

July 7, 1953

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2,644,527

DEVICE FOR CONTROLLING WELL FLOW

Original Filed July 7, 1944

3 Sheets-Sheet 1

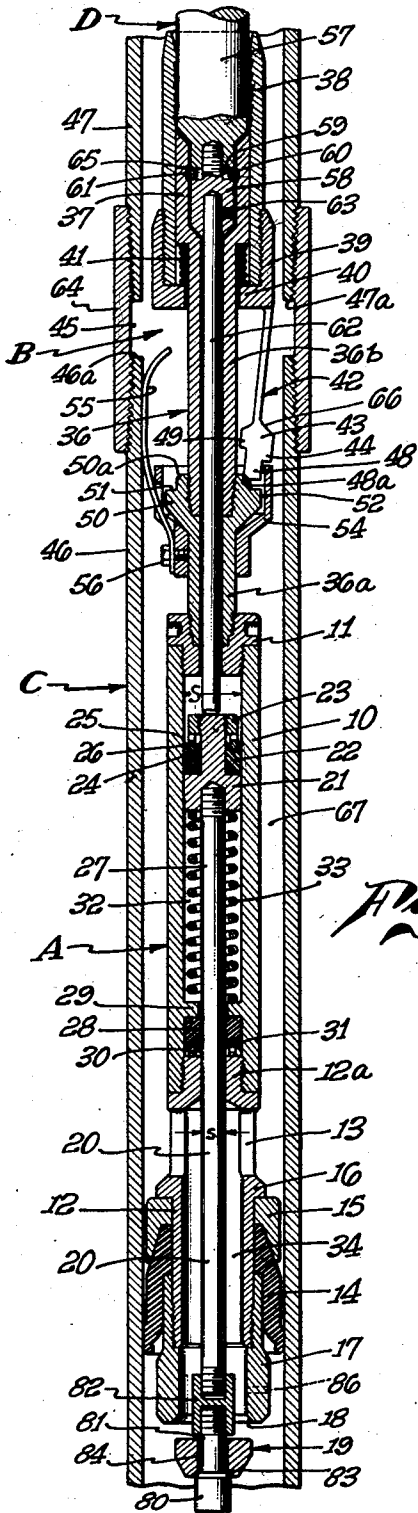


Fig. 2.

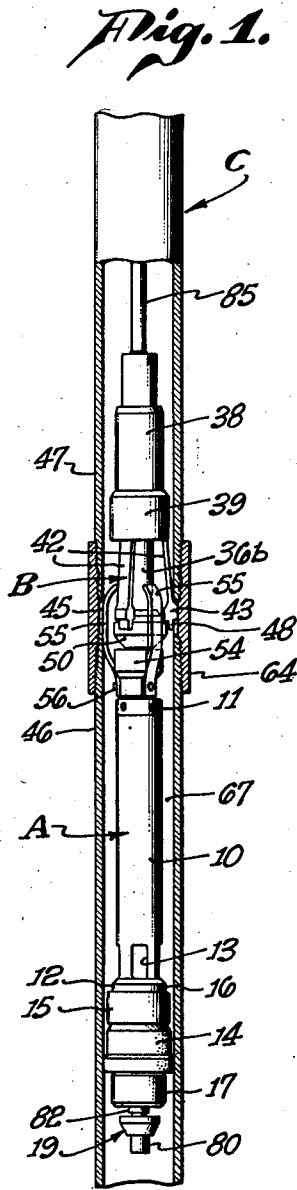


Fig. 1.

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*Fig. 3.*

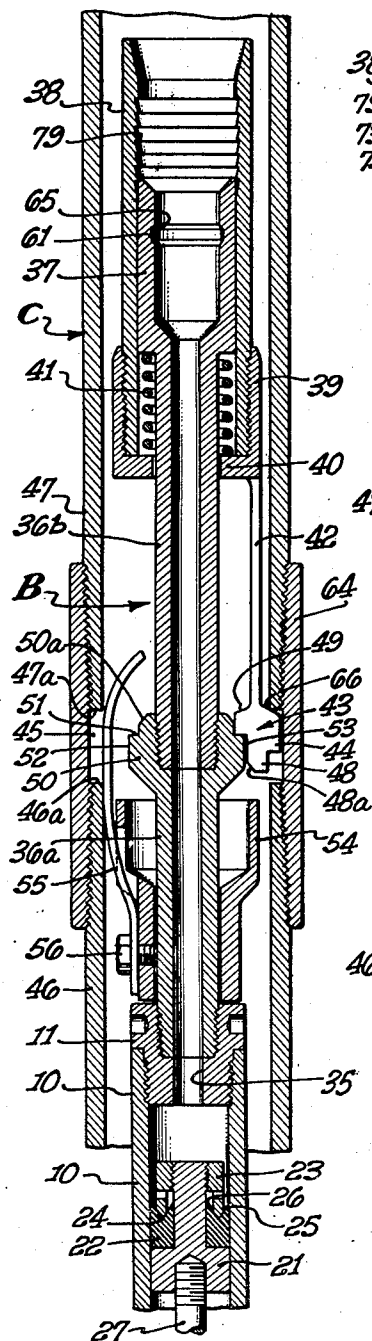


*Fig. 4.*

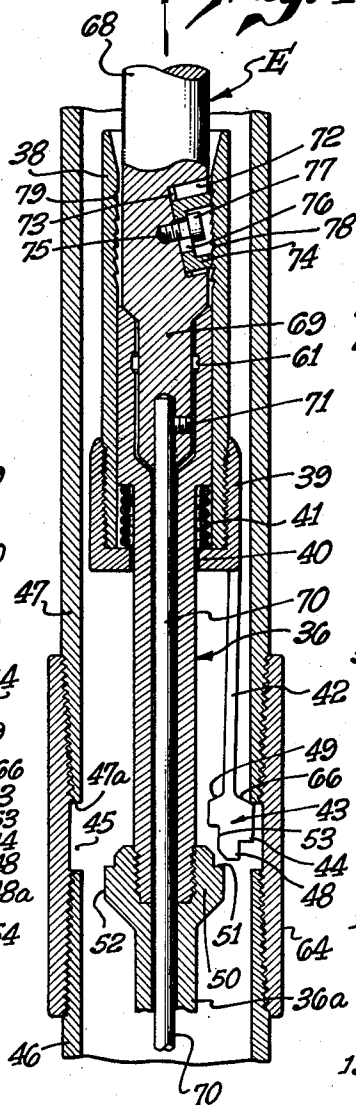
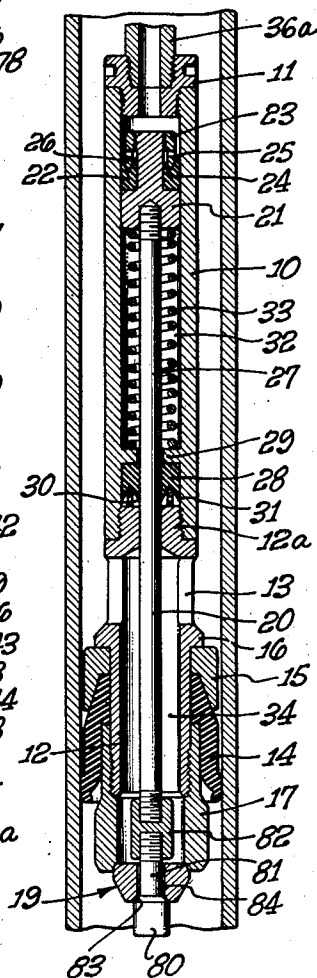


*Fig. 5.*



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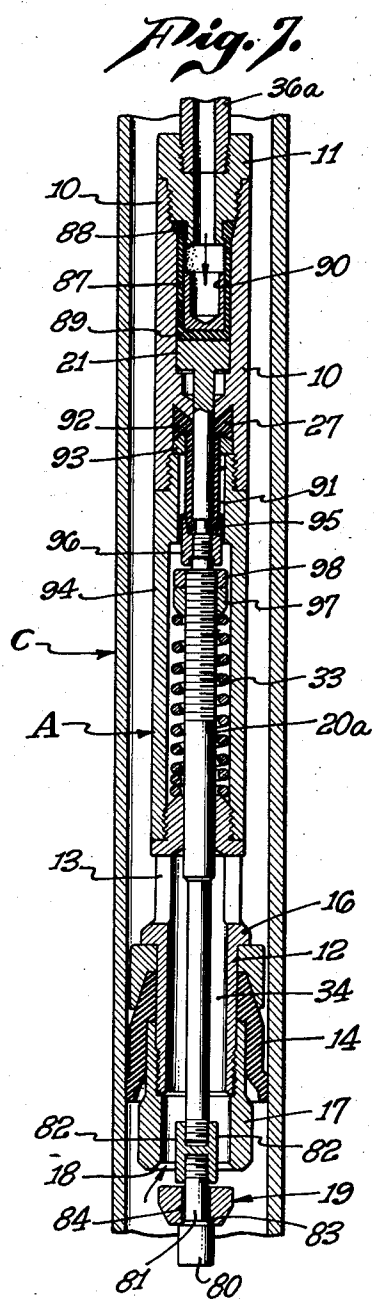
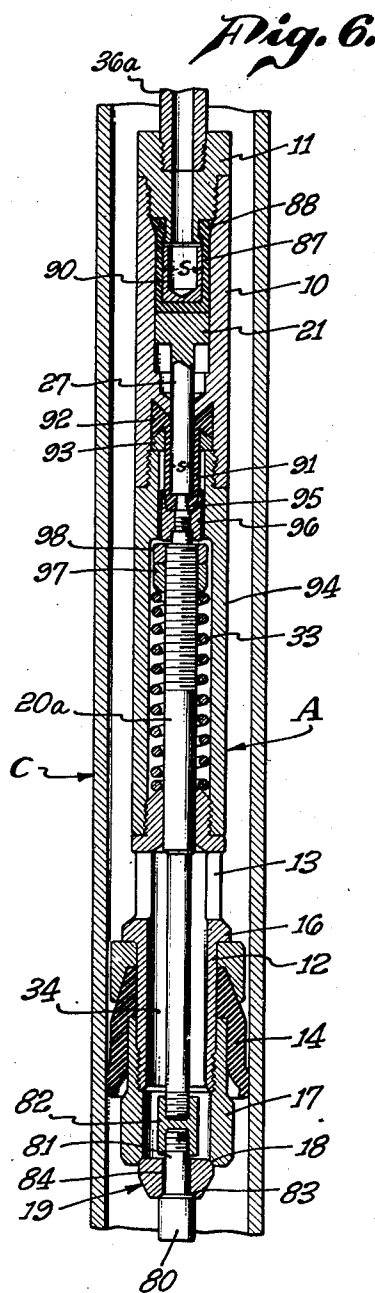
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DEVICE FOR CONTROLLING WELL FLOW

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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,644,527

## DEVICE FOR CONTROLLING WELL FLOW

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Continuation of application Serial No. 543,853,  
July 7, 1944. This application February 23,  
1950, Serial No. 147,631

15 Claims. (Cl. 166—2)

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This invention relates to well devices, and more particularly to devices for controlling the flow of fluids from oil and gas wells.

The present application is a continuation of my application for "Devices for Controlling Well Flow," Serial No. 543,853, filed July 7, 1944, and now abandoned.

An object of the invention is to provide a device adapted for use in well tubing and capable of automatically shutting off or greatly diminishing the flow through the tubing upon decrease of the well pressure below a predetermined value.

A further object of the invention is to provide a device adapted for use in well tubing which permits flow through the tubing to the surface of the well bore under normal pressure operating conditions, but which automatically shuts off or greatly restricts such flow upon drop in pressure below a predetermined value.

Still another object of the invention is to provide a device adapted for use in well tubing in which the pressure of the fluid flowing through the tubing under normal operating conditions acts on pressure actuatable surfaces of dissimilar areas to hold a flow control valve open against the action of a valve closing element. Upon decrease of the unit tubing pressure below a predetermined amount, the fluid acting on such surfaces of dissimilar areas is incapable of holding the valve open against the force exerted by the valve closing element.

Another object of the invention is to provide an automatic pressure responsive shut off valve device for controlling the flow of fluid through well tubing, which is capable of being reopened by applying external fluid pressure to the device.

Another object of the invention is to provide a valve device adapted for use in well tubing and which is held open by pressure acting on the device from above, and which will close upon decrease in such pressure to a predetermined degree.

Yet another object of the invention is to provide an improved retrievable locking device for anchoring flow control apparatus in tubing previously installed in a well.

A further object of the invention is to provide an improved flow control apparatus adapted to be anchored in well tubing, which can be run into and retrieved from the well tubing without substantially disturbing the disposition of fluid in

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the tubing, and without removing the tubing from the well bore.

In its general aspects, the invention contemplates the provision of a valve device which is controlled by fluid pressure acting on pressure actuatable surfaces of dissimilar areas. The pressure acts on a surface of greater area to exert a force tending to open the valve or hold it in open position, and this pressure also acts on a pressure actuatable surface of lesser area tending to move the valve toward closed position, or to a position in which flow through the valve is materially restricted. This last-mentioned hydraulic valve closing force is supplemented by the force of a spring. There is, accordingly, a total valve opening force provided by the unit fluid pressure acting on the pressure actuatable surface of greater area, and a total valve closing force provided by the spring force plus the force of the unit fluid pressure acting on the fluid pressure actuatable surface of smaller area. So long as the total force on the surface of larger area is greater than the total force exerted by the spring and the fluid acting on the surface of smaller area, the valve will remain in open position; but as soon as the first-mentioned total force is less than the sum of the last-mentioned forces, the valve will move automatically to closed position, or to a position in which flow through the tubing is materially decreased.

This invention has other objects and aspects which will become apparent from a consideration of the several forms of apparatus shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, but it is to be understood that such detailed description is not to be taken in a limited sense, since the scope of the invention is best defined by the claims appended hereto.

Referring to the drawings:

Figure 1 is an elevation of an apparatus shown installed in well production tubing;

Fig. 2 is a longitudinal section through the apparatus with its parts in retracted position for lowering through the production tubing;

Fig. 3 is a longitudinal section of part of the apparatus shown in Fig. 2, in another operative position;

Fig. 4 is a longitudinal section showing the

parts in position for elevating the apparatus through the tubing;

Fig. 5 is a longitudinal section showing the valve control portions of the apparatus in closed position;

Fig. 6 is a view similar to Fig. 5 of a modified form of apparatus; and

Fig. 7 is a view of the device disclosed in Fig. 6 in another operative position.

As disclosed in the drawings, the device consists of a lower flow control portion A and an upper locking portion B for anchoring the device in a well tubing C previously installed in the bore hole.

The flow control portion includes a cylindrical body 10 having an adapter or cylinder head 11 threaded into its upper end, and a tubular valve body 12 screwed into its lower end. The valve body has a plurality of lateral ports 13 establishing communication between its interior and exterior, below which is carried a suitable packing to effect a seal with the tubing wall; shown specifically as a packing cup 14, clamped between a thimble 15 engaging a shoulder 16 on the valve body below the ports, and a clamp nut 17 threaded on the lower end of the valve body 12 and engaging the base portion of the packing cup 14. The clamp nut is provided with a valve seat 18 adapted to be engaged by a valve head 19 mounted on a valve stem 20 extending upwardly through the valve body 12 and into the cylinder 10. A piston 21 is attached to the upper end of this stem 20 and carries a piston packing 22 secured to it by a suitable nut 23 threaded on the piston and engaging an annular V-shaped groove 24 in the packing to force its outer lip 25 against the cylinder wall and its inner lip 26 against the piston, thus preventing leakage of fluid past the piston from above the packing 22.

The valve stem 20 may be considered as a small piston or piston rod whose upper portion 27 extends into the cylindrical body or cylinder 10. Fluid through the valve body 12 is prevented from flowing or passing along the small piston portion 27 into the cylinder 10 by a rod packing 28, whose base portion engages the underside of a shoulder 29 extending inwardly from the cylinder, and whose inner and outer lip portions 30, 31 are forced against the piston or piston rod portion 27 and wall of the cylinder 10 by the clamping action of the end 12a of the valve body 12 screwed into the lower end of the cylinder. It will, accordingly, be seen that the rod packing 28 prevents fluid from below from passing into the cylinder space 32 between the large piston 21 and the shoulder 29, and that the piston packing 22 prevents fluid from above from passing downwardly into the cylinder space 32 below the large piston. The space 32 between the lower end of the large piston and the shoulder contains no liquid at all, but only air at approximately atmospheric pressure, trapped in the space upon assembly of the device prior to its lowering in the bore hole.

A helical spring 33 is disposed in the cylinder 10 around the smaller piston portion 27 with its lower end engaging the upper surface of the shoulder 29, which functions as a spring seat, and its other end engaging the underside of the large piston 21. This spring is in compression, and tends to shift the large piston 21, small piston portion 27 and valve stem 20 in an upward direction to engage the valve head 19 with its seat 18 and close the passage 34 through the valve body, thus preventing upward flow of fluid within

the tubing C through the device. Flow around the valve body and device in an upward direction is prevented by the sealing action of the packing 14 against the wall of the tubing.

The fluid under pressure in the tubing can act on the upper pressure actuatable surface of the large piston 21, having an area "S," by passing through the central passage 35 in the cylinder head 11. The total force exerted on the large piston by the pressure acting over its area "S" tends to shift the piston 21, and the small piston portion 27 and valve stem 20, in a downward direction, to hold the valve head 19 from its seat 18, or in open position. The total force acting in an upward direction and tending to move the valve head 19 to closed position is the force exerted by the coil spring 33 against the upper piston 21 plus the pressure of the fluid in the tubing acting across the pressure actuatable surface having an effective area "s," of the small piston or piston rod portion 27. So long as the tubing pressure is high enough to furnish a total hydraulic force acting downwardly on the large piston 21 greater than the sum of the hydraulic force acting upwardly on the small piston portion 27 plus the upward force exerted by the spring 33, the valve head 19 will be held from its seat 18, or in open position. When the pressure in the tubing diminishes sufficiently, the total downward force acting on the large piston 21 will be less than the sum of the upward force exerted by the spring 33 and the hydraulic force acting upwardly on the small piston portion 27, causing the spring 33 to move the valve head 19 to closed position against its seat 18.

The pressure at which the valve will close can be predetermined by the relationship between the area "S" across the large piston 21 and the area "s" of the small piston portion 27, and also by the degree of compression or force of the spring 33. For example, let it be assumed that the flow through the tubing is being substantially restricted by a flow bean (not shown) at the surface of the well bore to build up a back pressure in the tubing string both above and below the well device of 600 p. s. i. Let it further be assumed that it is desired to have the valve close upon drop in the tubing pressure to approximately 300 p. s. i., which will occur either as a result of opening the flow bean to a greater extent or through disruption of the surface well connections. If the area of the large piston is assumed to be  $\frac{3}{4}$  sq. in., and the area of the small piston  $\frac{1}{8}$  sq. in., the upward force "F" to be exerted by the coil spring when the valve is open can be predetermined from the following equation:

$$P \times S = F + P \times s$$

where:

P=desired unit closing pressure in p. s. i.=300

S=area of large piston in sq. in.= $\frac{3}{4}$

s=area of small piston in sq. in.= $\frac{1}{8}$

F=force exerted by coil spring in lbs.

$$300 \times \frac{3}{4} = F + 300 \times \frac{1}{8}$$

F=168.75 lbs., or approximately 170 lbs.

In other words, under the assumed conditions, if the spring 33 has a compressive force with the valve open of about 170 lbs., the valve will close upon drop in the tubing pressure immediately below 300 p. s. i. A pressure of 600 p. s. i., or any pressure at or above 300 p. s. i., will hold the valve open.

The valve device A can be made up and run in a

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well bore with the tubing string C, if desired, with the cylinder 10 or valve body 12 suitably secured to the tubing, or, as shown in the drawings, it can be run in and anchored to tubing already positioned in the well bore. In this latter instance, an anchoring device is attached to the cylindrical body 10 to form an upward extension thereof and includes a tubular mandrel 36 having its lower member 36a threaded into the adapter or cylinder head 11 and its upper member 36b threaded into the lower member. The upper mandrel member 36b is provided at its upper end with an enlarged head 37 slidably receiving a retrieving sleeve 38, on the lower end of which is threaded a latch carrier 39 having an inturned shoulder 40 forming a seat for a helical spring 41 whose upper end engages the mandrel head 37. A plurality of circumferentially spaced spring-like latches 42 are formed integrally with and depend from the latch carrier 39, each latch having a rigid head 43 at its lower end provided with an integral dog or slip 44 of such length as to be able to fit within a coupling space 45 formed between adjacent sections 46, 47 of tubing. The head 43 also has a foot portion 48 depending from the dog 44, and an inwardly projecting lug 49 above the foot. A latch lock or holder 50 is formed on the upper end of the lower mandrel member 36a, and has a shoulder 51 adapted to engage the lower end of the lug 49, and also an outer surface 52 engageable with the inner surface 53 on each foot 48 to prevent inadvertent inward movement of the latch 42 after its outward expansion into the tubing coupling space 45.

When the tool is run downwardly through the tubing, the latches 42 are prevented from moving outwardly, due to their inherent spring action, by a cup-shaped retainer 54 engaging the outer surface of each latch foot 48. This retainer is slidable longitudinally on the lower mandrel member 36a in moving to and from latch retaining position. Circumferentially spaced leaf springs 55 are secured to the latch retainer by screws 56 or the like, and frictionally engage the tubing C, tending to resist movement of the latch retainer 54 therewithin.

A running-in tool D is employed for lowering and setting the tool in the production tubing already installed in the well bore. This tool consists of an upper body 57 received within the retrieving sleeve 38 and having a depending pilot 58 provided with an external circumferential groove 59 in which is positioned a split coupling ring 60 which inherently tends to expand in an outward direction. A companion internal groove 61 is formed in the mandrel head 37 for reception of the split ring 60 to couple the running-in tool to the mandrel 36. A stinger or valve opening rod 62 is secured to the pilot 58, as by a set screw 63, and extends downwardly through the central passage in the mandrel and cylinder head into engagement with the upper end of the large piston 21. The valve opening rod 62 is of such length as to move the piston 21 downwardly against the action of the spring 33 when the coupling ring 60 is in the internal groove 61 to hold the valve in open position while the valve device is being run downwardly through the tubing C.

The parts are all arranged as disclosed in Fig. 2, with the running-in tool D in proper position within the mandrel 36 and cylinder 10. It is to be noted that the mandrel 36 has been moved down with respect to the retrieving sleeve 38 and

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latches 42 to dispose the latch lock 50 below the heads 43, which allows the latter to be forced inwardly and held in retracted position by the retainer sleeve 54 positioned over the foot portions 48 of the latches. The setting spring 41 has been compressed and is held in such compressed state by engagement of the foot portions 48 of the latches with the tapered portion 50a of the mandrel lock 50.

The running-in tool D is secured to a suitable wire line or tubing (not shown) for lowering the entire apparatus through the production tubing C. The body 57 has sufficient weight, which may be supplemented, if required, by a sinker bar (not shown) attached to its upper end, to force the apparatus down through the production tubing. This downward movement is not retarded by the fluid in the tubing, since the stinger 62 holds the valve head 19 open and allows fluid to by-pass the device by flowing upwardly through the valve body 12 and ports 13. Since the friction springs 55 tend to resist movement of the latch retainer 54 downwardly through the tubing, it remains in position over the foot portions 48 of the heads 43 to hold their dogs or slips 44 in retracted position.

When the approximate depth at which the apparatus is to be anchored in the well tubing is reached, the wire line is moved upwardly causing the entire apparatus to be elevated, with the exception of the latch retainer 54, whose upward movement is prevented by the friction springs 55. Such upward movement releases the latch retainer from the foot portions 48 of the latches 42 and allows them to expand outwardly under their inherent spring action against the wall of the tubing. This outward expanding action may be assisted by the force of the compressed setting spring 41 tending to move the lock 50 upwardly with respect to the latches to shift its conical expander portion 50a upwardly against and along the companion inclined surfaces 48a at the inner lower ends of the foot portions of the dogs or slips.

The entire apparatus is elevated until the next higher coupling space 45 formed by a coupling 64 connecting adjacent sections 46, 47 of tubing together is reached, whereupon the dogs 44 on the latches can inherently expand outwardly into this space 45, the setting spring elevating the upper mandrel member 36b and attached lower mandrel member 36a to position the latch lock or holder 50 behind the latches, as shown in Fig. 3, in which the lock shoulder 51 engages the lugs 49 and the periphery 52 of the lock engages the inner surfaces 53 of the foot portions 48 of the latches. When in this position, the apparatus cannot move upwardly, except to a very slight extent as limited by the coupling space, since the latches 42 are prevented from moving inwardly out of the coupling space 45 by engagement of the heads 43 with the periphery 52 of the latch holder 50. A continuation of the upward strain on the wire line or tubing attached to the running-in tool D causes the split coupling ring 60 to bear against the tapered upper surface 65 of the internal groove 61, which will shift it inwardly to release the running-in tool D from the mandrel head 37, permitting withdrawal of the running-in tool to the surface of the well bore, and also withdrawing its valve opening rod 62 from the mandrel 36 and cylinder 10. While this upward force is being exerted on the running-in tool to release it from the mandrel, the upwardly and inwardly inclined

surfaces 66 on the latch heads 43 engage the end 47a of the upper tubing section 47, but the latch holder 50 still prevents the dogs 44 from moving inwardly and holds the apparatus locked to the production tubing C against upward movement. Downward movement is prevented by engagement of the dogs 44 with the end 46a of the lower tubing section 46.

If the valve head 19 has engaged its seat 18 upon withdrawal of the running-in tool D from the apparatus, such head can be reopened simply by applying pressure from the surface of the well bore to the fluid in the production tubing C. This pressure acts on the large piston 21 to shift the piston rod 27 and valve stem 20 downwardly and move the valve head 19 from its seat 18. Discontinuation of this externally applied pressure will not cause the valve to close, because the pressure of the well fluid in the tubing is then capable of acting, through the open valve, in a downward direction on the large piston 21, as well as upwardly on the small piston portion 27. With the valve in open position this well fluid flows upwardly around the valve head 19, through the annular space 34 between the valve body 12 and valve stem 20, through the ports 13, and upwardly through the annulus 67 between the cylinder 10 and tubing C to the control mechanism at the surface of the well bore, where the flow is suitably beamed or throttled to provide the necessary normal back pressure in the tubing string. The well pressure is acting upwardly on the packing cup 14 but cannot pass therearound because of its sealing engagement with the wall of the production tubing, and this pressure is also incapable of forcing the entire apparatus in an upward direction because of the engagement of the latches 42 with the tubing end 47a of the coupling space 45. As aforesaid, the latches 42 cannot be moved inwardly out of this space because of the locking action of the latch holder 50 on the mandrel 36. When the tubing pressure drops below a predetermined value, the valve automatically closes because of the action of the helical spring 33, as described above. Such action normally takes place either through opening the flow valve at the surface of the well bore to decrease the fluid pressure in the tubing, or through inadvertent disruption of the surface connections, which can occur as a result of hurricane or other natural hazards, or as a result of explosive forces.

The device may be retrieved from the well bore whenever desired by running a retrieving tool E into the production tubing C on the end of a wire line or other suitable string (see Figure 4). The retrieving tool includes a body 68 adapted to be received within the retrieving sleeve 38, which is provided with a pilot 69 for reception within the mandrel head 58. This pilot also carries a depending stinger or valve opening rod 70 secured to it in suitable fashion, as by a set screw 71, which extends through the mandrel 36 and engages the large piston 21 to force it downwardly against the action of the spring 33 and move the valve head 19 from its seat 18. The tool body 68 is provided with a slip receiving groove 72 whose base portion forms a slip expander 73 inclined in a downward and outward direction. A slip 74 is received within this groove 72 and is held therein by a retainer screw 75 extending through an elongated slot 76 in the base portion of the slip and threaded into the body 68 of the retrieving tool. The head 77 of this screw engages the base of the slip to pre-

vent its loss from the body, but still permits sliding action of the slip on the expander portion 73 of the body. This slip 74 is provided with external wickers 78, preferably formed as a portion of a helical thread, which are adapted to engage companion internal ratchet threads 79 formed on the interior of the retrieving sleeve 38. When moving the tool downwardly the slip 74 tends to move and remain in an inward position free from engagement with the ratchet teeth 79 on the interior of the retrieving sleeve, but upon upward movement of the wire line and body 68 the expander 73 forces the slip 74 outwardly and causes its wickers 78 to engage the ratchet teeth 79. In effect, the slip and ratchet teeth on the retrieving sleeve form a one-way clutch, which allows downward movement of the body 68 and attached stinger 70 with respect to the retrieving sleeve 38, but prevents their relative upward movement.

The retrieving tool E is lowered through the production tubing C until it enters the mandrel 36 and retrieving sleeve 38. Engagement of the dogs 44 with the end of the lower tubing section 46 prevents downward movement of the latches 42 and retrieving sleeve 38, and allows the weight of the body 68 to be imposed on the stinger 70 to open the valve against the force of the spring 33 and production tubing pressure. This weight also forces the mandrel 36 down to recompress the setting spring 41 and shift the latch holder 50 downwardly from the latch dogs. The latch holder 50 is held in this lower position and the valve maintained open by the clutching engagement of the slip 74 with the retrieving sleeve 38 and engagement of the body 68 with the mandrel head 37. Upward movement of the wire line then elevates the entire mechanism through the production tubing, the inclined surfaces 66 of the latch heads 43 engaging the lower end 47a of each tubing section 47 to be forced inwardly free of the coupling spaces 45 during upward travel of the mechanism. These latches 42 ride along the walls of the tubing sections until the entire device is withdrawn from the tubing at the surface of the well bore. The retrieving tool E can then be withdrawn from the mandrel by unscrewing the body 68 and its slip 74 from the ratchet threads 79 in the retrieving sleeve 38.

For the purpose of facilitating opening of the valve, the valve head 19 may be formed in sections, being provided with an auxiliary or equalizing valve head 80 extending downwardly from a rod extension 81 secured to the valve stem 20 by a coupling 82. The equalizing valve head 80 is adapted to engage an auxiliary valve seat 83 at the lower end of the main valve head 19. When the valves are closed, the auxiliary valve head 80 engages its companion seat 83 on the main valve head 19 and the latter engages its seat 18 on the clamp nut 17. When the valve is to be opened, the first portion of the downward movement of the valve stem 20 disengages the auxiliary valve head 80 from its seat 83 and permits the pressure to equalize on both sides of the main valve head 19 by passing through the clearance space 84 provided between the rod extension 81 and main valve head 19. Continued downward movement of the valve stem 20 causes the coupling 82 to engage the main head 19 and remove it from its seat 18. The provision of the smaller auxiliary valve in connection with the main valve makes it easier for the retrieving tool E to open the passage 34 to upward flow of fluid.

It is apparent from the foregoing description

that the valve is open both while being run into and removed from the production tubing, and, therefore, can readily be moved through the tubing since the fluid therein is by-passed through the open valve and remains substantially undisturbed in the tubing.

As an alternative method of keeping the valve in open position after installation of the device in the tubing, fluid pressure may be supplied from the surface of the well bore, being conducted into the upper end of the cylinder 10 through a separate string of tubing 85 extending downwardly from the top of the bore hole and threaded into the retrieving sleeve 38. The pressure will be transmitted through the fluid in this tubing and through the mandrel 36 into the head end of the cylinder 10, where it will act downwardly on the large piston 21 to shift the valve head 19 from its seat 18. The well flow can then take place as before through the open valve, through the annular space 34 between the valve body 12 and stem 20, and through the ports 13 for upward passage around the tool and the annular space between the inner tubing string 85 and production tubing C to the surface of the well bore. With this arrangement, the pressure acting down on the large piston 21 is independent of the production tubing pressure, and the valve can be opened or closed at will simply by controlling the pressure of the fluid within the inner tubing string 85.

It is detrimental to some wells for its flow to be arrested completely. For wells of this type, the valve head 19 can be so arranged as not to close completely when the well pressure decreases below a predetermined degree. A suitable port 86 may be formed through the clamp ring 17 to allow some fluid to continue to by-pass the valve head 19 and flow through the ports 13 upwardly through the tubing to the surface of the well bore; or the valve stem 20 may be of such length as to leave the valve head 19 slightly spaced from its seat 18 when the large piston 21 is in its uppermost position. By materially decreasing the flow under the last-mentioned conditions, the well can still be controlled at the surface of the well bore, even upon disruption of the surface control valves by natural or man made forces.

A modified form of the invention is disclosed in Figs. 6 and 7. Essentially, the device illustrated in these figures is substantially the same as the other device insofar as the anchoring mechanism B is concerned. It also embodies the principle of the differential areas and predetermined spring tension or compression for controlling operation of the valve. The main difference resides in the provision of a different type of seals for the large and small pistons 21, 27, and also in the provision of an arrangement for readily adjusting the force of the spring 33.

As shown in the drawings, a cup-shaped extensible piston packing 87 has its upper end 88 clamped between the cylinder 10 and cylinder head, and its lower base portion 89 resting upon the head of the large piston 21a. A suitable filler cup or thimble 90 can be inserted in the cup-shaped packing for engagement by the valve opening rods 62, 70 of the running-in and retrieving tools D, E, and thus prevent potential damage to the cup-shaped packing. The piston rod or small piston 27a is also provided with an extensible piston or rod packing 91 whose upper end 92 is clamped to the cylinder 10a by a lower clamp ring 93 engaged by the upper end of a spring housing 94 threaded into the lower end of the cylinder 10a. The lower end 95 of the

small piston packing 91 is clamped to the small piston 27a by a clamp nut 96 threaded on this latter member.

The valve body 12 is threaded into the lower end of the spring housing 94 and forms a seat for the bottom end of the spring 33, whose upper end engages an adjusting nut 97 threaded on the valve stem 20a, which extends upwardly into the spring housing with its upper end engaging the lower end of the small piston 27a. A lock nut 98 is threaded on the upper end of the valve stem 20a to hold the nut 97 in any position of adjustment.

As described in connection with the other embodiment shown in the drawings, the pressure of the fluid in the production tubing acts upwardly over the effective area "s" of the small piston 27a to urge the valve head 19 to closed position, and this force is supplemented by the action of the spring 33, whose compression is predetermined by appropriately threading the adjusting nut 97 on the threaded valve stem 20a. The pressure of the fluid in the production tubing is also acting downwardly on the large piston 21a over its effective area "S," tending to move the piston 21a and valve head 19 downwardly to open and hold the latter in open position. When the pressure in the production tubing decreases below a predetermined value, the valve automatically closes under the action of the spring 33.

The inventor claims:

1. A well flow control device including a body adapted to be disposed within a flow line and having a passage through which well fluid may flow, means for preventing fluid flow longitudinally along the exterior of said body between said body and the flow line surrounding said body, a valve movable by said well fluid toward a position closing said passage, means having a fluid pressure actuatable surface responsive to the action of said well fluid under pressure on the outlet side of said valve for urging said valve to open position to permit flow of fluid through said passage, means having a fluid pressure actuatable surface of less area than said first-mentioned surface and responsive to the action of said well fluid under pressure for urging said valve toward closed position, and means supplementing the force of the fluid pressure on said surface of less area for urging said valve toward closed position.

2. A well flow control device including a body adapted to be positioned within production tubing and having a passage through which well fluid may flow upwardly through the tubing, means for preventing fluid flow longitudinally along the exterior of said body between said body and the production tubing surrounding said body, valve means coacting with said body and movable to positions regulating the flow of fluid through said passage, means for urging said valve means in an upward direction toward closed position, said valve means having an upper fluid pressure actuatable surface responsive to the action of fluid under pressure in said tubing above said device on the outlet side of said valve means for urging said valve means in a downward direction to open position to permit flow of well fluid upwardly through said passage, said valve means also having a fluid pressure actuatable surface of less area than said first-mentioned surface and responsive to the action of well fluid under pressure in said tubing from below said device for urging said valve means upwardly toward closed position, said areas and urging means being proportioned and related to each other as to cause

said urging means to shift said valve means toward closed position upon decrease in tubing pressure above the device from normal to a predetermined value.

3. A well flow control device including a body adapted to be positioned within production tubing and having a passage through which well fluid may flow upwardly through the tubing, means for preventing fluid flow between said body and the production tubing, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, said valve being movable by the pressure of said well fluid toward closed position, means for urging said valve in an upward direction toward closed position, and fluid operated means responsive to fluid pressure in the production tubing above said device on the outlet side of said valve for urging said valve downwardly toward open position to permit upward flow of fluid through said passage.

4. A well flow control device including a body adapted to be positioned within production tubing, means for preventing flow of fluid between said body and the production tubing, said body having a passage through which well fluid may by-pass upwardly around said flow preventing means for upward passage between said body and tubing, a valve coacting with said body and movable to positions regulating the flow of well fluid through said passage, means for urging said valve in an upward direction toward closed position, and fluid operated means responsive to the pressure of fluid on the outlet side of said valve and above said flow preventing means for urging said valve downwardly toward open position to permit upward flow of fluid through said passage.

5. A well flow control device including production tubing, a body positioned within said production tubing and having a passage through which well fluid may flow upwardly through the tubing, means for preventing fluid flow between said body and the production tubing, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, means for urging said valve in an upward direction toward closed position, a cylinder secured to said body and spaced laterally from said production tubing, means for feeding fluid into said cylinder, and piston means in said cylinder acted on by the fluid fed into the cylinder and coacting with said valve for urging said valve in a downward direction toward open position to permit upward flow of fluid through said passage and upwardly through said production tubing around said cylinder.

6. A well flow control device including a body adapted to be positioned within production tubing and having a passage through which well fluid may flow, means for preventing fluid flow longitudinally along the exterior of said body between said body and the production tubing, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, means for urging said valve toward closed position, a cylinder secured to said body and having an inlet for the entry of well fluid on the outlet side of said valve, piston means in said cylinder coacting with said valve for urging said valve toward open position to permit flow of fluid through said passage, said piston means having a larger fluid pressure actuatable surface subject to the pressure of the well fluid entering said cylinder through said inlet to urge said valve toward open position, and piston means coacting with said valve and having a smaller fluid pres-

sure actuatable surface subject to substantially the same pressure as the well fluid in said passage for urging said valve toward closed position, said areas of said surfaces and said urging means being proportioned with respect to each other as to cause said urging means to shift said valve toward closed position upon decrease in well pressure from normal to a predetermined lower value.

7. A well flow control device including a body adapted to be positioned within production tubing and having a passage therethrough through which fluid may flow upwardly through the tubing, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, a spring urging said valve in an upward direction toward closed position, a cylinder secured to said body and having an inlet for the entry of fluid from said production tubing on the outlet side of said valve, means for preventing fluid flow longitudinally along the exterior of said body between said body and production tubing, an upper piston in said cylinder exposed to the action of well fluid in said cylinder and inlet, a lower piston exposed to the action of well fluid from below said cylinder, said pistons coacting with said valve so that said upper piston urges said valve toward open position to permit flow of fluid through said passage and said lower piston tends to counteract the valve opening action of said upper piston, said upper piston having a fluid pressure actuatable surface of larger area than the fluid pressure actuatable surface of said lower piston, and said areas of said surfaces and force of said spring being proportioned and related to each other as to cause said upper piston to hold said valve in open position under normal well pressure flow conditions and said spring to shift said valve toward closed position upon decrease in well pressure from normal to a predetermined lower value.

8. A well flow control device including production tubing, a body within said production tubing and having a cylinder extending upwardly therefrom and spaced inwardly from said production tubing, means for preventing flow of fluid between said body and production tubing, said body having a passage through which fluid may by-pass upwardly around said flow preventing means for upward passage through the space between said tubing and cylinder, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, a spring urging said valve in an upward direction toward closed position, an upper piston in said cylinder exposed to the pressure action of the well fluid entering the upper end of said cylinder without being exposed to the pressure action of well fluid below said piston, a lower piston exposed to the action of well fluid from below said cylinder, said pistons coacting with said valve so that said upper piston urges said valve toward open position to permit flow of fluid through said passage and said lower piston tends to counteract the valve opening action of said upper piston, said upper piston having a fluid pressure actuatable surface of larger area than the fluid pressure actuatable surface of said lower piston, and said areas of said surfaces and force of said spring being so proportioned with respect to one another that the pressure of the well fluid flowing through the device under normal well flow conditions will act on said pistons to counteract the force of said spring to hold the valve in open position, said spring shifting said valve toward closed position upon decrease

in the well pressure from normal to a predetermined lower value.

9. A well flow control device adapted to be moved longitudinally through a tubular string, including a body having a passage through which fluid may flow through the tubular string, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, a spring urging said valve toward closed position, cylinder means secured to said body and having a fluid inlet, a piston in said cylinder means acted on by fluid fed into said cylinder means through said inlet and coacting with said valve for urging said valve toward open position to permit flow of fluid through said passage, and a tool releasably connected to said cylinder means for moving said device through said tubular string comprising a rod engageable with said piston for holding said valve open.

10. A well flow control device adapted to be lowered through a tubular string, including a body having a passage through which fluid may flow through the tubular string, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, a spring urging said valve toward closed position, a cylinder secured to said body and having a fluid inlet, a piston in said cylinder acted on by fluid fed into said cylinder through said inlet and coacting with said valve for urging it toward open position to permit flow of fluid through said passage, means secured to said cylinder for anchoring said body and cylinder to said tubular string, a tool releasably connected to said anchoring means for lowering said device through said tubular string comprising a rod engageable with said piston for holding said valve open, and means for holding said anchoring means in retracted position while said device is being lowered through said tubular string.

11. A well flow control device adapted to be secured within a flow line including a body having a passage through which well fluid under pressure may flow, means for preventing fluid flow between said body and the flow line, a valve movable to positions regulating the flow of fluid under pressure through said passage, means having a fluid pressure actuatable surface responsive to the action of fluid under pressure above said passage on the outlet side of said valve and within said flow line for urging said valve to open position to permit flow of fluid through said passage, means having a fluid pressure actuatable surface of less area than said first-mentioned surface and responsive to the action of fluid under pressure within said flow line for urging said valve toward closed position, means supplementing the force of the fluid pressure on said surface of less area for urging said valve toward closed position, said fluid pressure actuatable surfaces and said supplementing means being proportioned and related to one another as to hold said valve in fully opened position until the fluid pressure through said passage decreases substantially below normal to a predetermined value.

12. A well flow control device including a body having a passage through which well fluid may flow, a valve movable to positions regulating the flow of fluid through said passage, means having a fluid pressure actuatable surface and adapted to urge said valve to open position to permit flow of fluid through said passage, means on the outlet side of said valve for imposing static pressure only on said fluid pressure actuatable sur-

face of said urging means to urge said valve to open position, means provided with a fluid pressure actuatable surface of less area than said first-mentioned surface and responsive to the action of fluid under pressure for urging said valve toward closed position, and means supplementing the force of the fluid pressure on said surface of less area for urging said valve toward closed position.

13. A well flow control device including a body having a passage through which well fluid may flow, a valve coacting with said body and movable to positions regulating the flow of fluid through said passage, means for urging said valve toward closed position, a cylinder secured to said body and having an inlet for the entry of well fluid which is spaced longitudinally from said passage, piston means in said cylinder coacting with said valve for urging it toward open position to permit flow of well fluid through said passage, said piston means comprising large and small pistons operatively associated with one another and movable within said cylinder, said large and small pistons being in leakproof relation with respect to said cylinder providing a confined cylinder space therebetween into which said well fluid cannot enter, said large piston being subject to the pressure of the well fluid entering said cylinder through said inlet to urge said valve toward open position and said smaller piston being subject to the pressure of the well fluid above said valve for urging said valve toward closed position, the fluid pressure actuatable areas of said large and small pistons and said urging means being so proportioned with respect to each other as to cause said urging means to shift said valve toward closed position upon decrease in well pressure from normal to a predetermined lower value.

14. A well flow control device including a body having a passage through which well fluid may flow, a valve coacting with said body to regulate flow of fluid through said passage, means for urging said valve toward closed position, a cylinder secured to said body and having an inlet on the outlet side of said valve which is spaced longitudinally from said passage, first piston means in said cylinder coacting with said valve for urging said valve toward open position to permit flow of fluid through said passage, said first piston means having a fluid pressure actuatable surface subject to fluid pressure entering said cylinder through said inlet to urge said valve toward open position, means preventing the well fluid from acting upon said first piston means to urge said first piston means in the opposite direction such as would cause said valve to move toward closed position, and second piston means coacting with said valve and having a smaller fluid pressure actuatable surface than said first piston means subject to substantially the same pressure as the well fluid in said passage for enabling said valve to move toward closed position.

15. A well flow control device adapted to be lowered through a tubular string, including a body having a passage through which fluid may flow through the tubular string, valve means secured to and coacting with said body and movable to positions regulating the flow of fluid through said passage, a mandrel secured to said valve means, means on said mandrel for anchoring said mandrel to said tubular string, means on said mandrel for retaining said anchoring means in retracted position while the device is being lowered through the tubular string, said retaining

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means being frictionally engageable with said tubular string, a tool releasably connected to said mandrel for lowering said device through said tubular string, said retaining means being movable to a position with respect to said anchoring means releasing said anchoring means upon upward movement of said tool and mandrel to permit expansion of said anchoring means toward engagement with said tubular string.

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