

[54] **WELL FLOW CONTROL VALVES AND WELL SYSTEMS UTILIZING THE SAME**

[72] Inventor: Donald F. Taylor, Jr., Dallas, Tex.

[73] Assignee: Otis Engineering Corporation, Dallas, Tex.

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[51] Int. Cl. E21b 33/00

[58] Field of Search.....166/224, 224 S, 315; 137/384.8, 630.19

[56] **References Cited**

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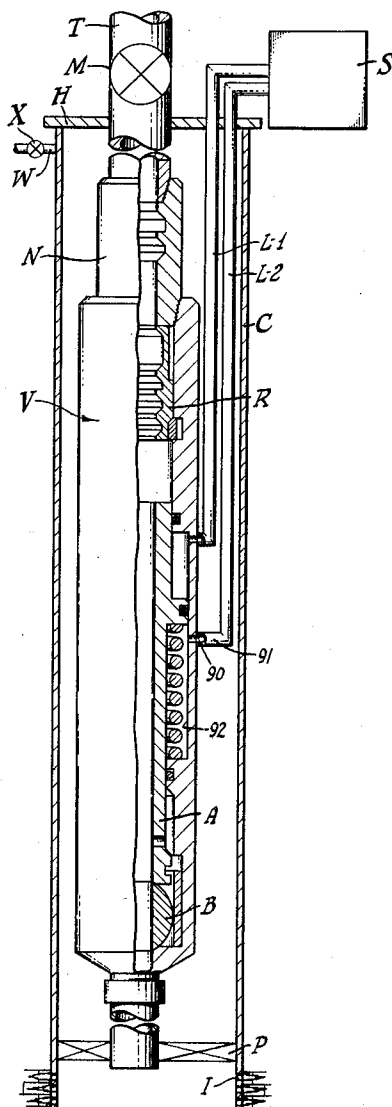
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Primary Examiner—James A. Leppink
Attorney—E. Hastings Ackley

[57] **ABSTRACT**

A valve for installation in a flow conductor for controlling flow of fluids through the conductor, which may be controlled from a remote point and which may act automatically as a safety valve, including means for positively propping the valve in the open position to hold the same in such open position when desired, for performing various well service operations through the valve, for taking the valve out of operation permanently or for flowing the well without affecting operation of the valve, and further including means for locating and operating a supplemental flow control valve at such point in the flow conductor. Also includes a releasable restraining device for holding the valve in the open position which is movable to a position freeing the valve for normal functioning.

24 Claims, 17 Drawing Figures



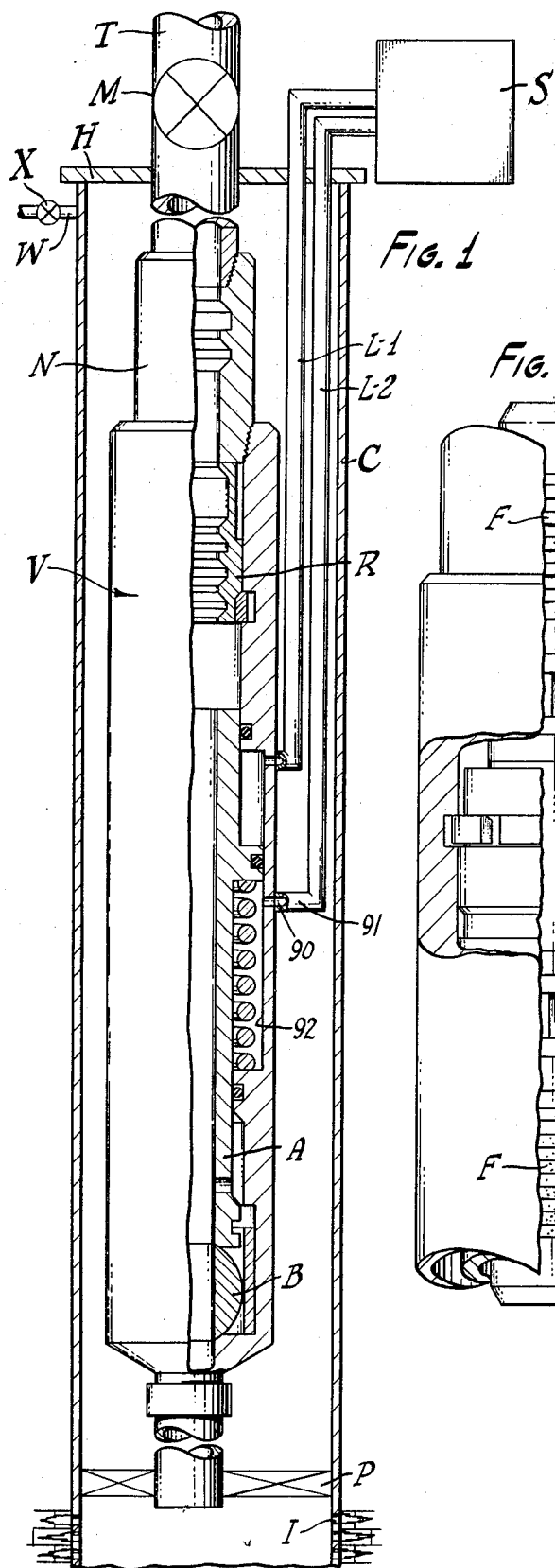


Fig. 1

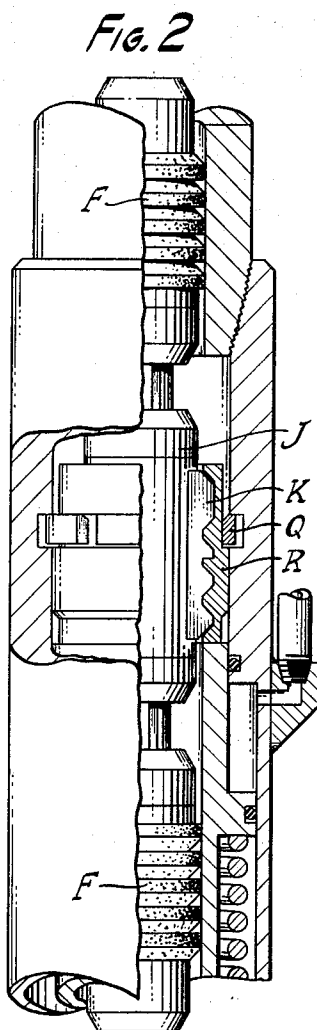


Fig. 2

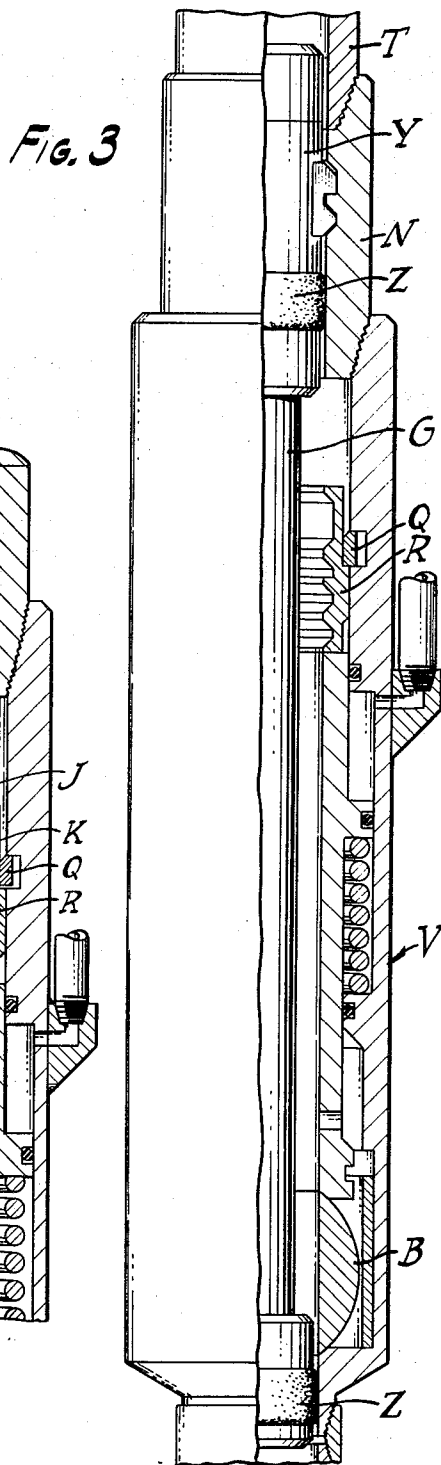


Fig. 3

INVENTOR.

Donald F. Taylor,

BY

Eschmeyer & Coughlin

ATTORNEY

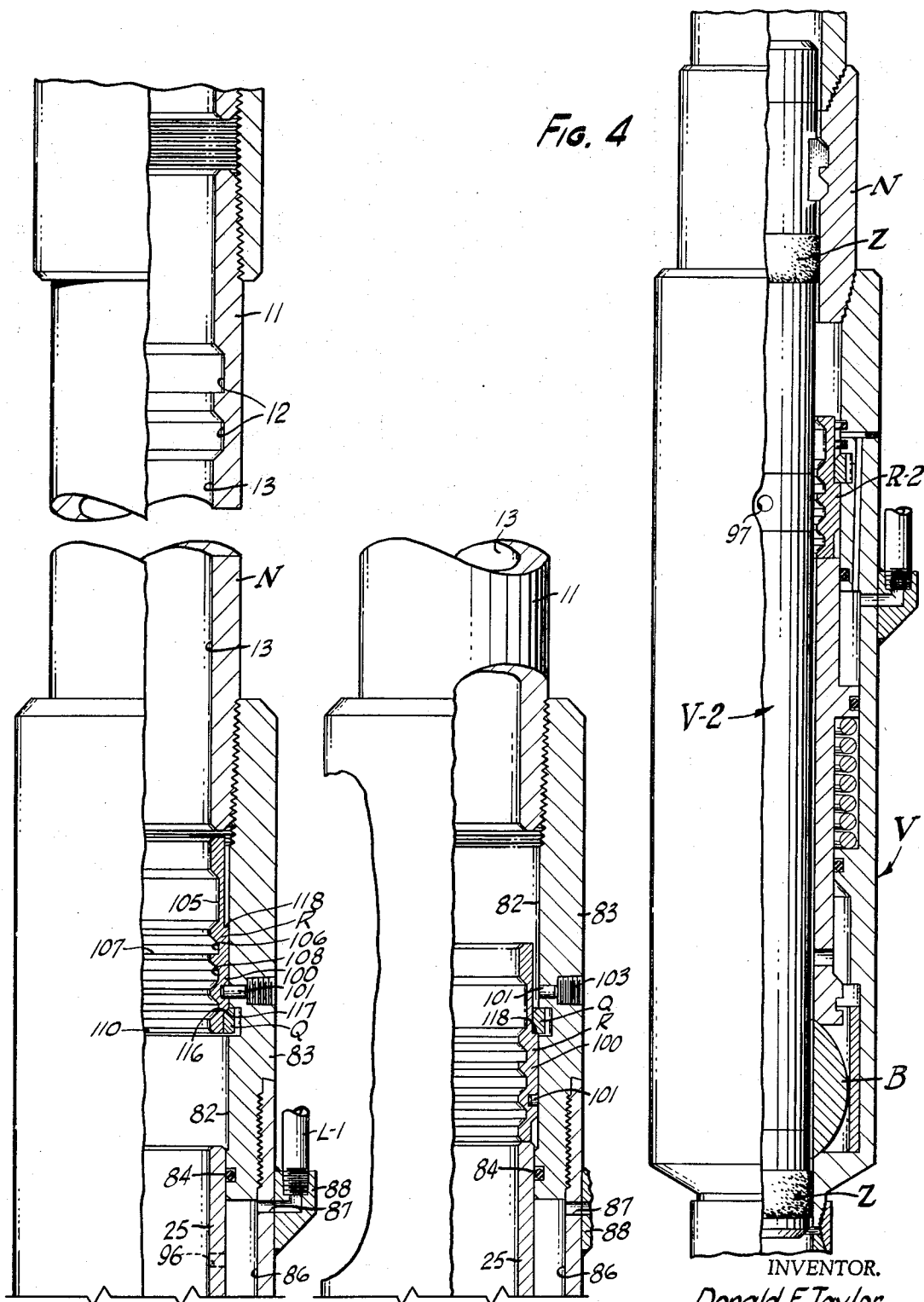


Fig. 6-B

Fig. 7

BY

INVENTOR.
 Donald F. Taylor.
Ernestine Ackley
 ATTORNEY

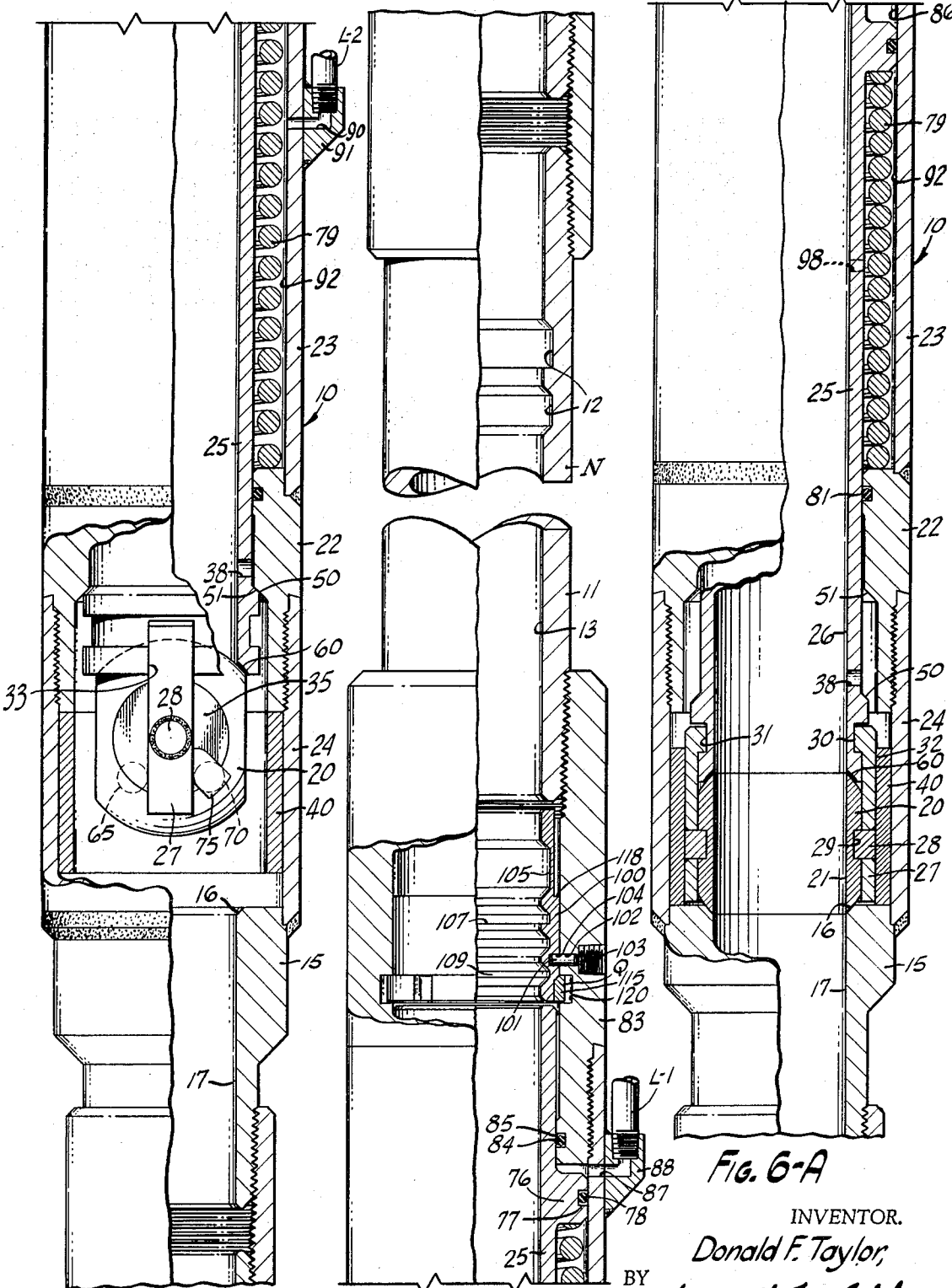


Fig. 5-A

Fig. 5-B

Fig. 6-A

INVENTOR.
Donald F. Taylor;

BY *E. Hastings Ashley*

ATTORNEY

Fig. 8

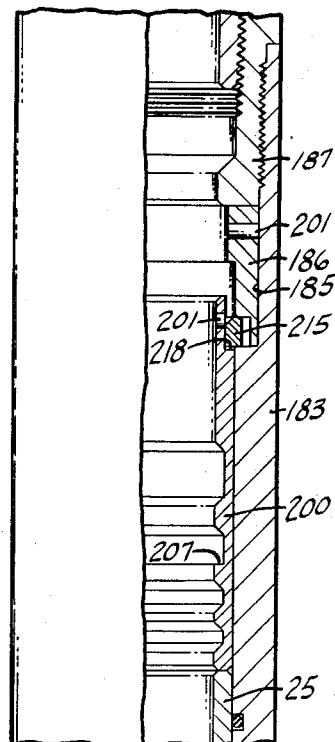
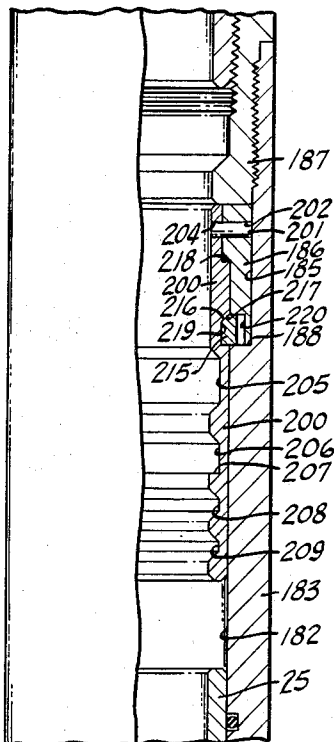


Fig. 9

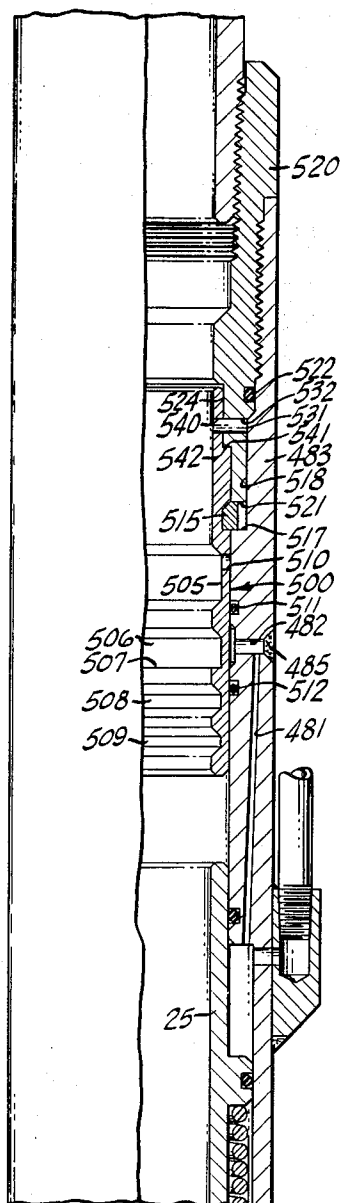


Fig. 14

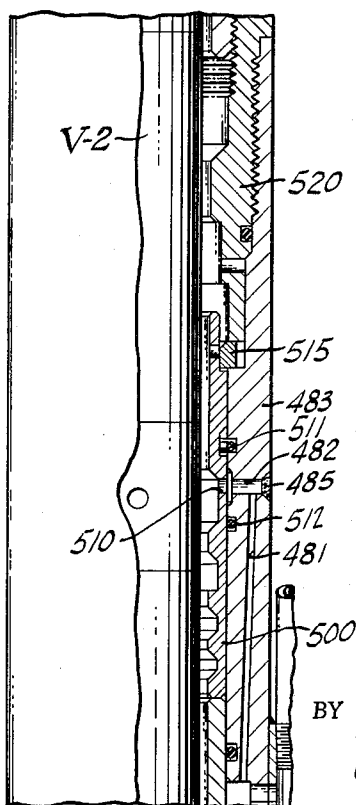


Fig. 15

INVENTOR.
Donald F. Taylor,
BY
Eastman & Cockey
ATTORNEY

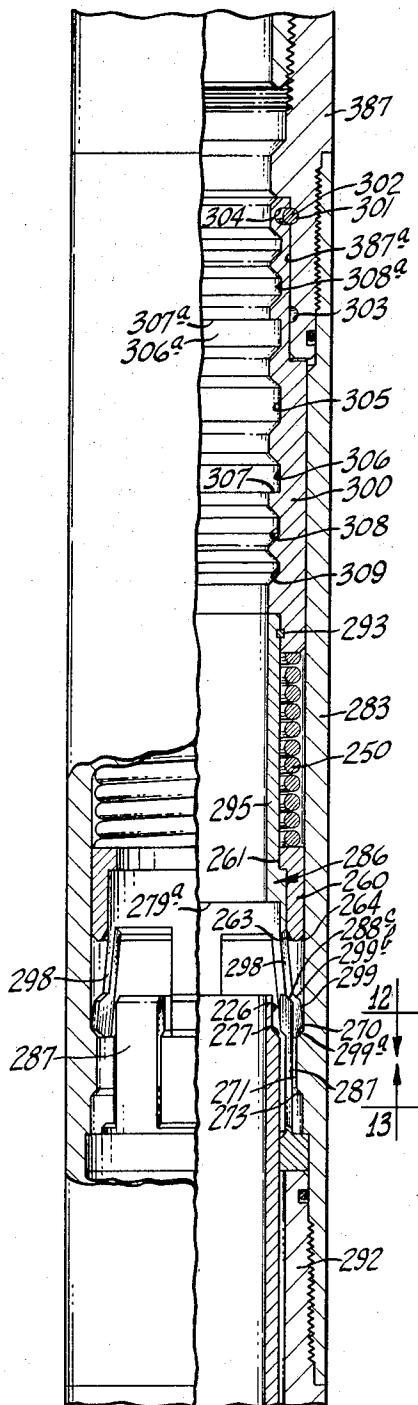


Fig. 10

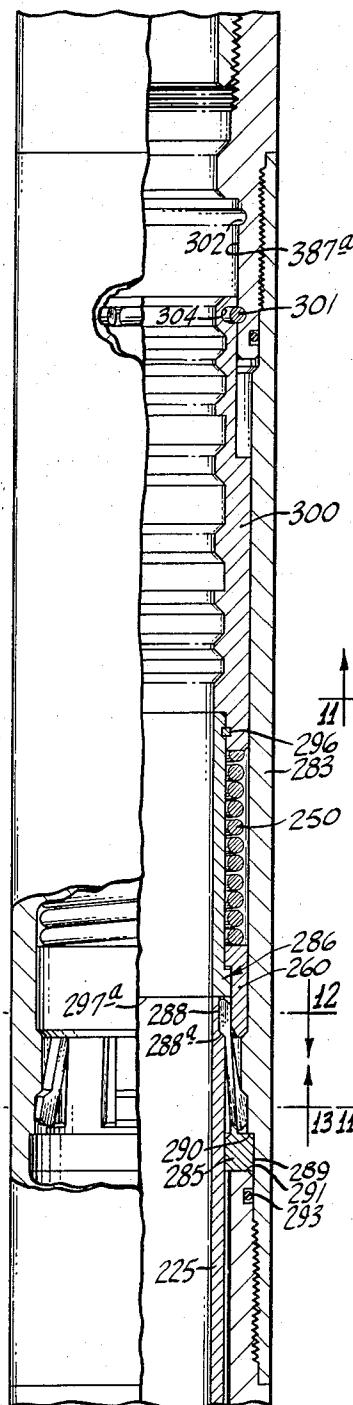


Fig. 11

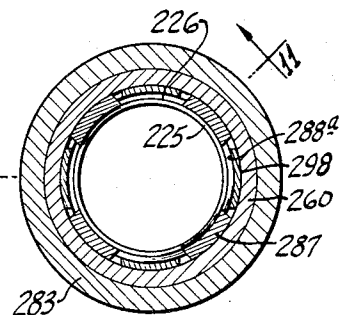


Fig. 12

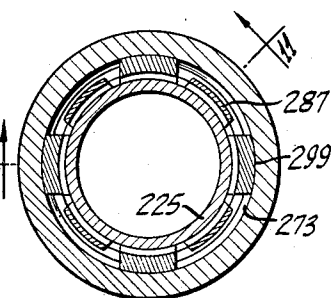


Fig. 13

INVENTOR.
Donald F. Taylor,
BY *Ernestine A. Ashley*
ATTORNEY

WELL FLOW CONTROL VALVES AND WELL SYSTEMS UTILIZING THE SAME

This invention relates to well flow control valves and well systems, more particularly to subsurface automatic safety devices for controlling flow of fluids through flow conductors in wells and which may be responsive to the flowing well fluids for operation or may be surface controlled.

It is one object of the invention to provide means for positively holding the valve in open position, when desired.

It is a particular object of the invention to provide means for positively holding the valve in open position, when desired, for performing well service operations therethrough, for flowing well fluids under certain conditions without effecting operation of the valve, and for removing the valve from service and inserting a supplemental valve in place at such location.

A further object of the invention is to provide a restraining device for holding the valve in the open position which is releasable for movement to a position permitting the valve to resume normal operation.

Still another object of the invention is to provide in a valve and well system of the character described means for receiving and supporting a supplemental flow control valve to replace the previously installed valve when the first valve has been rendered inoperative or unsuitable for operation for any reason.

Still another object of the invention is to provide a well flow control system including automatic well flow control valve responsive to the flowing conditions of the fluids flowing through the flow conductor in the well and/or surface controlled from a remote point, and means for holding the valve in open position for performing service operations through the valve, for rendering the valve inoperative to function in the normal manner, and for directing flow of fluids through the valve in a path isolated from the valve structure.

A further object of the invention is to provide a well system of the character just described including means for inserting or installing a supplemental valve at the location of the valve previously in service after said first valve has been taken out of operation for any reason.

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

FIG. 1 is a schematic view of a well installation showing the flow control valve and system of the invention, and showing the valve operative to permit flow through the flow conductor to the surface;

FIG. 2 is a fragmentary schematic view similar to FIG. 1 showing the flow control valve of the system being locked in open position;

FIG. 3 is a schematic view similar to FIG. 1 showing the valve of the well system with the valve propped in open position and a pack-off tool installed to isolate the valve from fluids flowing through the flow conductor;

FIG. 4 is a view similar to FIG. 3 showing the valve held open and with a pack-off tool having a supplemental flow control valve connected therein;

FIG. 5-A is an enlarged view, partly in elevation and partly in section, of the lower portion of a flow control valve constructed in accordance with the invention showing the same in closed position;

FIG. 5-B is a continuation of FIG. 5-A, showing the upper portion of the valve;

FIG. 6-A is a view similar to FIG. 5-A showing the lower portion of the valve in the open position during normal operations;

FIG. 6-B is a continuation of FIG. 6-A, showing the upper portion of the valve;

FIG. 7 is a fragmentary view similar to FIG. 6-B showing the valve mechanism locked in the open position;

FIG. 8 is a fragmentary view, partly in elevation and partly in section, of a modified form of valve locking or propping mechanism showing the same in position permitting the normal operation of the valve;

FIG. 9 is a view similar to FIG. 8 showing the locking or propping mechanism engaged with the valve for positively holding the same in open position;

FIG. 10 is a fragmentary view, partly in elevation and partly in section, of a releasable restraining device for holding the valve in open position, and showing the restraining device in position permitting normal operation of the valve;

FIG. 11 is a view similar to FIG. 10 showing the restraining device operated to releasably hold the valve in the open position;

FIG. 12 is a horizontal cross-sectional view taken on the line 12 — 12 of FIG. 11;

FIG. 13 is a horizontal cross-sectional view taken on the line 13 — 13 of FIG. 11;

FIG. 14 is a fragmentary view, partly in elevation and partly in section, of a further modified form of a locking device for use with the valve showing the same in position permitting normal operation of the valve; and,

FIG. 15 is a view similar to FIG. 14 showing the locking mechanism operative to positively hold the valve in open position and providing a supplemental control fluid flow path for controlling actuation of a supplemental control valve anchored in the first valve assembly.

In the drawings, FIGS. 1 through 4, is schematically shown a well installation having the flow control valve and system of the invention illustrated as disposed within the well for operation therein. As shown, the well casing C extends downwardly to a producing zone near the bottom thereof where inlet perforations I are provided for admitting well fluids into the bore of the casing. A tubing string T extends downwardly from the surface of the well to serve as a flow conductor in the usual manner, being supported and sealed off by a well head H at the upper end of the string of casing. On the lower end of the string of tubing T is a packer P for sealing between the tubing and the casing above the perforations I in the usual manner. The flow control valve V is connected in the tubing string above the packer and at a desired suitable depth in the well. Above the valve is a landing nipple N which is connected to the upper end of the valve and to the tubing string thereabove. A lateral flow line or service line W is provided at the upper end of the casing and has a valve X therein for controlling entrance or withdrawal of fluids from the annulus between the tubing and casing when desired. A master valve M is connected in the tubing string above the well head for controlling flow into or out of the tubing string.

As shown, control fluid lines L-1 and L-2 are connected at their lower ends to the valve V and extend upwardly in the annular space between the tubing and casing through the well head H and to a surface control unit S by means of which control fluid for controlling actuation of the valve may be transmitted to the valve for operating the same, or for controlling operation of the valve from the surface.

In the usual operation of the well, the valve is in the open position shown in FIG. 1 to permit flow of fluids upwardly therethrough to the surface through the master valve and surface flow line (not shown). Should a condition arise which would result in the need to close off flow through the tubing string, the valve V may be operated to shift the closure member B to a closed position, closing off flow through the valve. The structure of the valve V is illustrated in FIGS. 5, 6, and 7, and will be described in detail hereinafter. However, in general, the ball closure B is moved between open and closed positions in response to longitudinal movement of an actuating sleeve A movable longitudinally in the valve housing.

Under some conditions, it is desirable to positively hold the valve in the open position shown to permit moving well tools downwardly therethrough to the tubing string therebelow, or for other purposes, as will be hereinafter more fully set forth. For such control of the movement of the valve, a restraining or locking mechanism R is provided which is normally initially in the inoperative position shown in FIG. 1, but which may be moved to a lower position in the valve housing to engage the upper end of the actuating sleeve A to lock the same downwardly and thus positively hold the ball closure B in the open position. The restraining or locking member R is shown in FIG. 2 moved into such lower position.

For moving the restraining tool to the lower position shown in FIG. 2, a shifting tool similar to that shown in the patent to Grimmer et al., U.S. Pat. No. 3,051,243, dated Aug. 28, 1962, is moved into the well by wireline lowering and raising mechanisms (not shown) or by means of a pump-down tool locomotive F, which may be of the type illustrated and described in the application of Donald F. Taylor, Ser. No. 784,162, filed Dec. 16, 1968 issued as U.S. Pat. No. 3,543,852 on Dec. 1, 1970. As is illustrated in the aforesaid application and in FIG. 2, locomotive tools may be connected to the shifting tool J at opposite ends thereof for moving the shifting tool in opposite directions in the well tubing.

The shifting tool is provided with keys K which engage in complementary recesses formed in the bore of the restraining member R, as shown in FIG. 2, for actuating the restraining member from the upper position to the lower position. The configuration on the face of the keys and in the recesses in the bore of the restraining member is so chosen that it does not correspond to that of any other recess or series of recesses or grooves in the tubing string, or in the valve or landing nipple connected in the tubing string, whereby it is assured that the shifting tool J will only actuate the restraining member R when desired.

The retaining mechanism R is positively held in its lower position by a snap ring or detent member Q which engages suitable shoulders on the valve housing and on the retaining mechanism to lock or positively

hold or restrain the actuating sleeve A in the lower position in which the valve ball closure member B is held in the open position.

With the valve held in the open position, the shifting tool J may be removed from the tubing string by the locomotives F, or wireline tools, as desired, and flow through the valve may take place regardless of any operating fluid pressure acting on the valve, or regardless of whether the control lines L-1 and L-2 have ruptured or been damaged to admit loading fluid or foreign pressure, such as sea water in a submarine well installation, to act on the actuating sleeve of the valve.

Further, it is believed readily apparent that, should the valve mechanism in any manner be damaged so that the valve would not be operative in the normal fashion, it may be desirable to isolate the valve from the flowing well fluids and to assure that the valve does not function. The isolation from flowing fluids could be desirable in the event a leak developed in the valve structure or any part thereof.

In such an event, a pack-off tool G may be lowered through the tubing string and anchored in the landing nipple N by means of a suitable latching device Y, which may be a tool similar to that shown in the patent to Tamplen, U.S. Pat. No. 3,208,531, issued Sept. 28, 1965, having locking dogs which engage in a suitable locking recess formed in the landing nipple N in the manner set forth in the patent. The pack-off tool G would include a pair of longitudinally spaced seal elements Z at the opposite ends thereof and a tubular central body flow conductor section between said seal elements. The upper seal element seals in the bore of the landing nipple N while the lower seal element seals in the bore of the valve housing below the ball closure member, or in the tubing string therebelow, as desired. Since the pack-off tool has a tubular body between the seal elements Z thereof, the flow of fluids from the producing formation will be conducted through the pack-off tool in a path completely isolated from the valve structure.

If desired, it is believed readily apparent that a supplemental flow control valve V-2 may be positioned within the landing nipple N and the valve V, as shown in FIG. 4, for controlling flow through the tubing string after the valve V has been rendered inoperative for any reason. In this arrangement, a valve such as that shown in the application of Dollison, Ser. No. 786,149, filed Dec. 23, 1968, now U.S. Pat. No. 3,583,442, issued June 8, 1971 may be incorporated in the tubular body of the pack-off tool G between the packing or sealing elements Z at the opposite ends thereof and held positively in place in the valve housing by the locking mechanism Y. Any other suitable valve may also be used, however.

In such an installation a modified restraining mechanism and control fluid valve structure would be provided in the valve housing of the valve V, as shown in FIG. 4, and as will be explained hereinafter more fully in connection with the details of structure of such a valve and restraining member. The restraining means R-2 of FIG. 4 also functions as a valve to control flow of control fluid into the valve housing. When the restraining means R-2 is moved to the position holding the valve V open, a supplemental path for control fluid is opened into the bore of the housing communicating

with the annular space between the supplemental valve V-2 and the bore of the valve housing V between the packing elements Z, and such control fluid would function to control actuation of the valve V-2 in the same manner as the control fluid previously functioned to control actuation of the valve V.

It will, therefore, be seen that a well system has been provided in which a flow control valve is connected in the flow conductor of a well for controlling flow therethrough, and that such valve may be of any desired type in which the valve closure member is moved between open and closed positions by longitudinally movable actuating sleeve or member; and, that a restraining means is provided in the valve engageable with the actuating sleeve to positively hold the same in a position in which the closure member is open for flow through the valve.

It will also be seen that a system has been provided which permits the installation of a pack-off tool in the bore of the valve to isolate the valve from the well fluids being flowed through the flow conductor to the surface when it is desired to do so, as for example, when the valve fails to function properly, or leaks or other undesirable conditions arise.

It has further been shown that a supplemental valve may be installed in the original valve, in combination with a pack-off tool for utilizing the control fluid previously utilized for operating the original valve to control actuation of the supplemental valve. It has also been made apparent that the means for restraining or retaining the valve in the open position may be actuated by suitable wire line flexible line actuating means or by means of a pump-down tool systems, and that the pack-off tool and supplemental valve may be similarly installed in the system.

It is further believed readily apparent that, if desired, prior to installation of the pack-off tool and supplemental valve, a supplemental flow path may be provided for permitting the control fluid from the control line or lines to be admitted into the bore of the valve in the annular space between the supplemental valve V-2 and the primary valve V for controlling actuation of the supplemental valve when desired.

The valve V of FIG. 1 may be any desired type valve in which the closure member is moved between open and closed positions by a longitudinally movable actuator member in the valve. One satisfactory form of the device is shown in FIGS. 5-A through 7, inclusive, wherein the valve V includes an elongate tubular housing 10 having internal threads at its upper end into which the lower end of the landing nipple N is threaded. The landing nipple comprises a body 11 having a locking recess 12 consisting of a plurality of annular grooves providing an upwardly facing stop shoulder therein in the same manner as that shown in the patent to Tamplen, U.S. Pat. No. 3,208,531, previously identified. Below the locking recess is a reduced bore providing a sealing surface 13 which is polished and adapted to receive and be engaged by seals on well tools anchored in the landing nipple as has been explained.

The lower end of the housing 10 of the valve is provided with a seat bushing or sub 15 which is welded or otherwise suitably secured to the housing and provides an upwardly facing interval concave seating surface 16

surrounding the bore 17 through the sub. A ball valve closure member 20 is movable in the enlarged bore of the valve section 24 of the housing 10 above the seat 16 and is adapted, when in its lower position, to engage said seat to position the closure member in an open position with its diametrical flow bore 21 in axial alignment with and communicating with the bore 17 of the sub. As has been explained, the valve may be identical to that shown in the application of W. W. Dollison, Ser. No. 786,149, filed Dec. 28, 1968, now U.S. Pat. No. 3,583,442, issued June 8, 1971 and will not be described in great detail for that reason. Other types of valves such as that shown in the patent to Fredd, U.S. Pat. No. 3,007,669, issued Nov. 7, 1961, may also be used, if desired.

Above the ball valve closure 20 is an elongate tubular actuating sleeve 25 which is movable longitudinally in the housing or body 10 and is connected with and moved the ball valve closure member 20 longitudinally therewith. The valve closure member is operatively connected with the lower end of the actuating sleeve by means of a pair of connector links 27 each having a support pin 18 welded or otherwise suitably secured thereto and engaged in one of a pair of diametrically opposed recesses 29 formed in the ball and each receiving one of the pins 28. The upper end of each connector link 27 has an inwardly projecting flange or arm 30 which is engaged in an annular slot or groove 31 formed in the enlarged lower portion 32 of the actuator sleeve 25. The extreme lower portion 32a of the sleeve is still further enlarged below the annular groove, and this further enlarged portion is provided with a pair of diametrically opposed vertical cut-away guide slots 33, in each of which the longitudinal upper portions of one of the connector members 27 is slidably disposed. The opposite sides of the ball closure member 20 surrounding the recesses 29 are flattened as at 35, and the lower portions of the connector members 27 are slidable on these flattened surfaces with the pins 28 engaged in the recesses 29 in the ball. A slidable operator or rotator sleeve 40 is disposed in the enlarged lower portion 41 of the bore of the valve section 24 of the housing or body 10 and is slidable between a shoulder 43 at the upper end of the lower enlarged portion 41 of the bore on the lower end of a guide bushing 22 welded or otherwise suitably secured to the lower end of the seat and spring housing section 23 of the valve body 10, which is threaded into the upper end of the valve housing section 24 of the valve body for a purpose which will be hereinafter more fully explained.

A beveled seat shoulder or surface 50 is formed at the upper end of the enlarged portion 32 at the lower end of the actuating sleeve 25, and this seat shoulder engages a downwardly facing beveled seat 51 formed in the bore of the guide bushing 22, above the enlarged portion of the bore of said bushing therebelow and intermediate the ends of the bushing. When the actuating sleeve is in the upper position shown in FIG. 5-A, the seat shoulder 50 engages the seat 51 to close off flow exteriorly of the actuating sleeve. When the sleeve is in the lower position shown in FIG. 6-A, the seat shoulder 50 is spaced below the seat 51 and fluids may flow past the enlarged lower portion 32 of the actuating sleeve, and the fluids so entering will flow upwardly then inwardly through a plurality of lateral equalizing ports 38

formed in the wall of the tubular actuating sleeve 25 above the seat shoulder 50 and into the bore 26 of the tubular sleeve.

When the valve is in the open position, all surfaces exposed to pressure in the housing of the valve are equalized. However, when the sleeve is in the closed position shown in FIG. 5-A, the equalizing ports are closed off from communication with the bore of the valve housing section 24 therebelow, and flow from below the seat 51 inwardly through such ports to the bore 26 of the sleeve is prevented.

The ball valve closure member 20 seats upon a hardened wear material seat surface 60 formed at the lower end of the bore 26 of the sleeve 25, and when the valve is in the upper closed position the bore of the sleeve is closed and no flow can take place in either direction through the housing and sleeve.

Guide pins 65 are each welded or otherwise suitably secured in an aperture formed in the rotator sleeve 40 on each side of the ball valve closure member 20 and engage one side of the adjacent connecting links 27. A similar pair of turning pins 70 are also secured by welding or the like to the rotator sleeve on the opposite side of the connector link 27 on each side of the closure member and, with the pins 65, maintain the positional relationship of the valve closure member and the connecting links during longitudinal movement of the valve closure member and the rotator sleeve. The guide pins 65 are sufficiently short that their inner ends will ride along the flattened surfaces 35 of the ball valve closure member as the ball valve and actuating sleeve move rotatably with respect to each other. The turning pins 70 engage in angularly disposed grooves or slots 75 formed in the exterior of the ball valve closure member on opposite sides of such closure member, and these turning pins engage the inclined surfaces of the angularly disposed slots to rotate the ball between open and closed positions when the ball is moved longitudinally with respect to the rotator sleeve 40 by the connector links 27 moved by the actuating sleeve 25.

As the rotator sleeve 40 is moved upwardly when the actuating sleeve 25 is moved upwardly, the upper end of the rotator sleeve engages the downwardly facing shoulder 43 in the bore of the housing 10 and further upward movement of the rotator sleeve is stopped. However, the elongate tubular actuating sleeve 25 may continue to move upwardly until the seat shoulder 50 engages the downwardly facing seat 51 in the bushing 22 forming a part of the housing or valve body 10. Such upward movement of the actuator sleeve lifts the connecting links 27 and also lifts the ball valve closure member 20 upwardly with respect to the rotator sleeve 40. Due to the engagement of the actuating or turning pins 70 and the slots 75 in the ball, the ball will be turned from the open position shown in FIG. 6 to the closed position shown in FIG. 5 during such upward movement. Further details of the construction and operation of the ball valve is contained in the aforementioned application of W. W. Dollison, Ser. No. 786,149, now U.S. Pat. No. 3,583,442.

During upward movement of the ball valve closure member, the pressures in the housing and across the closure member are equalized, due to the provision of the lateral equalizing ports 38 in the tubular actuating sleeve 25. However, when the valve actuating sleeve

has moved upwardly to its uppermost position, with the seat shoulder 50 engaged with the seat 51, the equalizing ports 38 in the sleeve are disposed above the seat and are closed off from the flow of fluids from below the seat and from communication with the bore of the valve housing section 24 therebelow. Therefore, all flow through the valve is closed off due to the fact that the ball closure member is now in closed position with respect to the seat 60 at the lower end of the bore of the actuating sleeve. Thus, the ball valve will be rotated between open and closed positions under equalized pressure conditions, while the equalizing ports 38 are open, so that there is no pressure differential across the valve closure to cause a drag in the movement of the valve closure member or to cause wear on the valve closure member and the seat.

When the valve is moved from the closed position shown in FIGS. 5-A and 5-B to the open position shown in FIGS. 6-A and 6-B, the valve actuating sleeve 25 is moved downwardly in the usual manner, and the connecting links 17 move the ball valve closure member 20 and the rotator sleeve 40 simultaneously downwardly until the lower end of the rotator sleeve engages the upwardly facing upper end of the bushing 15 at the lower end of the housing, whereupon further downward movement of the rotator sleeve or operator sleeve is stopped. Further downward movement of the valve actuating sleeve 25 and the connecting links 27 connected with the ball closure member 20 then causes the ball closure member to move downwardly with respect to the rotator sleeve, and the turning pins 70 engaged in the slots 75 formed on opposite sides of the ball closure member cause the ball closure member to be rotated until the flow passage 21 therethrough is moved from the closed position shown in FIGS. 5-A and 5-B to the open position shown in FIGS. 6-A and 6-B before the valve closure member engages the upwardly facing seat 16 in the bushing 15 at the lower end of the housing.

Once the tubular actuating sleeve 25 is moved downwardly to move the seat shoulder 50 off the seat 51, the lateral equalizing ports 38 in the actuating sleeve are placed in communication with the bore of the valve housing section 24 below said seat 51, and fluid pressures are equalized above and below the valve closure member so that there is no fluid pressure differential across the closure member 20 when it is rotated from the closed to the open position. With the closure member in the open position shown in FIGS. 6-A and 6-B, no differential exists across the valve actuator member closure member itself other than the normal impingement and frictional forces of the flowing fluids. It will therefore be seen that the valve closure member is moved between open and closed positions under conditions of equalized pressure across the closure member, and that the closure member is rotated or moved between such open and closed positions by longitudinal movement of the actuating sleeve 25 in the housing.

For moving the actuating sleeve 25 to cause rotation of the valve closure member, a piston 76 is formed on the exterior of the actuating sleeve 25 by means of an external annular flange formed integral with the actuating sleeve and provided with an external annular groove 77 in its mid-portion for receiving a seal ring 78 for sealing between the piston and the bore wall of the

spring housing 23. A helical coiled spring 79 is confined between the lower end of the piston 76 and the upper end of the bushing 22 and this spring acts to bias the piston and the actuating sleeve upwardly in the housing to move the seat 50 into engagement with the seat 51. An internal annular groove 80 is formed in the bore of the bushing 22 below its upper end and a sealing ring or member 81 is disposed therein and seals between the bushing 22 and the exterior of the actuator sleeve 25.

The upper end of the actuator sleeve 25 is slidable in the lower portion of the bore 82 of a latch section 83 forming the upper portion of the valve body 10. An internal annular seal ring 84 is disposed in an internal annular groove 85 formed in the lower portion of the bore 82 of the latch housing. Thus, the bore 86 of the spring housing 23 between the lower end of the latch housing 83 and the piston forms an operating cylinder 86 into which control fluid may be conducted through an angular flow passage 87 in a boss 88 welded or otherwise suitably secured to the exterior of the spring housing 23 and having the control line L-1 connected thereto for conducting control fluid pressure through the angular path 87 into the chamber 86 for biasing the piston 76 downwardly to move the actuating sleeve 25 downwardly to open the valve.

If desired, as shown in FIG. 1, a second angular flow passage 90 may be provided in a boss 91 welded or otherwise suitably secured to the exterior of the spring housing below the piston and arranged to communicate with the chamber 92 formed between the upper end of the bushing 22 and the lower end of the piston and the seal on the piston.

The lower end of the control fluid line L-2 is connected to the boss 91 and a column of control fluid is conducted into the chamber 92 to act on the underside of the piston the balance the hydrostatic force of the column of operating fluid conducted into the chamber 86 through the control line L-1, whereby a lesser force is required to be applied to the control fluid at the surface to cause operation of the valve to move it to the open position. It also enables the spring to move the valve to closed position against such hydrostatic column of control fluid acting in the chamber 86 on the upper end of the piston. Thus, the hydrostatic pressure of the columns of control fluid in the control lines L-1 and L-2 cancel each other, substantially, in their action on the piston of the actuator sleeve 25 and a relatively small pressure at the surface will cause operation of the valve, but the column of fluid will not prevent the spring from closing the valve due to the hydrostatic head applied to the piston. This structure permits the valve to be installed at any desired depth in the well without limitation by the effect of the hydrostatic pressure on the piston. Of course, if desired, the control line L-2 may be omitted and the angular passage 90 closed or plugged, and the valve may be actuated by control fluid conducted into the cylinder 86 only through the control line L-1. This is particularly true under conditions in which the valve is installed at a depth which is not so great that the spring cannot overcome the hydrostatic head of the control fluid acting on the piston thereabove by a suitable margin of safety.

Thus, the valve is normally biased to a position in which the closure member closes off flow

therethrough, but is placed into operation to permit flow by introducing control fluid through the control line L-1 into the chamber 86 to act downwardly on the piston 76 to move the actuator sleeve 25 downwardly and cause the valve to be rotated to the open position shown in FIGS. 6-A and 6-B to permit flow therethrough until the actuating fluid or control fluid pressure is reduced for any reason, which may be controlled by various sensing apparatus or devices at the surface, or which may be caused by the occurrence of some condition in the well system which has been sensed by various types of sensing devices connected in the system, such as pressure reducing system, fire detecting systems, remote control systems, liquid level control systems and sensing systems and the like.

Should a situation arise creating a need for holding the valve closure member in the open position, as has been previously described, the retainer mechanism R is utilized. As is shown, the retainer mechanism in this device is contained within the latch housing 83 below the lower end of the landing nipple N and above the upper end of the actuating sleeve 25.

The retainer mechanism includes an elongate sleeve 100 which fits slidably within the bore 82 of the latch housing 83 immediately below the lower end of the landing nipple N connected thereto, and is retained in such position by a shear pin 101 disposed in a lateral opening 102 in the latch housing and confined therein by a retaining set screw 103 which may be secured in place by means of a suitable compound preventing leakage past the threads and disengagement of the plug from the bore of the opening. The inner end of the pin 101 engages in a recess 104 formed in the exterior wall of the sleeve 100 and so positively holds the sleeve in the upper position until the pin is sheared. Any desired number of such pins may be provided to obtain a required desired force to be applied to the sleeve to move it downwardly from such position.

The bore of the latching or retainer sleeve 100 is formed with a plurality of internal annular recesses or grooves having a total configuration which does not conform to any other series of grooves in the bore of the flow conductor, packer or landing nipples thereabove or therebelow. As shown in FIG. 5-B, an upper internal annular recess 105 having flared beveled surfaces is provided at the upper end of the sleeve, another internal annular recess 106 having a beveled upper shoulder and an abrupt or right angle lower stop shoulder 107 formed below the groove 105, and below the groove 106 a pair of spaced grooves 108 and 109 are provided each having flared or divergent upper and lower surfaces. The lower end of the sleeve is beveled outwardly at 110.

A detent or retainer latching ring Q is formed by a split snap latching ring 115 having an internal beveled upper edge surface 116 engaging a beveled downwardly facing surface 117 formed at the upper end of the reduced lower portion of the exterior of the sleeve 100. The latching ring 115 is disposed in an internal annular groove 120 formed in the bore of a latch housing 83 and having a diameter sufficiently great to permit the latching ring 115 to be expanded therein as the latching sleeve 100 is moved downwardly. The lower end of the ring will engage the upwardly facing shoulder at the lower end of the annular groove 120 to

prevent downward movement of the latching ring or detent ring while the sleeve 100 is moved downwardly therepast after the shear pin 101 has been sheared. The sleeve 100 may be moved downwardly until the lower end thereof engages the upper end of the valve actuating sleeve 25 to hold the same when the actuating sleeve is in its lower position to hold the same in such lower position.

To assure that the latching sleeve is positively held in engagement with the valve actuator sleeve 25, the latching ring 115 engages an upwardly facing shoulder 118 formed intermediate the ends of the exterior of the latching sleeve at a point at which the ring 115 will move inwardly above the shoulder just before the latching sleeve engages the upper end of the valve actuator sleeve 25 when the valve actuator sleeve is in its lower position. The entire upper outer portion of the latching sleeve is reduced in diameter above the shoulder 118 for ease of assembly and manufacture.

As has already been explained, the latching sleeve 100 of the retainer mechanism R may be moved downwardly by a shifting tool J. Downward movement of the latching sleeve may be effected before the valve actuator member has moved the valve member from closed to open position. As a matter of fact, if desired, the keys K of the shifting tool J may be engaged in the recesses 105, 106, 108, and 109 of the latching sleeve 100 while the valve is in the closed position, and fluid pressure applied to the locomotive F to force the shifting tool downwardly and force the latching sleeve 100 downwardly and will positively move the valve actuator sleeve 25 downwardly to move the valve closure member 20 to the open position. This operation may be accomplished even though there is no control fluid pressure available to act on the piston 76 to move the actuator sleeve downwardly to open the valve. Also, as has been explained, the latching sleeve may be moved downwardly while the valve is in the open position to positively engage and hold the actuator sleeve in the lower position in which the valve is open.

For installing the pack-off tool G in place in the valve V, as illustrated in connection with the showing in FIG. 3, the landing nipple N is utilized to anchor the pack-off tool assembly in place in the valve bore. The locking recesses 12 in the bore of the landing nipple will position and secure the pack-off tool in place in the valve bore at a position determined by the location of the locking recesses with respect to the valve therebelow. The upper seal Z of the pack-off tool will seal against the seal surface 13 in the landing nipple body 11, while the lower seal assembly Z will seal against the bore 17 of the seat bushing 15 at the lower end of the valve body, and these sealing members on the pack-off tool will therefore direct all fluids flowing through the tubing string T into the bore of the tubular body of the pack-off tool G and upwardly therethrough to the tubing string T above the landing nipple N to provide a means for isolating the valve assembly from the fluids flowing through the tubing string from the producing zone or formation to the surface of the well. This structure provides means for sealing off the valve from the flowing fluids should a condition of leakage or damage to the valve parts occur, or any other undesirable situation exist, in which it would be desirable to produce fluids through the valve without replacing the same.

Also, the pack-off tool may be utilized to position the supplemental valve V-2 as illustrated and described in FIG. 4. In this case, the valve actuator sleeve 25 may be perforated at a point above the piston 76 and below the seal ring 84 as shown in dotted lines at 96 in FIG. 16-B to provide an inlet so that the control fluid pressure from the control line L-1 may be conducted into the chamber 86 and through the perforation 96 into the bore of the valve actuator sleeve 25 exteriorly of the body portion of the valve V-2 between the seals Z at the upper and lower end of the body sealing between the landing nipple and the seat bushing of the valve. The fluids will enter the inlet port 96 and flow through the inlet ports 97 in the wall of the housing of the valve V-2 for actuating the valve in the same manner as the primary valve V already described, the difference being that of size. The valve mechanism structure may be the same.

Likewise, if desired, the wall of the valve actuating sleeve 25 may be perforated below the piston 76 and above the seal ring 81, as shown at 98, to provide an inlet path for control fluid from the control line L-2 for actuation of the supplemental valve V-2 by control fluids conducted through the perforation 98 into the annular space between the valve V-2 and the bore of the actuating sleeve 25. This may be desirable when the valve V originally in operation has failed because of failure of the control line L-1. In this event, the perforation 96 would not be made, but a perforation 98 would be made to permit use of control fluid from the control line L-2 for controlling actuation of the supplemental valve V-2. Of course, other conditions might arise in which failure of packing or the like might occur, in which event perforations might not be necessary for conducting the control fluid from the control lines L-1 or L-2 into the bore of the sleeve of the valve for controlling actuation of the secondary valve or supplemental valve V-2. In any event, with the supplemental valve V-2 in place with the seal members packings Z at the upper and lower ends of the valve mechanism, the original valve V is isolated from fluids flowing through the tubing string to the surface.

It will therefore be seen that the valve of FIGS. 5-A through 7 illustrates an operative device for use in the system and in carrying out the methods explained in connection with FIGS. 1 through 4. While a particular valve closure and actuator mechanism has been disclosed, it is obvious that any suitable valve and actuator mechanism may be used so long as the longitudinal movement of an actuator effects movement of the closure member between open and closed positions.

A modified form of latching arrangement or restraining mechanism is shown in FIGS. 8 and 9 which illustrate only the upper latching housing of the valve assembly, since the same valve mechanism as that of FIGS. 5, 6 and 7 may be used. In this form of the device, the latching housing 183 has a bore 182 into which the upper end of the valve actuator sleeve 25 extends. The latching housing 183 is connected at its lower end to the spring and cylinder section 23 of the valve body or housing 10 therebelow in the manner already described. The upper portion of the bore of the latching housing is enlarged as shown at 185 for receiving a stationary latching sleeve section 186 which has its upper end abutting a retainer bushing 187 threaded

into the upper end of the latching section 183 and having internal threads for receiving the threaded bore end of the landing nipple N thereabove. The bushing 187 confines the stationary latching sleeve 186 between its lower end and the upwardly facing shoulder 188 at the lower end of the enlarged bore 185 in the latching section, as clearly shown in FIG. 8. The lower portion of the bore of the stationary latching sleeve 186 is enlarged to provide an internal annular recess or groove 220 therein in which a split snap latching ring 215 is disposed and movable in the same manner as the latching ring 115 of the form previously described.

The movable latching sleeve 200 has the internal annular grooves or recesses 205, 206, 208, and 209 formed therein and the abrupt shifting shoulder 207 for engagement by the shifting tool J in the same manner as the latching sleeve 100 of the form previously described. The movable latching sleeve is provided in the mid-portion of its exterior surface with an external annular recess or groove 219 having a downwardly facing beveled shoulder 217 at its upper end for camming the beveled shoulder 216 at the inner upper edge of the split latching ring 215 outwardly in the annular groove 220 to permit the sleeve to move downwardly therepast. A shear pin 201 is disposed in a radial opening 202 in the upper portion of the stationary or fixed latching sleeve 286 and projects therefrom through a radial opening 204 in the wall of the movable latching sleeve 200 for retaining the movable latching sleeve in the upper position shown in FIG. 8. The upper external portion of the movable latching sleeve is reduced in diameter to provide an upwardly facing stop or latch shoulder 218 at the lower end of such reduced portion which is arranged to be moved below the latching ring 215 as the movable sleeve is moved downwardly to hold the valve actuator sleeve 25 in its lower position. The bore 189 of the stationary latching sleeve is reduced in its upper portion as shown at 190 to conform substantially to the externally reduced upper portion of the movable latching sleeve to provide support for the shear pin and to assure shearing the same when the latching sleeve is moved downwardly. When the pin is sheared, as shown in FIG. 9, the movable sleeve is movable downwardly until the shoulder 218 is disposed below the lower end of the latching ring 215, and the latching sleeve is thus latched in such lower position to positively hold the valve actuator sleeve 25 in the lower position in which the valve is held open. This form of the latching mechanism permits removal and replacement or "redressing" of the latching mechanism when desired by simply removing the retainer bushing 187 from the threaded bore at the upper end of the latch section 183. This permits the stationary latching sleeve 186 to be withdrawn from the enlarged bore 185 of the latching section of the valve housing and the latching sleeve 200 to be drawn upwardly and the latching ring 215 moved downwardly relative to the latching sleeve 200 into the recess 219 in the midportion thereof. The shear pin is then replaced in the bores 202 and 204 and the retainer bushing 187 is again made up in the threaded upper end of the latch section of the housing. The device is then again ready for use as shown in FIG. 8. Otherwise the function of this form of the latching mechanism or retainer mechanism is the same as that of the form first described, and the same results are obtained by use thereof.

A further modified form of the latching mechanism is illustrated in FIGS. 10 through 13, inclusive, wherein the latching mechanism is movable to restraining position and is then releasable from latching engagement with the valve actuator sleeve and movable to inoperative position to permit normal functioning of the valve.

In this form of the device, the latching or retainer mechanism includes a pair of collet sleeves facing in opposite directions, a stationary collet sleeve 285 and a movable latching sleeve 286. The stationary latching sleeve has a plurality of longitudinally upwardly projecting collet fingers 287 having internal bosses 288 on their upper ends. An external annular flange 289 at the lower end of the stationary collet member is confined between a downwardly facing shoulder 290 in the bore of the latching section 283 of the valve housing and the threaded upper end of the pin end 291 of a connector sub 292 threaded into the upper end of the bore of the spring and cylinder section 23 of the valve housing 10. An O-ring seal 293 is disposed in an external annular groove on the pin end of the connector sub and seals between the sub and the bore wall of the latch housing 283. The stationary collet member 285 is thus positively held against longitudinal movement in the latch section 283 of the housing.

The stationary collet member 285 is slidable on the exterior of the upper end of an upward extension 225 of the valve actuator 25 of the form previously described. The outer upper portion of the valve actuator extension is reduced in diameter to provide a locking recess 226 having an upwardly facing cam and locking shoulder 227 at its lower end for a purpose to be hereinafter more fully explained.

The movable collet member 286 is in the form of an elongate sleeve 295 connected to the slidable latching sleeve 300 by a lock wire 296 disposed in an external annular groove in the upper end of the body 295 of the movable collet and an internal annular groove in the lower end of the slidable latching sleeve, whereby the movable collet 286 is positively connected to the latching sleeve and movable therewith. The lower portion of the bore of the movable latching sleeve is enlarged at 297 to telescope over the upper end of the valve actuator extension 225 as will be hereinafter further described. A plurality of circumferentially spaced longitudinally downwardly extending spring fingers 298 project downwardly from the lower end of the body 295 below the shoulder 297a formed at the upper end of the enlarged lower portion of the bore of the movable collet member. Each of the fingers has an outwardly projecting boss 299 at its lower end which is formed with lower and upper beveled surfaces 299a and 299b, respectively, on the opposite ends thereof.

As shown in FIG. 10, the collet fingers 298 are formed to be inherently sprung outwardly until the lower ends of the bosses 299 engage an upwardly facing beveled detent stop shoulder 270 at the upper end of an internal annular detent latch flange 271 formed in the bore of the latch housing 283 spaced above the shoulder 290 therein which confines the external flange 289 of the stationary collet member 285. The beveled downwardly facing detent stop shoulder 273 at the lower end of the detent latch flange 271 is engageable by the upper beveled shoulders 299b of the bosses 299 on each of the movable collet fingers. The downwardly facing beveled shoulders 299a on the bosses engages

the shoulder 270 on the flange to resist downward movement of the collet member in the latch section of the housing.

As is clearly seen in FIGS. 10, 12, and 13, the spring collet fingers 287 of the stationary collet member and the spring collet fingers 298 of the movable collet member 286 intermesh, whereby the collet fingers of one of the collet members are disposed between the collet fingers of the other of the collet members and are movable longitudinally in the spaces between the fingers.

An upwardly facing external annular shoulder 295a is formed at the lower end of the reduced upper portion of the body 295 of the movable collet member and a latching ring 260 having an internal annular flange 261 at the upper end of its bore is slidable on such reduced upper portion of the body of the collet member, the lower surface of the flange 261 engaging the upwardly facing shoulder 295a on the collet sleeve to limit downward movement of the latching ring thereon. The latching ring is biased toward such position by a helical coil spring 250 confined between the upper end of the ring and the downwardly facing lower end of the movable latching sleeve 300. The lower edges of the latching ring 260 are each beveled, and the inner beveled surface 263 is adapted to engage the externally beveled shoulders or surfaces 288c on the upper ends of the collet fingers of the stationary collet member, whereby the latching ring may telescope over the upper ends of such fingers as will be hereinafter more fully described.

When the valve actuating sleeve 25 with the extension 225 at its upper end is in the lower position in which the valve closure member is open, and it is desired to latch the actuating sleeve and valve in such position, the shifting tool J is lowered into the bore of the movable latching sleeve 300 until the keys engage the lower set of internal annular selector grooves 305, 306, 308, and 309 formed therein, and engages the upwardly facing stop shoulder 307 in the set of grooves to act on the latching sleeve to move the same downwardly. The sleeve is releasably restrained in the upper position shown in FIG. 10 by a split ring 301 which is disposed in an external annular groove 304 in the exterior of the latching sleeve. The annular groove is sufficiently large and deep to permit the normally or inherently expanded latching detent ring 301 to be sprung inwardly by the curved lower surface of a complementary internal annular latching detent recess 302 formed in the enlarged bore 387a in the lower portion of the retainer sub 387 threaded into the upper end of the latching section 283. The engagement of the outwardly biased or expanded detent ring 301 in the internal annular recess 302 releasably restrains the latching sleeve 300 in the upper position. A sufficient force applied downwardly to the latching sleeve by the shifting tool will cam the ring 301 inwardly into the recess 304 and permit the sleeve to move downwardly until the ring enters a lower detent groove 303 spaced below the groove 302 in the enlarged bore 387a of the sub 387, where it will releasably restrain the latching sleeve in the lower position.

When the latching sleeve is moved downwardly as just described, the movable collet 286 is also moved downwardly, as is the latching ring 260. As the movable collet member 286 is moved downwardly, the cam sur-

faces 299a at the lower end of the external bosses 299 on the collet fingers are cammed inwardly by the beveled detent shoulder 270 at the upper end of the latching flange 271 to pass said shoulder and move along the bore of the flange until the upwardly facing beveled shoulders 299b at the upper ends of said bosses are disposed below the downwardly facing beveled detent stop shoulder 273 at the lower end of the latching flange. The engagement of the shoulders 299b of the bosses with the downwardly facing shoulder provides positive restraining means holding the latching sleeve 300 in the lower position, which is supplemented by that of the detent ring 301 and lower detent groove 303 in the sub 387.

As the movable collet member 286 is moved downwardly, the locking ring 260 is also moved downwardly, being biased by the spring 250 into engagement with the upwardly facing shoulder 295a on the movable collet member. The internal beveled surface 263 at the lower end of the bore of the locking ring 260 engages the upper outer beveled edges 288c at the upper ends of the collet fingers 287 of the stationary collet member 285 and cams those fingers inwardly until the internal bosses 288 on the upper ends of the fingers are engaged in the locking recess 226 at the upper end of the operator sleeve, with the downwardly facing beveled surface 288a of said bosses engaging the upwardly facing beveled shoulder 227 at the lower end of the recess. Downward movement of the locking ring 260 is limited by the engagement of the beveled outer surface 264 at the lower end thereof with the upwardly facing beveled shoulder 270 of the locking flange 271.

With the collet members in the position shown in FIG. 11, the latch ring 260 positively holds or locks the collet fingers 288 of the stationary collet member in engagement with the shoulder 227 in the locking recess 226 at the upper end of the valve actuator sleeve extension 225, and the downwardly facing shoulder 299a in engagement with the upper end of such extension, and therefore positively holds the valve actuator sleeve in the lower position in which the valve closure is open. The restraining force of the engagement of the bosses 299 of the movable collet fingers 298 with the downwardly facing shoulder 273 and of the detent ring 301 with the detent groove 303 restrains upward movement of the latching sleeve 300, and so positively holds the same in the position in which the actuating sleeve holds the valve open.

When it is desired to move the latching sleeve 300 upwardly to the released or inoperative position in which the valve may function in the normal manner, the shifting tool is reversed in position and lowered into the bore of the latching sleeve 300 until the keys K of the shifting tool engage in the upper set of recesses, comprising the recess 305, a recess 306a, a recess 308a and 309a formed in the bore of the latching sleeve above the lower set of recesses previously described as being used for opening the latching sleeve. The keys of the shifting tool engage the abrupt stop shoulder 307a in the groove 306a, so that upward force applied to the shifting tool will lift the latching sleeve 300 from its lower position shown in FIG. 11 to the position shown in FIG. 10. Such upward movement of the latching sleeve lifts the movable collet member 286 and lifts the latching ring 260 therewith to disengage the latching

ring from the collet fingers 287 of the stationary collet member to permit the bosses 288 on the upper ends of such collet fingers to move outwardly to free the valve actuator sleeve 225 for movement longitudinally in the housing in the normal manner. With the collet members and latch sleeve returned to the position shown in FIG. 10 the valve is operable in the normal manner.

With the collet members and latching sleeve in the position shown in FIG. 11 the valve is latched in the open position and the latching mechanism functions in the same manner as the forms previously described. In this form of the device, however, the latching mechanism is resettable or repeatedly operable as desired in the manner described.

A still further modification of the restraining device is shown in FIGS. 14 and 15, wherein the latching sleeve serves as a valve for controlling admission of control fluid into the bore of the valve housing to provide an alternate path of circulation of operating or control fluid pressure for actuating the supplemental valve V-2 in the case of failure of the primary valve V.

In this form of the device, the latch housing 483 is elongated and a supplemental control fluid passage 481 is drilled longitudinally within the wall of the latch section 483 to a point substantially above the upper end of the operator sleeve 25 of the ball closure valve. A radial hole or port 482 is drilled inwardly through the wall communicating with the longitudinal opening 481 and opening into the bore of the latch section 483 through an internal annular relief or recess 484 in such bore. A closure plug 485 may be formed by welding or otherwise to close the outer end of the radial port 482 to provide an angular or L-shaped flow passage in the wall of the housing communicating with the chamber 86 above the piston 76 on the actuator sleeve 25. Thus, operating fluid or control fluid from the chamber 86 may flow upwardly through the longitudinal passage 481 then inwardly through the radial passage or port in the latch section 483 of the housing.

The movable latching sleeve 500 is also elongated and provided in the lower portion of its bore with the plurality of internal annular recesses 505, 506, 508, and 509, and with the stop shoulder 507 whereby the sleeve may be shifted by means of the shifting tool J in the manner already described. A lateral port 510 is formed in the wall of the latching sleeve communicating with the annular recess 505 and is adapted to be moved downwardly into registry with the lateral port 482 of the supplemental fluid passage in the latch section of the housing for admitting control fluid therethrough. O-ring seal members 511 above and 512 below the internal annular recess 484 are mounted in internal annular grooves formed in the bore wall of the latch section above and below the recess and seal between the latch section and the exterior of the movable latching sleeve. Thus, the latching sleeve, when in its upper position as shown in FIG. 14, provides a closure for the lateral port 482 to prevent control fluid from passing from the chamber 86 above the piston 76 through the passage 481 and port 482 into the bore of the housing. However, when the sleeve is moved downwardly to the position shown in FIG. 15, the lateral port 510 is moved into registry with the lateral port 482 in the housing section and control fluids may flow inwardly into the bore of the latching sleeve and

may be utilized to actuate or control the actuation of the supplemental valve V-2 positioned in the bore of the valve V in the manner shown in FIG. 4 and described in connection therewith.

A latching ring 515 is disposed in an internal annular recess or groove 516 defined by an upwardly facing shoulder 517 at the lower end of an enlarged upper bore 518 in the latch section of the housing into which the sub or bushing 520 is threaded. The lower end 521 of the sub or bushing provides a stop shoulder at the upper end of the groove 516 and limits movement of the split latching ring 515 upwardly in the groove. An O-ring 522 is disposed in an external annular groove formed in the end portion of the sub 520 and seals between the sub and the latch section of the housing. A radial opening 530 is formed in the wall of the pin of the sub 520, spaced below the seal ring 522 and above the lower end 521 of such sub, and a shear pin 531 is disposed in said radial aperture and projects therefrom through a registering radial opening 540 formed in the upper end of the wall of the latching member 500. The upper external portion of the latching member 500 is reduced in diameter to provide an upwardly facing latching shoulder 541 which is movable downwardly below the latching ring 515 to be engaged by the lower end of the ring to hold the latching sleeve 500 in the lower position in which the valve actuator sleeve 25 is held in its lower position holding the valve closure member open. A downwardly facing shoulder 523 is formed in the bore of the sub 520 below the lateral opening 530 and abuts the upwardly facing shoulder 541 on the latching sleeve. The reduced bore 524 of the bore into which the reduced upper portion of the latching sleeve telescopes coacts with the upper reduced portion of the latching sleeve to provide means for shearing the pin 531.

When the sleeve 500, which is designated in FIG. 4 by the letter R-2, is in the upper position shown in FIG. 14, the supplemental or alternate control fluid path formed by the passages 481 and 482 is closed. When the sleeve is moved to the lower position shown in FIGS. 4 and 15, the lateral port 510 in the bore wall of the latching sleeve is moved into registry with the lateral passage 482, and control fluid from the chamber 86 above the piston 76 may flow upwardly through the passages 481 and 482 and into the bore of the latching sleeve 500 for use in actuating the supplemental valve V-2 disposed in the valve V. It is believed obvious that a similar structure may be provided for use with each of the latching sleeves previously described, to provide an alternate or supplemental control fluid path from the operating chamber of the valve V to the bore of the valve for acting on the supplemental valve V-2 to control actuation thereof in the same manner as valve V was actuated.

It will readily be seen that the sub 520 may be removed from its threaded engagement in the upper end of the latch section 483 of the valve housing to permit the latch ring 515 and the latch sleeve 500 to be removed from latched position in the bore of the latching section 483, and the O-ring seals 511 and 512 to be replaced, if desired. This permits "redressing" or servicing of the latching or retaining mechanism of this form of the device in the same manner as that of the form of FIGS. 8 and 9.

From the foregoing it will be seen that a plurality of forms of the restraining mechanism for holding the longitudinally movable valve actuator member in a position in which the valve is open have been provided. It will also be seen that the restraining mechanism may be serviced to be redressed for re-use. It will further be seen that a restraining mechanism has been provided which is repeatedly usable, being movable from inoperative to operative latching or restraining position, and from latching or restraining position back to inoperative position, whereby the valve may be latched in the open position when desired, and the restraining mechanism may subsequently be moved to inoperative position to permit the valve to resume normal operation without the necessity of removing the valve and tubing string or flow conductor from the well. It will also be seen that means has been provided for isolating the valve from the flow of fluids through the tubing string from the producing formation to the surface, and that means has been provided for securing a supplemental valve in place in the bore of the primary valve V for use in case of failure of the primary valve or for any other desired reason.

The foregoing description of the invention is explanatory only, and changes in the details of the constructions 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 well flow control system for a well having a flow conductor therein communicating with a producing formation and leading to the well head and surface flow connections of the well, said system including: a flow control valve connected in the flow conductor for controlling flow of fluids through said conductor and having valve closure operator means movable longitudinally of the flow conductor between positions in which the valve is open and closed, means for controlling movement of said valve closure operator means between valve closure opening and closing positions, said valve operator means being normally movable longitudinally to move said valve closure to closed position by well fluid pressure to shut off flow through the flow conductor; means in said valve normally inactive and movable to a position to engage the valve operator means to lock the same in a position positively holding said valve closure open.

2. A well flow control system of the character set forth in claim 1 including: pack-off tool means having a flow passage therethrough securable in said flow control valve and having sealing means thereon sealing between said pack-off tool and said flow control valve on longitudinally opposite sides of said valve closure and operator means to isolate the same from fluids flowing through said flow control valve through said flow passage of said pack-off tool means.

3. A well flow control system of the character set forth in claim 2 including: supplemental flow control valve means in said pack-off tool means operable to control fluid flow through said flow passage of said pack-off tool means.

4. A well flow control system of the character set forth in claim 1 including: fluid pressure responsive means on said valve operator means for moving said

operator means longitudinally of said flow control valve in response to control fluid pressure; and control fluid conductor means from the surface of the well to the flow control valve for conducting control fluid under pressure to said valve to act on said pressure responsive means to move said valve operator means to control actuation of said valve closure from the surface.

5. A well flow control system of the character set forth in claim 4 including: pack-off tool means having a flow passage therethrough securable in said flow control valve and having sealing means thereon sealing between said pack-off tool and said flow control valve on longitudinally opposite sides of said valve closure means and operator means to isolate the same from fluids flowing through said flow control valve through said flow passage of said pack-off tool means and from said pressure responsive means and the control fluid pressure acting thereon.

6. A well flow control system of the character set forth in claim 5 including: supplemental flow control valve means in said pack-off tool means operable to control fluid flow through said flow passage of said pack-off tool means; and means for admitting control fluid from said control fluid conductor means and said pressure responsive means of said flow control valve means for controlling actuation of said supplemental flow control valve means.

7. A well flow control system of the character set forth in claim 6 including: means for conducting control fluid from said flow control valve means to said supplemental valve means; and means coaxing with said means for holding the valve operating means in a position locking said valve closure open for controlling flow of operating fluid to said supplemental valve means.

8. A well flow control system for a well having a flow conductor therein communicating with the producing formation in the bore of the well and supported at the surface by a well head assembly and having flow line connections at the surface, including: a flow control valve in said flow conductor having a valve closure member therein movable between positions opening and closing off flow through said valve; actuating means in said valve for actuating the valve closure means movable longitudinally of said valve for actuating said valve closure means between open and closed position; valve locking means in said valve initially in an inoperative position in said valve and movable to an operative position engaging said longitudinally movable valve actuating means to positively lock said valve actuating means in position holding said valve closure means open.

9. A well system of the character set forth in claim 8 wherein said valve locking means includes: means releasably holding said locking means in position holding the valve open and releasable to unlock said valve locking means for movement from such position to the initial inoperative position to permit resumption of operation of the valve in a normal manner.

10. A well system of the character set forth in claim 8 wherein: means is provided in the flow conductor downstream of the valve for supporting and holding a pack-off tool in place in the flow conductor extending through the valve for isolating the valve from well fluids flowing through the flow conductor.

11. A well system of the character set forth in claim 10 wherein said pack-off tool includes: supplemental flow control valve means on said pack-off tool operable for controlling flow through said pack-off tool while the same is in place in said flow conductor.

12. A well flow conductor valve including: a housing having means for connecting it in flow communication with a well flow conductor; valve means disposed in the housing and movable therein between open and closed positions for controlling flow through the housing; operating means in said housing movable longitudinally thereof for actuating said valve to move the same between open and closed positions; locking means in the housing initially in an inoperative position spaced from said operating means and movable to a position engaging said valve operating means to positively lock said valve operating means in position holding said valve in open position.

13. A valve of the character set forth in claim 12 wherein: said locking means is positively locked in said position holding said valve open.

14. A valve of the character set forth in claim 12 wherein: said locking means is releasably held in position locking said valve operating means in position holding the valve open, and is releasable from engagement with said valve actuating means for movement to said initial inoperative position to permit the valve to resume operation.

15. A valve of the character set forth in claim 12 wherein said locking means comprises: a pair of opposed collet members having intermeshing projecting spring resilient fingers with bosses on their ends; a stop shoulder on the valve housing engagable by the bosses of a first one of said collet members for initially holding said collet member in a position in which said locking means is inoperative; second shoulder means on said housing engagable by said bosses on said first collet for releasably restraining said locking means in position holding said valve actuating means in position locking the valve open; said valve actuating member having a shoulder thereon engagable by the bosses of the second of said collet members for locking said actuating member in position holding the valve open.

16. A valve of the character set forth in claim 15 including: additional restraining means on said first collet member and said housing for holding said first collet means in position holding the actuating member in position locking the valve open.

17. A valve of the character set forth in claim 12 including: fluid pressure responsive means on said operating means; means for conducting control fluid pressure to said valve housing for acting on said fluid pressure responsive means to control movement of said operating means in response to such control fluid pressure; and means at the surface for controlling control fluid pressure conducted through said control fluid conductor means to the valve in response to predeter-

mined conditions.

18. A valve of the character set forth in claim 17 including: second fluid pressure conductor means communicating with the valve housing to act on said operating means in a direction opposite the control fluid pressure from said first control fluid conductor means, said two conductor means for control fluid providing means for counterbalancing the hydrostatic pressure of the control fluids in such conductor means from the surface to the valve housing to reduce the effect of such hydrostatic pressure on the valve operator means.

19. A valve of the character set forth in claim 12 including: a tubular landing nipple having locating, locking and sealing surfaces in its bore connected with the valve housing for receiving and positioning a pack-off tool; and a pack-off tool having longitudinally spaced sealing means thereon, one engaging the sealing surface of said landing nipple and the other engaging the housing on the longitudinally opposite side of the valve means, the valve operating means and the restraining means in the housing from said landing nipple; and a flow passage through said pack-off tool for conducting fluids therethrough in a path isolated from said valve.

20. A valve of the character set forth in claim 19 including: supplemental fluid flow control valve means in said pack-off tool operable to control flow through the flow passage of said pack-off tool and means for conducting control fluid from one of said control fluid conductors connected with said valve housing to said supplemental valve means for controlling actuation of said supplemental valve means.

21. A method of operating a well including: installing a flow conductor in said well for conducting fluids from a producing formation therein to the surface; controlling flow through said flow conductor by a valve in said flow conductor controlled by control fluid from the surface in response to predetermined conditions of flow through the flow conductor and at the well surface; moving said valve to open position independently of said control fluid from the surface; locking said valve in such open position for performing well servicing operations through the open valve.

22. A method of the character set forth in claim 21 including: providing a flow path through the valve isolated from the valve for conducting well fluids from the producing formation through such isolated path without contacting the valve.

23. A method as set forth in claim 21 including: providing a supplemental valve for control of fluid flow through the first valve while said first valve is held in the open position.

24. A method of the character set forth in claim 22 including: controlling fluid through the isolated path through the valve in response to said control fluid from the surface.

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Disclaimer

3,696,868.—*Donald F. Taylor, Jr.*, Dallas, Tex. WELL FLOW CONTROL VALVES AND WELL SYSTEMS UTILIZING THE SAME. Patent dated Oct. 10, 1972. Disclaimer filed May 13, 1975, by the assignee, *Otis Engineering Corporation*.

Hereby enters this disclaimer to claims 1, 4, 8, 12, 13, 17, and 21 of said patent.

[*Official Gazette August 5, 1975.*]