

[54] **SELF-CLOSING, SUB-SURFACE WELL SAFETY VALVE**

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[58] Field of Search **166/72, 73, 122, 224, 226**

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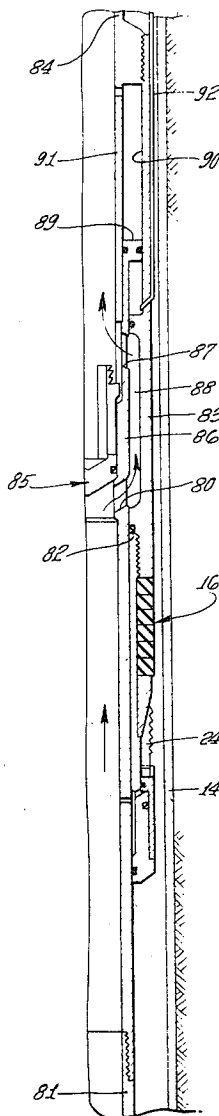
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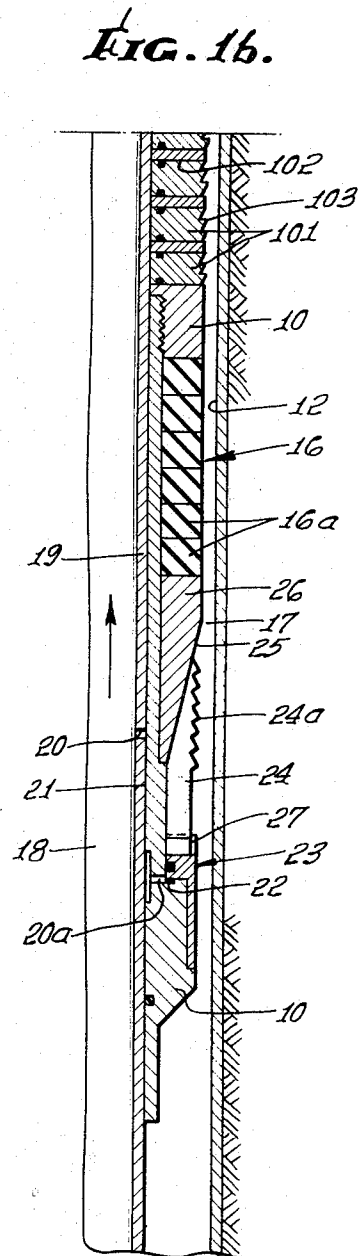
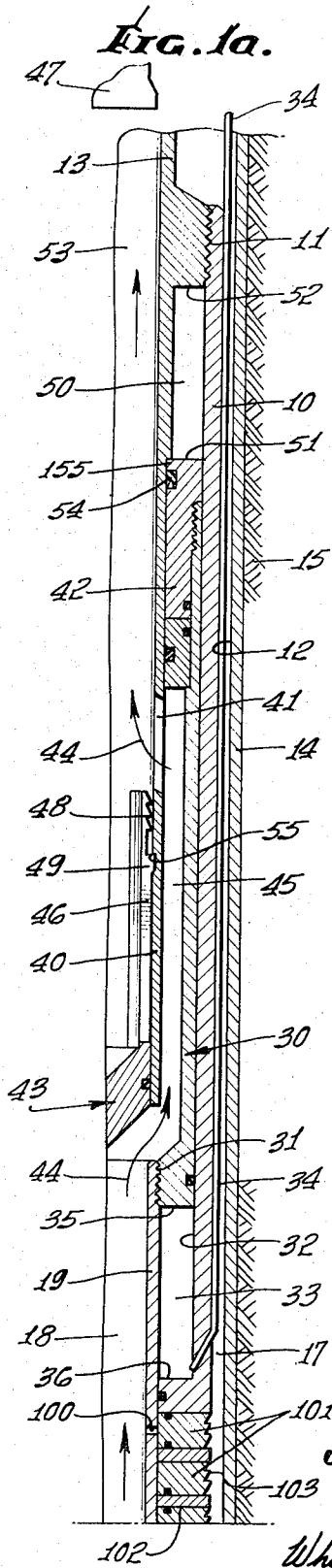
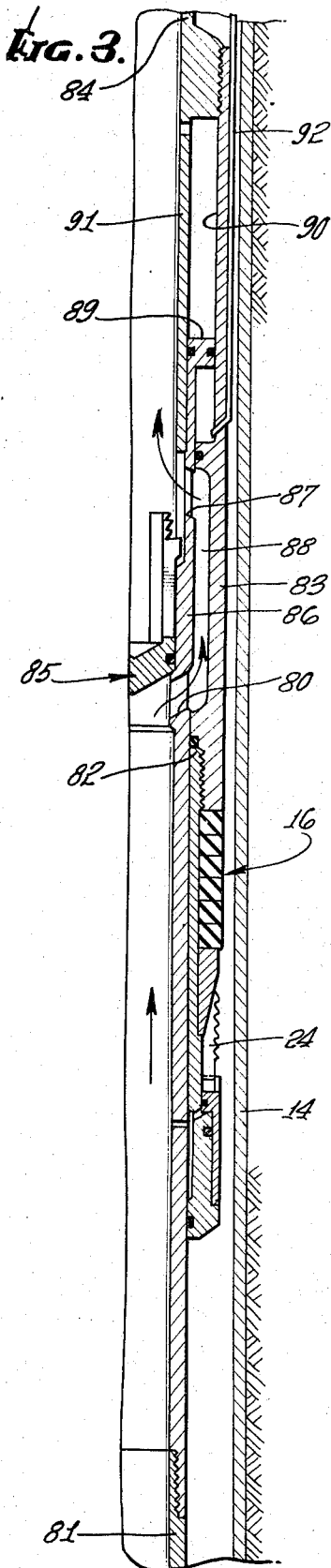
[57] **ABSTRACT**

Sub-surface well flow control apparatus comprises:

- a. a tubular body,
- b. production tubing extending into the well below said body,
- c. a source of control fluid pressure,
- d. actuator means cooperating with the body and responsive to sufficient increase of control fluid pressure application to elevate the tubing within a limited range, and to sufficient reduction of said fluid pressure application to effect lowering of the tubing, and
- e. valving means responsive to said lifting and lowering of the tubing to change the rate of production flow from the tubing to the upper interior of the body.

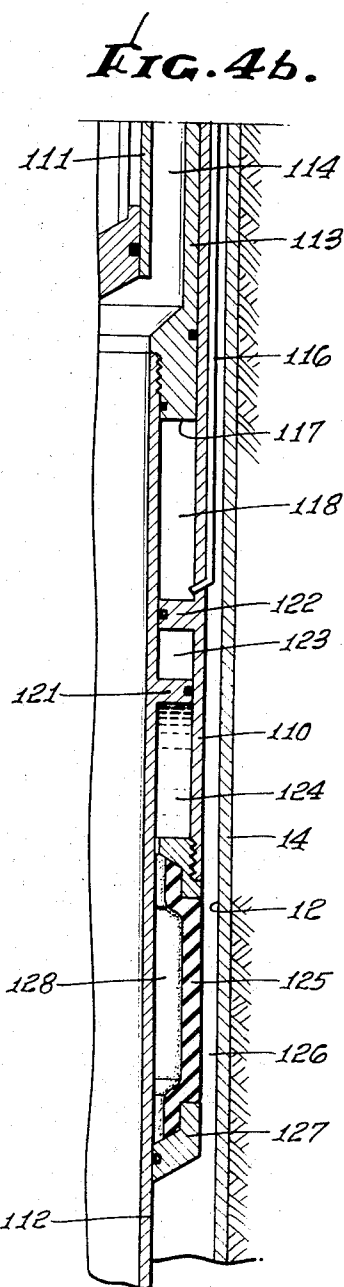
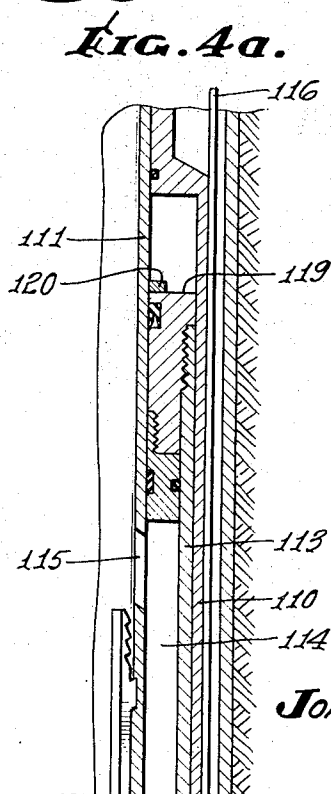
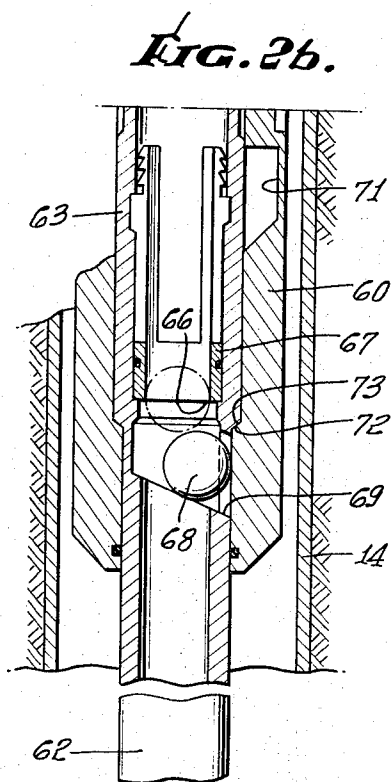
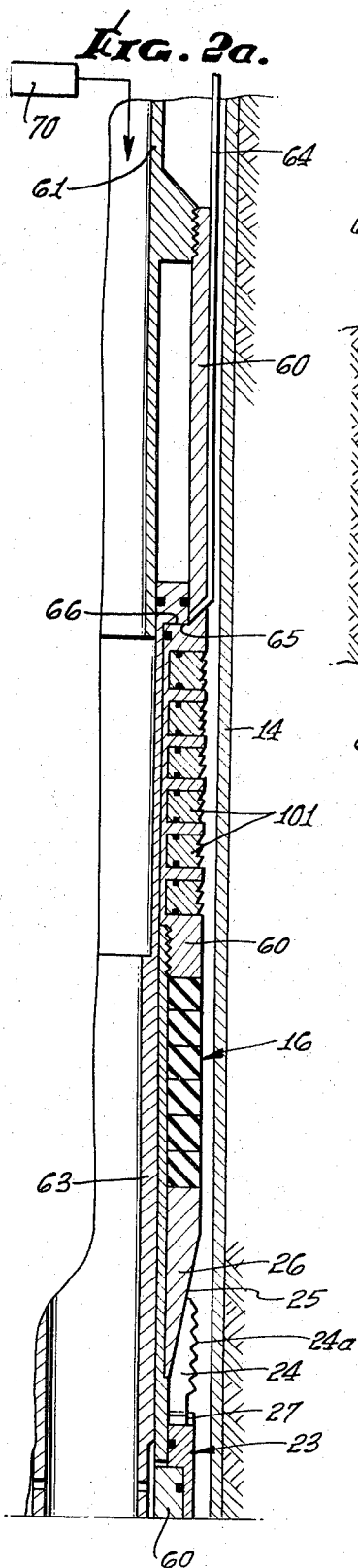
14 Claims, 7 Drawing Figures





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SELF-CLOSING, SUB-SURFACE WELL SAFETY VALVE

BACKGROUND OF THE INVENTION

This invention relates generally to improvements in sub-surface safety valves for use in wells, and more particularly concerns a sub-surface well safety valve characterized as self-closing through imposition of tubing string weight.

As the oil industry develops the technology necessary for drilling, completing, and producing oil wells in deeper water, the need for a sub-surface safety valve that will operate dependably in deep installations increases. The surface controlled sub-surface safety valves available today cannot be installed below 400 feet of depth. This limitation is due to the fact that the fluid in the control tubing builds up a hydrostatic pressure at the rate of about 0.43 P.S.I. for every foot of depth of valve installation. A valve installed at 400 foot depth has about 172 P.S.I. of static pressure exerted at the valve. Even when the boosted control pressure is relieved at the surface, the valve will still have this 172 P.S.I. of static pressure applied against the operating piston which is trying to maintain the valve open. If the well pressure inside the valve is low, perhaps around 200 P.S.I., the valve won't close. Most surface controlled valves depend on the well pressure to push on the operating piston in the valve to close the valve. They often use a spring to assist the closure. The seals in the valve cause considerable frictional drag on the operating piston, such drag often requiring 100 to 150 P.S.I. just to overcome it. A valve normally should have at least 300 P.S.I. more well pressure than static pressure in the control tubing.

It is clear that as installation depth requirements increase, the valves of present day design will not operate in the later low pressure stages of the well. In a 1,000 ft. deep installation there will be a 430 P.S.I. static control line pressure, which will require a well pressure of 730 P.S.I. to cause the valve to close. Many wells do not have this much pressure to begin with. Accordingly, a serious problem exists

SUMMARY OF THE INVENTION

It is a major object of the invention to provide means for overcoming the above problem, and enabling installation and use of safety valves at much greater depths.

In accordance with an important concept embodied in the invention, well fluid pressure is not needed to close the valve, but rather the weight of the tubing hanging below the valve is used to pull the valve closed. Such tubing typically extends from the producing zone in the lower part of the well up through the inside of the packer and is connected onto the operating piston of the valve. Sufficient control pressure from the surface is applied down the central tubing to the valve to actually lift the tubing up and hold it up, which is the open position of the valve. When the control pressure is relieved at the surface, the tubing weight will pull the valve closed. Accordingly, the tubing weight below the packer is used as a means of operating the safety valve, the latter having several possible configurations, as will be seen.

Basically, then, the invention may be considered as embodied in the combination which includes:

- a. a tubular body,
- b. production tubing extending into the well below the body,
- c. a source of control fluid pressure,
- d. actuator means in the body and responsive to sufficient increase of control fluid pressure application to elevate the tubing within a limited range, and to sufficient reduction of control fluid pressure application to effect lowering of the tubing, and
- e. valving means in the body and responsive to such lifting and lowering of the tubing to change the rate of production flow from the tubing interior to the upper interior of the body.

As will appear, the actuator may typically have an upper terminal confined against exposure to well pressure, whereby additional tubing may be added to the lower string in the well; the tubing may have a down position in which the valving

means is closed, and an up-position in which valving means is open; and the actuator means and body may form an annular chamber to receive the control fluid pressure, the actuator means being integral with the tubing.

The valving means may typically comprise tubular elements which respectively form a port and gate therefor, and alternatively the valving means may comprise an annular seat against which a plug seats, the plug being receivable in a side pocket after being unseated when the actuator means is moved vertically relative to the body.

Finally, the production tubing may be of length and weight sufficient to counterbalance the static pressure created by 400 feet of control fluid pressure exerted upwardly against the actuator means; and packer structure to seal off between the body and well bore may include a fluid pressure inflatable elastomeric element to which inflating pressure is applied in response to lowering of the tubing relative to the body, to stop flow through the annulus.

These and other objects and advantages of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the detailed description of the drawings, in which

DRAWING DESCRIPTION

FIGS. 1a and 1b are vertical half-sections illustrating one form of the invention;

FIGS. 2a and 2b are vertical half-sections illustrating another form of the invention;

FIG. 3 is a vertical half section showing another form of the invention; and

FIGS. 4a and 4b are vertical half sections illustrating yet another form of the invention.

DETAILED DESCRIPTION

Referring first to FIGS. 1a and 1b, a tubular body 10 is shown suspended at 11 in a well bore 12 as by means of upper string 13 of production tubing. The bore 12 may be formed as by casing 14 set in the well formation 15. Body 10 carries packer means generally indicated at 16, and adapted to be set as by radial expansion into engagement with the bore 12 to seal off the annulus 17. Such expansion may be effective as by pressurizing the interior 18 of lower string of production tubing 19, thereby to effect fluid pressure transmission via port 20, clearance 21, and port 20a to the surface 22 of annular piston 23. The latter then moves upwardly to lift the slips 24 which bear against the taper 25 of conical ring 26. Accordingly, the slips are displaced outwardly to grip the casing bore at jaws 24a, and the ring 26 is elevated to compress the packer rings 16a to effect the pack-off, the jaws 24a locking the packer in expanded position. Slips 24 may have T-slot connection at 27 to the piston 23.

In addition, such fluid pressure application may be transmitted via port 100 to the inner sides of piston buttons 101 carried in body bores 102. The buttons are urged outwardly to engage jaws 103 carried thereby with the bore 12, to hold the tool down in the well. The mentioned lower string of tubing 19 extends deeply into the well below the body 10, to exert weight for assisting the control of valving which is otherwise surface controlled. In this regard, actuator means is provided in the body to be responsive to sufficient increase of control fluid pressure application to raise the tubing within a limited range, and to sufficient reduction of the control fluid pressure application to effect lowering of the tubing. For example, the actuator means may include a sleeve 30 attached at 31 to the lower tubing string and slidable in the bore 32 of body 10. The latter body and the actuator sleeve form an annular chamber 33 to receive control fluid pressure from the surface, and via a line 34, for upward exertion against piston surface 35, shown in extreme up-position in FIG. 1a. Upon sufficient reduction in that control pressure application, the sleeve drops until piston surface 35 engages stop surface 36.

Valving means is provided in the body to be responsive to lifting and lowering of the tubing to change the rate of production flow from the tubing to the upper interior of the body. In this regard, the valving means may comprise tubular elements, one of which (as for example 40) forms a port or ports 41, and another of which (as for example 42) forms an annular gate to control the port. As illustrated, the gate element 42 may be carried by the sleeve 30 which is in turn carried by the lower string of tubing 19; and, the port forming element or tube 41 may be integral with the body 10, which is in turn carried by the upper tubing string 13.

Element 40 is closed below the level of port 41 as by means of a retrievable plug 43, whereby in the up-position of the sleeve 30, well fluid may flow as indicated by arrows 44 into annular passage 45 (between sleeve 30 and element 40) and through port 41 into the upper interior of the body 10 and into the upper string 13 for upward flow to the surface. In down-position, the gate 42 closes the port, interrupting such flow. Plug 43 has upward extending spring fingers 46 which may be urged inwardly by a retrieval tool 47 engaging the serrations 48, to grip the plug and release the latch dog 49 from retention in groove 55.

Another highly advantageous feature is found in the provision of the empty chamber 50 found between the top surface 51 on the actuator structure and the shoulder 52 on the body, whereby the surface 51 is isolated from pressure of well fluid in either annulus 17 or bore 53. If well pressure were allowed to push downwardly on the surface 51, the control pressure exerted via line 34 would have to be sufficient to overcome it as well as the weight of the lower string of tubing 19. As a result, deeper lengths of lower string tubing 19 may be run in the well below the valve. Seal 54 between elements 40 and 42 acts as a check valve to pass any liquid trapped in chamber 50. Shoulder 155 limits upward stroking of element 42.

The modified form of the invention seen in FIGS. 2a and 2b includes a body 60 suspended in a well by upper string of production tubing 61. The lower tubing string 62 exerts weight applied to actuator sleeve 63, indicated in lowermost position. Control pressure exerted via line 64 elevates the sleeve and lower string in response to upward application against piston surface 65, shown engaged against stop shoulder 66. Button elements 101, packer 16, piston 23 and slips 24 are the same as in FIG. 1.

The valving means responsive to upward and downward movement of the lower string 62 includes an annular seat 66 carried by the actuator tubing 63 and formed by retrievable ring 67, and a plug 68 (in the form of a ball, for example) urged upwardly against the seat in response to well pressure upward application to close the port formed by the ring. A side opening 69 in tube 63 passes the plug 68 laterally when the tubing is raised and when fluid pressure is applied down the upper tubing 61 (as from source 70), the plug thereby being unseated and becoming trapped in side pocket 71 formed by the body 60. Shoulder 72 seats the shoulder 73 on the tube 63, as is clear in FIG. 2b.

FIG. 3 is similar to FIG. 1, with the exception that the lower port 80 is the control port, and is moved up and down with the lower string 81, and relative to gate 82 formed by the body 83 suspended by the upper string 84. Retrievable plug 85 is latched into the sleeve 86 which forms port 80 and also suspends the lower string of production tubing. Sleeve 86 also forms the upper port 87 to which fluid flows via passage 88. Actuator piston 89 is slidably received between body bore 90 and tubular element 91, to receive control pressure application via line 92.

In FIG. 4 the body 110 and tubular element 111 are integral. The lower tubular string 112 is attached to sleeve 113 which forms, with element 111, an annular passage 114 to pass production flow via control port 115 to the upper interior of the body, as in FIG. 1. Control pressure exerted via line 116 is applied to the piston surface 117 at the upper side of chamber 118 below the level of passage 114, thereby to elevate the lower string until the upper terminal 119 of the

sleeve structure strikes stop 120. At this time piston 121 on tubing 112 and flange 122 on body 110 are spaced apart to keep pressure in chamber 123 from undesirable increase, that pressure normally being atmospheric when the actuator sleeve 113 is in down-position.

Chamber 124 below piston 121 may contain liquid such as oil adapted to be urged downwardly by the piston 121 (when control pressure is reduced sufficiently to lower the actuator sleeve), thereby to expand an inflatable elastomer packer ring 125 against bore 12, to seal off annulus 126. When the piston 121 moves down with the tubing string, the packer 125 is expanded to seal against casing bore 12 as a result of displacement of oil from space 124 into space 128 inwardly of the packer. Thus, annulus production flow is shut off simultaneously with the shut-off of tubing production flow. In this regard, piston 127 moves upwardly when oil expands packer 125. During normal production flow up through the tubing 112, the packer 125 is not expanded as described. Piston 127 is further responsive to shut-in annulus pressure to keep it packed off after the tubing 112 has moved down to shut-off tubing flow.

I claim:

1. Sub-surface well flow control apparatus, comprising, in combination

- a. a sub-surface tubular body,
- b. a lower string of production tubing extending into the well below said body,
- c. a source of control fluid pressure,
- d. actuator means cooperating with the body and responsive to sufficient increase of control fluid pressure application to elevate said tubing string relative to the body and within a limited range, and to sufficient reduction of said fluid pressure application to effect lowering of the tubing string relative to said body, and
- e. valving means in the body responsive to said lowering of the tubing string to shut-off the production flow from the tubing string to the upper interior of the body.

2. The combination of claim 1 wherein said actuator means has an upper terminal confined against exposure to well pressure.

3. The combination of claim 1 wherein a central vertical passage is formed within said body, and including a retrievable plug closing said passage to vertically separate the upper interior of said body from the interior of said production tubing.

4. The combination of claim 1 including an upper string of production tubing suspending said body, and relative to which said first mentioned production tubing is vertically movable up and down.

5. The combination of claim 1 wherein said valving means comprises an annular seat carried to move vertically with said tubing, and a plug urged upwardly against said seat in response to well pressure application to close the valve, there being a side opening in the tubing to pass the plug laterally when the tubing is elevated and when fluid pressure is transmitted down a body suspending upper string of tubing to unseat the plug.

6. The combination of claim 1 wherein said production tubing below the valve is of length and weight sufficient to counterbalance the static pressure created by the control fluid pressure exerted upwardly against said actuator means.

7. The combination of claim 1 including packer means to seal off between said body and the well bore.

8. The combination of claim 7 wherein said packer means comprises a fluid pressure inflatable elastomeric element to which inflating pressure is supplied to response to lowering of said tubing relative to said body.

9. The combination of claim 8 wherein said element has an expanded position for sealing off the annulus formed between said apparatus and the well bore when the tubing has a relatively lowered position.

10. The combination of claim 1 wherein said tubing string has a down-position in which said valving means is closed, and an up-position in which said valving means is open.

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11. The combination of claim 10 wherein said actuator means and said body form an annular chamber to receive said control fluid pressure, said actuator means being integral with the tubing string.

12. The combination of claim 11 wherein said valving means comprises tubular elements one forming a port and another forming a gate to control said port, a first of said ele-

ments integral with the tubing and a second of said elements integral with the body.

13. The combination of claim 12 in which the gate is integral with the actuator means.

14. The combination of claim 12 in which the gate is integral with the body.

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