lug ram inwardly toward the hanger sub. Due to the depth of the slots **594** between the faces **594***a* and **594***b* the clamp rams may be backed off sufficiently to disengage the toothed inward ends from the hanger sub while the spring will remain in a sufficiently contracted position to bias the lug ram inwardly toward the sub. The polished joint is rotated to rotate the hanger sub until the lug **631** snaps into the longitudinal recess **539** along the hanger sub below the annular recess **538**. At the time the lug snaps into the longitudinal recess the hanger sub and polished joint will be held against rotation by the lug **631** so that the polished joint may be rotated to unthread the lower end of the coupling **526** from the upper end of the hanger sub. The lock pin **527** between the lower end of the polished joint and the upper end of the coupling **526** locks the polished joint with the coupling to insure that rotation of the polished joint will disconnect the coupling from the upper end of the hanger sub **475**. The jack screws **600** are rotated to move the clamp rams inwardly until the inner toothed ends of the rams engage the hanger sub in the annular recess **538** to firmly secure the hanger sub within the hanger assembly with the weight of the inner tubing through the weight section being supported from the hanger assembly. The O-ring seals **540** and **547** around the hanger sub seal with the bore of the seal sub **640** closing off the upper end of the annular space **44** between the inner and outer tubing strings.

The pressure gauge is removed from the conduit **451** and a pressure source **452** is connected to the conduit. A suitable source **452** of fluid pressure operable to apply fluid pressure within the annular space **44** to support the weight column of the subsurface ball valve for holding the valve in an open position is an Otis Surface Control Manifold as shown at page 3710 of the Composite Catalogue of Oil Field Equipment and Services, supra. With the pressure source connected into the hanger assembly the fluid pressure within the annulus **44** is raised and lowered several times to hydraulically open and close the subsurface valve to determine if it is functioning properly. Caution must be exercised to make sure that the bleed-off valve is closed before building up the annulus pressure to open the subsurface valve and that the annulus pressure is reduced or bled off before opening the bleed-off valve from the inner tubing string. These precautions are preferred to minimize the probability of pressure in the inner tubing string blowing liquid in the string out through the polished joint.

After determining that the subsurface valve is functioning properly in accordance with the above described procedures the polished joint is fully disengaged from the hanger sub and the valves **425** and **430** are closed. The blow-out preventer **653** is removed from the well head and the flange **433** along with the valve **434** and pressure gauge **435** are installed on the top of the well head. The subsurface valve may now be hydraulically opened by activating the pressure source **452** and the master valve **425** may be opened to allow the well to flow through the inner tubing string upwardly through the well head and outwardly through the flow line **432**.

The pressure source **452** is connected to operate in response to either or both flow-dependent and nonflow-dependent variables to control the fluid flow control operation. For numerous reasons it may be desirable to suddenly shut in a flowing well. As previously indicated, a sub-sea well may be damaged by an impact received by the well structure from a ship or barge to such an extent that the well head might be severed allowing the well to blow out and present among the many hazards a serious fire potential. Under such circumstances the pressure source **452** may be interconected with a detector system which would deactivate the pressure source in response to an impact to bleed off the pressure within the annular space **44** allowing the weight column of the subsurface valve to drop downwardly effecting closing of the valve.

The actual opening of the subsurface valve when the pressure within the annulus between the tubing strings is increased by the source **452** is carried out in the following manner. The pressure is transmitted throughout the an-annular space **44** above the seal assembly **324** which seals around the lock mandrel **40** within the landing nipple. The movable portion of the apparatus and thus that portion which is sealed with the fixed members of the assembly extends from the piston **53** downwardly through and including the operator tube **83** of the valve assembly. The O-ring **60** seals around the piston head **53** with the inner wall of the housing **50** of the telescoping joint while a seal between the operator tube **83** and the head **171** of the valve assembly is formed by the O-ring **190**. The pressure within the annular space tending to lift the piston, weight section, and operator tube acts on annular downwardly facing surfaces having an area which equals the area encompassed by the line of contact between the O-ring **60** and the inner wall of the housing **50** reduced by the area enclosed by the line of contact between the O-ring **190** and the outer surface of the operator tube **83**. The pressure within the annular space **44** acting on this annular area exerts an upward force on the piston **53** determined by the size of this annular area and the pressure differential between the annular space **44** and the flow passage through the valve at the piston **53**. This force acts in an upward direction in opposition to the downward force of the weight section and the spring **200**. The pressure within the annular space **44** is is increased to a level which lifts the piston, the piston rod, the weight section, and the operator tube **83** sufficiently to open the ball valve **232**. So long as the pressure within the annulus **44** is maintained sufficiently high, the valve will be held in open position. If there is a variation in the pressure in the flow through the valve it may be necessary to adjust the pressure in the annular space **44** since the differential pressure between the annular space and the flow line acting across the piston **53** holds the weight section and other related apparatus in an upward position to maintain the valve in open position. For example, if the pres-

sure in the flow line through the valve increases it may be necessary to increase the pressure in the annual space **44** to continue to provide sufficient pressure differential to overcome the weight section and the spring **200**.

So long as the pressure within the annulus **44** is maintained from the pressure source **452**, the valve will be supported in open position. Any lowering of the pressure provided from the source **452** below a predetermined minimum will reduce the pressure differential across the piston allowing the weight section resting on the operator tube to push the operator tube downwardly rotating the valve to closed position. The pressure source **452** may be interconnected to sense flow variables in the production system at the well head or other variable conditions at remote control stations which may act through the pressure source **452** to release the pressure within the annular space allowing the valve to be moved to the closed position. The valve is therefore fail-safe and unaffected by depth and flow line condition. Due to the short longitudinal stroke of the operator tube necessary to rotate the valve between open and closed positions only a small quantity of fluid is bled off or pumped into the annular space for opening or closing the valve. The operation of the valve is completely unaffected by the depth at which the valve is positioned since the opening and closing of the valve is controlled by the net force acting across the annular piston resulting from the pressure differential maintained across the piston. When this pressure differential is allowed to drop to essentially zero due to an interruption in the pressure provided in the annular space from the surface the ambient pressure around the annular piston does not affect its action and thus the weight section acts as a dead weight to push the operator tube downwardly rotating the valve from the open to the closed position.

When desired the valve may be removed for inspection or service. The valve **425** at the wellhead is closed to stop production through the inner tubing string **43**. The valve **35** is then closed by releasing the pressure within the annular space **44** by adjustment of the pressure source **452** to permit the weight section to force the valve to closed position. When the valve is closed the wellhead is then bled off by opening line valve **425** to allow pressure relief into the flow line **432**. With the pressure then being bled from the flow line to the atmosphere a suitable blow-out preventer is then installed on the wellhead along with the polished joint. The pressure within the inner tubing string **43** and the annular space **44** is raised to substantially the level of the pressure within the well below the closed valve. The inner tubing string **43** is lifted to disengage the detent latch **33** from the operator tube of the valve. Upward movement of the housing of the detent assembly forces the base ring **91** of the collet **82** upwardly compressing the spring portions **90** of the collet causing the heads **92** of the collet fingers to be pushed against the shoulder **115** on the operator tube camming the collet finger heads outwardly into the locking recess **110** of the body **81** when the locking recess has been aligned with the heads of the collet fingers. The upper ends of the collet fingers are shaped to conform to the downwardly sloping shoulder **111** on the lower end of the locking flange **105** within the body so that when the collet finger heads are cammed into the locking recess they will be latched with the body out of engagement with the operator tube and cannot retract inwardly when the detent assembly is lifted from the operator tube. In raising the inner tubing string the telescoping joint will extend until the lower end of the shoulder **54** of the annular piston rests on the upper end of the retainer assembly **64**. Since the spring **160** is disengaged from the lower rim of the flapper valve **130**, the valve is held open by the outer surface of the operator tube and when the lower edge of the valve passes the upper end of the operator tube, the spring **143** will pull the valve to the closed position shown in FIGURE 14. As the tubing string is raised, fluid trapped within and escaping from the tubing may swing the flapper valve open sufficiently for the fluid to drain out of the tubing with the spring biasing the valve toward the closed position so that it will act in the nature of a check valve in the event something occurs which would tend to force the fluid upwardly out of the tubing string.

When the lower end of the weight section is lifted off the upper end of the operator tube of the subsurface valve, the inner tubing string is fully disengaged from the valve and the ball valve is closed by the spring **200**. The wellhead is now bled off since the subsurface valve is closed holding the well pressure at the ball valve and allowing the pressure above the valve to be reduced. The stuffing box coupling **518** of the polished joint assembly is disengaged from the flange on the blowout preventer and the clamp rams are retracted to release the hanger sub from the hanger assembly. The inner tubing string down through the lower end of the weight section is lifted by the hanger sub and polished joint until the entire tubing string has been removed from the well bore.

With the polished rod, the hanger sub, and the entire inner tubing string including the weight section of the subsurface valve assembly removed, the blow-out preventer is disengaged from the wellhead and the previously discussed wire line valve and lubricator along with the required associated apparatus is installed on the wellhead. The pulling tool illustrated in FIGURE 26 is connected on the lower end of a wireline tool string including oil or spring jars. The pulling tool is identical in structure to the running tool except in the use of the more shear resistant pins **413** and a shorter spacer skirt **414**. The shorter skirt is required because the operator tube of the ball valve over which the pulling tool fits will be downward with the ball valve in the closed position. The shorter length skirt is required to permit the collet of the pulling tool to be positioned downwardly sufficiently to engage the locking recess on the operator tube of the valve. The pulling tool is lowered on the wireline tool string downwardly over the upper end of the valve operator tube with the freely positioned collet **385** riding upwardly within the housing **371** until the upper ends of the collet fingers engage the upper end of the recess **403**. The collet finger heads are forced outwardly around the locking flange **113** on the operator tube until the collet fingers pass the locking flange and spring inwardly into engagement with the shoulder **115** at the lower end of the locking flange. The running tool is lifted slightly bringing the flange **405** in alignment with the outer surfaces of the heads of the collet fingers holding the collet in engagement with the operator tube in the position shown in FIGURE 26. Upward force on the pulling tool will now force the operator tube in an upward direction with the lock segments **173** and **174** as shown in FIGURE 1–C engaging the upper end of the recess **180** within the head **171** to lift the head and the tubular housing **172** together with the collet housing **253**. It will be recognized at this point that the collet fingers **312** are still engaged in the landing nipple holding the lock mandrel against upward movement. Upward force is now applied by the jars in the tool string to the operator tube causing upward impacts to be transmitted downwardly to the various tubular members connected to the operator tube to lift the collet housing **253**. The collet fingers **285** are engaged in the locking recess **290** in alignment with the locking flange **292**. The upward force on the collet fingers **285** transmitted through the locking recess **290** lifts the collet against the shear pins **282** which are held against upward movement by the retainer **272** engaged at the upper end thereof against the shoulder **274**. The upward jars shear the pins **282** releasing the collet to be lifted by the locking recess **290** upwardly past the locking flange **292** so that when past the flange, the collet fingers are cammed inwardly by the locking recess freeing the collet housing to be lifted to the position

relative to the lock mandrel **262** illustrated in FIGURE 1–E. The locking fingers **303** are thus retracted from within the heads of the collet fingers **312** so that the collet fingers may be contracted to disengage the collet from the landing nipple. After the shear pins have been severed, the wireline tool string is lifted with the upper surface of the locking recess **40***a* of the landing nipple camming the primary locking fingers **312** inwardly releasing the lock mandrel for upward movement through the tubing string. Also, the selector keys **342** are readily cammed inwardly to a retracted position by the sloping surfaces of both the keys and the complementary recesses of the landing nipple.

When the lock mandrel is released from the landing nipple the wireline tool string is lifted into the lubricator and subsequently removed in accordance with standard wireline procedures.

The subsurface flow control valve is reinstalled within the landing nipple by following the initial installation procedure described above. It will be recognized of course, that several of the shear pins, such as the shear pins **280** and **282** were severed during the previous installation and removal procedures and thus such shear pins will have to be reinstalled in the valve assembly components so that it may again be landed and locked within the tubing string.

As indicated above in the detail description of the subsurface valve assembly the weight column **32** may be varied in length by the addition or removal of the pipe sections which make up the column. The determination of the amount of weight required in the weight column is affected by a number of factors related to the predetermined well conditions under which it is desired that the subsurface valve shut-off fluid flow through a well. These factors may be categorized as those forces acting downwardly tending to move the operator tube in a downward direction to rotate the ball valve to a closed position and those forces acting in an upward direction tending to lift the operator tube and thus rotate the ball valve to an open position. The forces acting downwardly biasing the valve toward a closed position result from the following: the hydrostatic pressure of the column of fluid within the inner tubing **43** acting downwardly on the piston **53**; the pressure of the well fluid flowing through the valve which acts downwardly on the piston; the strength of the spring **200**; and the weight of the weight column. The hydrostatic pressure may vary between a maximum when the inner tubing **43** is liquid full to a minimum when the tubing is gas filled. The pressure of the well fluids in the tubing, other than hydrostatic, will, of course, depend upon the formation penetrated by the well and providing the fluids to the tubing. This pressure is readily ascertainable by measurement of the pressure within the well at the approximate elevation at which the piston **53** will be located. Both the hydrostatic pressure and the formation pressure within the flow control device act across the piston tending to force the piston in a downward direction in conjunction with the weight column and the spring to tend to force the ball valve toward closed position.

Those forces which act on the under side of the piston tending to lift the piston and within the operator tube tending to lift the tube combine to bias the valve toward the open position are the following: the force resulting from any pressure drop within the well fluids flowing through the central flow passage of the operator tube; the hydrostatic pressure beneath the piston due to the column of control fluid extending from the surface within the annular space **44** between the inner and outer tubing strings; and the control pressure provided in the annular space from the source **452**.

In evaluating these various factors to determine the amount of weight needed in the weight column and thus the value of the control pressure necessary to support the weight, certain of the factors are essentially fixed by well conditions while others are determinable based on the conditions under which it is desired that the valve close upon interruption of the control pressure. In considering the hydrostatic pressure of the column of well fluids within the inner tubing string, it is generally preferred that it be assumed the wellhead might be so damaged or even knocked off that all liquid would be blown out of the inner tubing string leaving only a column of gas with essentially zero hydrostatic pressure existing in the tubing string at the piston. The force provided by the spring **200** will be a minimum due to the limited space available for such a spring and since the spring is not primarily to perform the complete function of closing the valve under flowing conditions of the well. As previously indicated, of course, the pressure within the inner tubing string from the formation fluids is readily ascertainable.

Considering now the forces which tend to open the valve, the hydrosatic pressure at the piston resulting from the column of control fluid within the annular space between the tubing strings is readily calculatable knowing the fluid which is to be used and the depth at which the piston of the flow control device will be located. Knowing the flowing conditions through the operator tube, an estimate may be readily made of the pressure drop through the tube and thus the force resulting from such drop which tends to lift the tube. In progressing to a solution of the problem of the amount of weight which should be in the weight column, the first value obtained is the amount of weight which combined with the hydrostatic pressure in the inner tubing string, the spring force, and the well fluids pressure would be required to counterbalance the pressure drop through the operator tube in the fluid flowing through the tube combined with the hydrostatic pressure at the piston of the control fluid within the annulus. Knowing this amount of weight, it will then be obvious that any additional weight in the weight column will force the operator tube downwardy to close the ball valve when the control pressure is interrupted. It is this additional weight which is supported by the control pressure in the annulus. It is preferred therefore that the additional weight be several hundred pounds to allow quick and positive closing of the valve. For example, if it is determined that a weight column of 200 pounds coupled with the other downwardly acting forces would counterbalance the force from the pressure drop through the operator tube and the hydrostatic pressure in the annulus, both acting upwardly, it may then be preferred that an additional 300 pounds be added to the weight column to bias the valve toward the closed position. The control pressure must, therefore, support this 300 pounds and provide still further force to insure that the valve will be held in an upward open position. Thus, in order to insure that the control pressure will hold the operator tube in an upward position, a control pressure in excess of that necessary to support the additional 300 pounds of weight is provided from the source **452**. Therefore, when any condition occurs which interrupts the control pressure, the excess 300 pounds weight in the weight column will be free to force the operator tube downwardly to close the ball valve against the pressure drop through the operator tube and the hydrostatic pressure within the annular space at the piston.

If it is desired to pump fluids into the well through the inner string of tubing after the valve has moved to its closed position, the fluids are pumped into the upper end of the inner tubing string through the flow line **432** and the wellhead. As the pressure in the inner tubing above the ball is thus raised and exceeds the pressure therebelow to the degree necessary to overcome the upward force exerted on the ball and lower seat **223** by the spring **224** and by the pressure below the ball and the lower seat, the ball rotates about the opeartor knobs since the operator members **242** and **243** are now in their lower-

most positions and cannot move further downwardly. The ball valve rotates downwardly about an axis offset from its center and is thus moved away from the top upper seat **204** and moves the lower seat **223** downwardly against the force exerted by the spring **224**. Such downward and rotary movement of the ball moves its passage into communication with the passages of the upper and lower seats and thus permits the downward flow of fluids from the surface through the inner string of tubing.

If conditions develop requiring service or replacement of the master valve **425** and it is desired that the upper end of the inner tubing string be closed, the back pressure valve assembly **550** may be installed within the hanger sub **475**. The FIGURE 2–D illustrates the back pressure valve positioned within the hanger sub with the running tool **555** engaged with the valve. The back pressure valve may be installed in the hanger sub by use of standard equipment and operating procedures. For example, with the valve **430** closed the plate **433** may be removed and replaced with a blow-out preventer on top of which a tubing stuffing box is engaged to permit tubing to be run under pressure through the wellhead into the well. The running tool **555** is threaded on the lower end of a section of tubing and the back pressure valve **550** is connected with the running tool as illustrated in FIGURE 2–D. The running tool and back pressure valve are inserted through the stuffing box into the wellhead with the back pressure valve being threaded into the upper end of the hanger sub by the running tool as illustrated. When the back pressure valve is secured in the hanger sub, the tubing section and running tool are lifted causing the fingers of the collet on the running tool to expand disengaging from the neck portion of the valve. The two collet fingers of the running tool fit over the neck of the valve such that the running tool rotates the valve to engage and disengage the valve in the threaded upper end of the hanger sub. With the valve installed in the hanger sub pressure may be held by the valve in the inner tubing string. The pressure within the hanger sub below the ball valve element **571** is held by the engagement of the ball valve with the seat **572**. If it is desired to inject fluid into the inner tubing string, the fluid may flow through the bore **562** depressing the ball valve against the spring **570** to allow the fluid to pass around the ball through the chamber **561** outwardly through the lateral ports **560** and downwardly within the hanger sub bore around the reduced lower end section of the back pressure valve. With the back pressure valve holding the pressure within the inner tubing string, the master valve **425** and any other desired equipment above the hanger assembly may be removed and/or serviced as needed. When the required work on the wellhead is finished it may again be equipped with a blowout preventer and a tubing stuffing box to permit the tubing section with the running tool to enter the wellhead under pressure to engage the back pressure valve for unscrewing it from the hanger sub. When the valve is unthreaded from the sub it is withdrawn through the stuffing box by the running tool. The well master valve **425** may again be closed and the well re-equipped to resume production.

It will now be seen that there has been described and illustrated a new and improved fluid flow control system for controlling fluid flow through a flow conductor responsive to a predetermined change in one or more variables which may be independent of the conditions within the conductor.

It will be further seen that a new and improved safety valve system for use in a flow conductor of a well has been described and illustrated.

It will also be seen that there has been described and illustrated a new and improved method of controlling fluid flow in a well bore.

It will be seen that the method of controlling fluid flow through a well bore includes positioning within the well bore at a desired depth a subsurface valve having weight means for biasing the valve toward a closed position with such weight means being supportable in an upper position to hold the valve open by fluid pressure in an annular space around the valve, applying fluid pressure in the annular space to support the weight means for holding the valve in open position, and closing the valve by reducing the fluid pressure in the annular space to permit the weight means to move downwardly to move the valve to a closed position.

It will also be seen that the subsurface valve included in the flow control system may be installed within a well bore at any desired depth.

It will be additionally seen that the flow control system includes a subsurface valve assembly which because of its lack of a depth limitation may be installed below the normal paraffin level as distinguished from conventional safety valves which are often limited to the paraffin zones or above such zones within a well bore.

It will be further seen that the flow control system does not necessitate the use of the conventional small hydraulic line outside of the tubing string extending between surface control elements of the system and the subsurface valve.

It will be seen that the flow control system includes a subsurface valve which is biased toward a closed position by a weight column and counterbalanced to hold the valve in open position by surface controlled fluid pressure in an annular flow passage around and separate from the flow passage in which the subsurface valve is disposed and through which the valve controls the flow of fluid.

It will also be seen that the flow control system is operable in response to variations in operating conditions independent of the fluid which the system is controlling.

It will be further seen that the flow control system permits the subsurface valve to be landed in a nipple in a well conductor without the necessity of removing the conductor from the well for the purpose of attaching the conventional small hydraulic line extending down the well bore to the valve.

It will also be seen that the subsurface valve included in the system has a full bore passageway which allows various well tools to pass through the section of the flow conductor in which the subsurface valve is positioned.

It will be seen that the subsurface valve included in the flow control system may be installed in a flow conductor utilizing a minimum of surface equipment.

It will be seen that a running tool for installing the subsurface valve of the flow control system has been described and illustrated.

It will also be seen that there has been described and illustrated a tool for removing the subsurface valve of the flow control system.

It will additionally be seen that the flow control system includes a polished joint assembly having a stuffing box and an elongated slidable tubular member for use in the landing and locking of the principal components of the subsurface valve assembly.

It will be further seen that the fluid flow control system includes a tubing hanger assembly for supporting the inner string of tubing while permitting fluid pressure to be applied from the surface into the annular space between the inner and outer tubing strings for the purpose of providing the necessary hydraulic pressure to counterbalance the weight column of the subsurface valve.

It will be seen that the tubing hanger assembly includes radially movable clamp rams and a lug ram through which fluid pressure is applied to the annulus between the inner and outer tubing strings and which is spring biased inwardly by a spring actuated by the clamp rams.

It will be further seen that there has been described procedure for installing and removing a fluid flow control system used in conjunction with a well.

It will be seen that the method of installing the fluid flow control system includes the steps of landing and locking in the well bore a subsurface valve having weight means for biasing the valve toward a closed position,

such weight means being supportable by a fluid pressure in an annulus around the valve to hold the weight means in an upper position for holding the valve open, lowering a tubing string including a detent latch, a weight section, and a telescoping joint into the well bore, positioning the detent section of the tubing string over the operator tube of the subsurface valve, releasably locking the detent section on the operator tube, lowering the tubing string until the telescoping joint is positioned intermediate its end positions whereby the weight section may be raised and lowered to actuate the valve without affecting the longitudinal position of the tubing string, landing and locking the tubing string within a hanger assembly included in a wellhead at the surface end of the well, and connecting to the wellhead a source of fluid pressure for applying fluid pressure through the wellhead into an annular space extending from the surface to the subsurface valve whereby a fluid pressure may be applied from the surface through the annular space to support the weight means of the subsurface valve at an upper position for holding the valve open.

It will additionally be seen that the flow control system includes a hanger sub for supporting the inner tubing string from the tubing hanger assembly of the invention.

It will also be seen that there has been described and illustrated a back pressure valve for use in the hanger sub when it is necessary to hold a pressure within the inner tubing string while servicing the wellhead above the upper end of the hanger sub.

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.

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

1. A fluid flow control system comprising: a subsurface valve positioned within a well bore for controlling fluid flow through said bore including a tubing string connected with said valve and providing an annular flow passage in said well bore exteriorly of said tubing string extending through said well bore from the surface end thereof to said subsurface valve; tubing hanging means at the surface end of said well bore supporting said tubing string extending to said subsurface valve, said tubing hanging means having flow passage means communicating with said annular flow passage extending to said subsurface valve; tubular weight means forming a part of said valve and connected with said tubing string to provide a flow conductor from said valve to said tubing string, said weight means being movable with respect to said tubing string while maintaining fluid communication therewith for biasing said valve toward closed position; means on said weight means providing a pressure surface exposed to fluid pressure exteriorly of the valve and exteriorly of said tubing string for application of fluid pressure thereto for suppporting said weight means at a position to hold said valve open by such fluid pressure; fluid pressure source means connected with said tubing hanging means for applying fluid pressure through said tubing hanging means into said annular space extending to said subsurface valve, said pressure source means being operable responsive to a predetermined state of at least one operating condition being monitored to reduce the pressure being applied to said annular flow passage to a level below the value required to support said weight means of said subsurface valve for holding said valve in open position to allow said valve to close upon occurrence of said predetermined state of said monitored operating condition.

2. A system for controlling fluid flow through a well bore of the character set forth in claim 4 comprising means for moving said flow conductor and said weight means longitudinally from the surface of the well to move said valve between open and closed positions.

3. A fluid flow control system according to claim 2 wherein said fluid pressure source means is operable responsive to a monitored condition for controlling said pressure source means to close said subsurface valve upon occurrence of a predetermined state of said condition.

4. A fluid flow control system according to claim 1 including: a hanger sub supported by said tubing string hanging means and secured to the supper end of said tubing string; said tubing string hanging means and said hanger sub having operatively associated seal means for sealing the upper end of said annular space extending to said subsurface valve; and locking means in said tubing hanger assembly engageable with said hanger sub, said hanger sub having an annular recess for receiving said locking means of said tubing hanger assembly and a longitudinal recess communicating with said annular recess; a lug carried by said tubing hanger assembly engageable in said longitudinal recess of said hanger sub for releasably holding said hanger sub against rotation within said tubing hanger assembly.

5. A fluid flow control system according to claim 4 including a back-pressure valve insertable into said hanger sub for holding fluid pressure within said tubing string and said hanger sub below said back-pressure valve and permitting introduction of fluid into said tubing string through said hanger sub from above said back-pressure valve.

6. A fluid flow control system according to claim 4 including: a polished joint assembly adapted to be secured on the wellhead at the surface of said well bore and engaged with said hanger sub for raising and lowering said hanger sub during the landing and locking of said tubing string within said well bore, said polished joint assembly comprising a stuffing box securable on said wellhead and a polished joint slidably engaged through said stuffing box, said polished joint being engageable at the lower end thereof with the upper end of said hanger sub and being longitudinally movable through said stuffing box with a seal relationship being maintained between said stuffing box around said polished joint whereby said tubing string and said hanger sub may be moved longitudinally within said well bore while maintaining fluid pressure within said well bore below said stuffing box.

7. A fluid flow control system in accordance with claim 1 including: a polished joint assembly engageable with said tubing string for moving said tubing string longitudinally within said well bore for landing and locking said tubing string within said well bore and interconnecting said tubing string with said subsurface valve, said polished joint assembly including a stuffing box securable on a wellhead at the surface of said well bore and a polished joint longitudinally slidable through said stuffing box and securable at the lower end thereof with the upper end of said tubing string whereby said polished joint may be raised and lowered through said stuffing box for longitudinally manipulating said tubing string within said well bore.

8. A flow control system of the character set forth in claim 4 wherein said valve comprises: upper and lower tubular members telescoped one within the other and having a flow passage therethrough communicating with said tubing string; a ball valve member rotatably supported by said upper tubular member and moved downward by said weight means to cause said ball valve member to move to closed position.

9. A flow control system of the character set forth in claim 1, wherein said valve means comprises: upper and lower tubular members telescoped one within the other and having a flow passage therethrough communicating with said tubing string; a valve member rotatably mounted in one of said tubular members and having a flow passage alignable with the passage of said tubular members when said valve member is in an open position, said valve member being rotatable to a closed position to close off flow through the passage in said upper tubular

member; and means interconnecting one of said tubular members and said valve member to rotate said valve member between open and closed positions in response to relative longitudinal movement between said tubular members.

10. A flow control system of the character set forth in claim **9** wherein the weight means is connected to the upper of said tubular members and has sufficient mass to move said upper tubular member longitudinally solely due to weight to rotate said valve member to closed position.

11. A flow control system of the character set forth in claim **10** wherein: said weight means connected with said upper movable tubular member is provided with pressure responsive means exposed to fluid pressure for holding said upper movable tubular member in a position holding said valve member in open position.

12. A system for controlling fluid flow through a well bore of the character set forth in claim **9** wherein said rotatable valve member is supported by one of said tubular members and is rotatable by the movable one of said members.

13. In safety apparatus for controlling the flow of fluid in a well bore of the character set forth in claim **1** wherein the weight of the weight means is sufficiently great to overcome the effect of the static pressure of the fluid pressure from the source means acting on the pressure surface provided in said weight means.

14. A fluid flow control assembly comprising: a subsurface valve adapted to be supported at the lower end of a tubing string within a well bore, said subsurface valve including weight column means for biasing said valve toward a closed position, said valve having pressure responsive means communicating with the well bore exteriorly of the tubing string and the valve for actuation by fluid pressure from exteriorly of the valve to support said weight column means at an upper position for holding said valve open by fluid pressure applied in said annular space around said valve, said subsurface valve including a telescoping joint permitting said weight column means to be raised and lowered for opening and closing said valve responsive to said fluid pressure; a tubing string connected with said telescoping joint of said subsurface valve extending to the surface end of said well bore for conducting well fluids flowing through said subsurface valve to the surface; a hanger sub connected with the upper end of said tubing string; means providing an annular fluid flow passage extending to said subsurface valve from said surface end of said well bore; a tubing hanger assembly engaged at the surface end of said well bore, said tubing hanger assembly having at least two radially movable clamp rams for releasably supporting said hanger sub on said tubing string at said surface end of said well bore, a lug ram radially movable within said hanger assembly body into and out of locking engagement with said hanger sub, said lug ram having a passage means providing longitudinal fluid communication through said ram, said ram having cam surfaces for moving said ram longitudinally within said body, a spring operatively associated with said clamp rams and having ends engageable with said cam surfaces of said lug ram for moving said lug ram inwardly and outwardly within said hanger assembly body and biasing said lug ram inwardly responsive to the position of said clamp rams, said lug ram being positioned within a fluid flow passage extending through said hanger assembly body for applying fluid pressure through said body into said annular flow passage; a seal sub supported on said hanger assembly body above said clamp rams around said bore through said body; said hanger sub being releasably engageable through said bore of said hanger assembly, said hanger sub having an external annular recess engageable by said clamp rams for longitudinally supporting said hanger sub within said hanger assembly and a longitudinal external recess communicating with said annular recess for receiving said lug on said lug ram to hold said hanger sub against rotational movement within said hanger assembly, and external seal means around said hanger sub to form a seal with said seal sub of said hanger assembly for sealing the upper end of said annular space extending to said subsurface valve, the lower end of said hanger sub being engageable with the upper end of said tubing string extending to said subsurface valve; a polished joint assembly engageable with the said well-head above said hanger assembly and connectable with the upper end of said hanger sub for manipulating said hanger sub both rotationally and longitudinally within said hanger assembly, said polished joint assembly having a stuffing box including a coupling engageable with the wellhead, a polished joint slidable and rotationally positioned through said stuffing box, the lower end of said polished joint being engageable with the upper end of said hanger sub, a seal within said stuffing box around said polished joint to seal with said polished joint permitting said polished joint to be moved relative to said stuffing box while maintaining a seal between said stuffing box and said polished joint, a valve connected with said polished joint above the upper end of said joint to control fluid flow through said polished joint assembly, and means for supporting said polished joint from pipe handling equipment positioned above said wellhead; a fluid pressure source adapted to supply fluid pressure in said annular space around said subsurface valve for supporting said weight column of said valve to hold said valve in open position, said pressure source being operable responsive to a predetermined state of a monitored operating condition for reducing the fluid pressure within said annular space when said predetermined state of said operating condition is detected to reduce the pressure within said annular space to a valve below the pressure required to support said weight column of said subsurface valve allowing said weight column to close said valve; and conduit means connected into said radial flow passage of said hanger assembly extending to said fluid pressure source.

15. In safety apparatus for controlling the flow of fluid in a well bore: upper and lower tubular members telescoped one within the other and having a passage through which fluid can flow; coengageable valve means in said members closing said passage when said upper member is in a lower position along said lower member; said passage being open when said upper member is in an elevated position along said lower member; a conductor string extending downwardly in the well bore; tubular flow conductor weight means connected to said upper tubular member and slidably connected with the lower end of said conductor string in flow communication with said conductor string and movable axially of said conductor string in the well bore; means for moving said conductor string and said weight means longitudinally from the surface of the well for elevating and lowering said upper tubular member to positively move said valve means between positions opening and closing said passage; fluid pressure responsive means connected with said weight means and said conductor string exposed to fluid pressure exteriorly of said conductor string for elevating said weight means for elevating said upper member to open said passage and to hold said passage open, said pressure responsive means being operable by fluid pressure of a predetermined minimum value to act on said weight means connected to said upper member to retain said upper tubular member in an elevated position whereby said passage remains open while said predetermined fluid pressure acts on said pressure responsive means, said weight means being operable to drop suddenly in said well bore to cause said upper member to move downwardly along said lower member and move said coengageable valve means to position to close said passage when

said fluid pressure is reduced below said predetermined minimum value.

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