

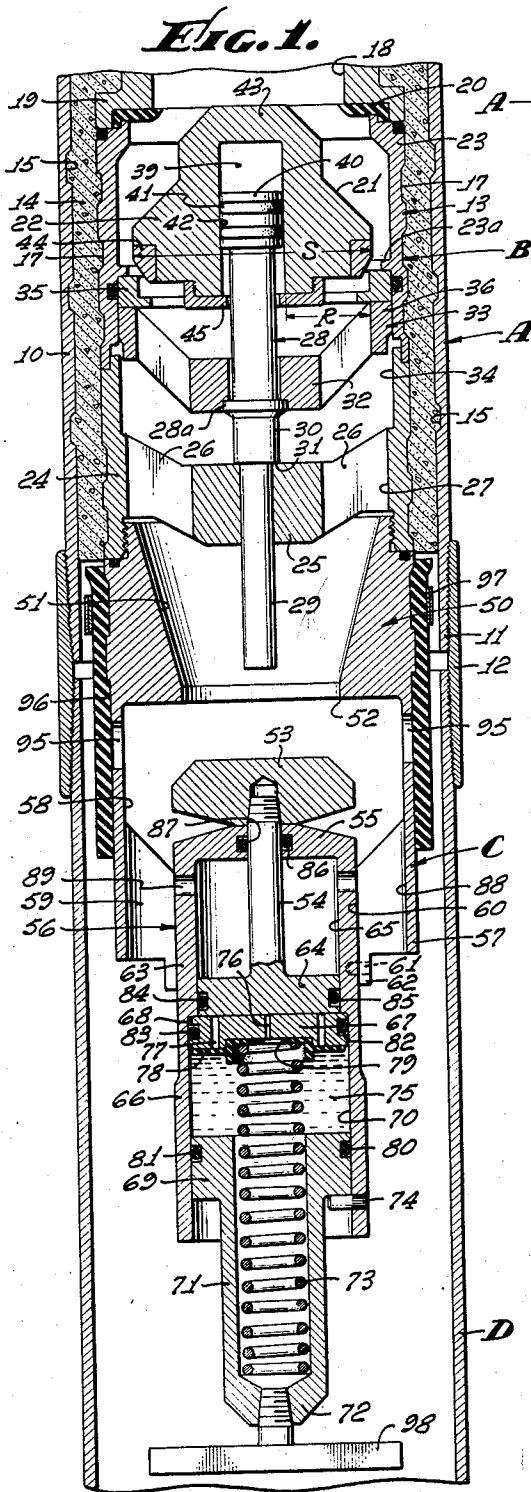
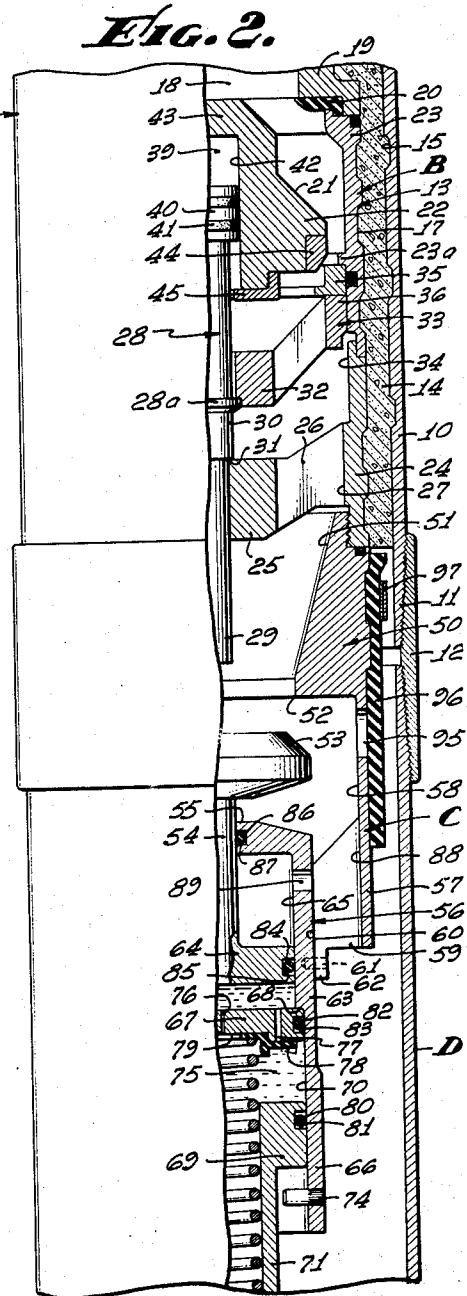
Nov. 29, 1960

E. H. CLARK, JR
BLOWOUT CONTROL VALVE

2,962,099

Filed Jan. 20, 1956

4 Sheets-Sheet 1



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Fig. 5.

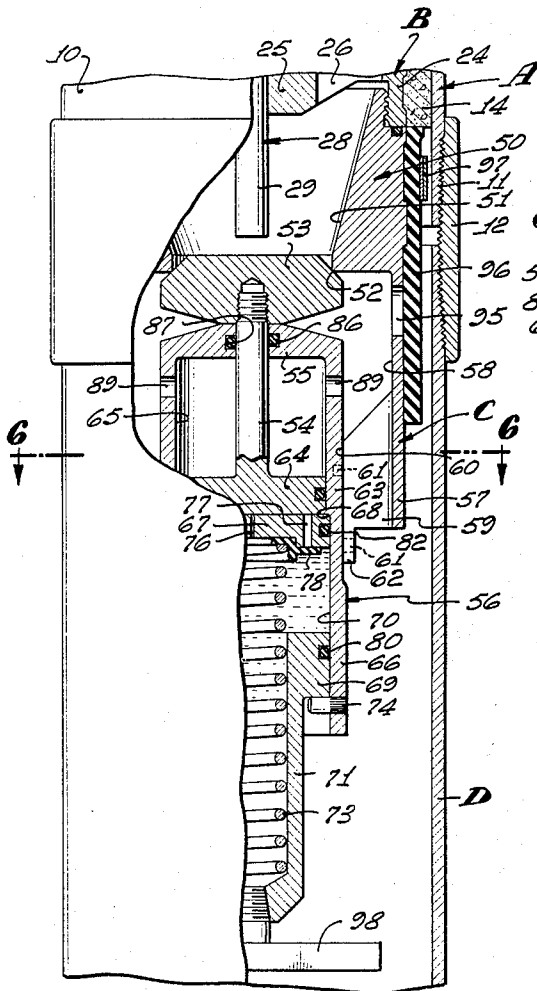


Fig. 6.

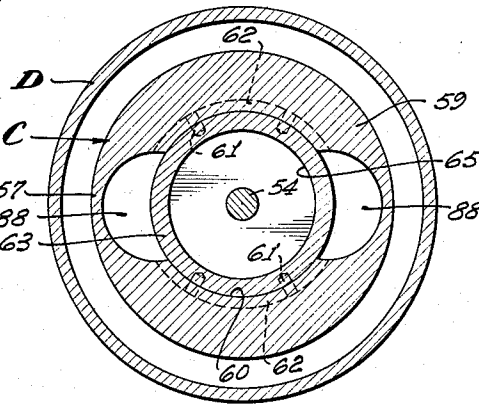
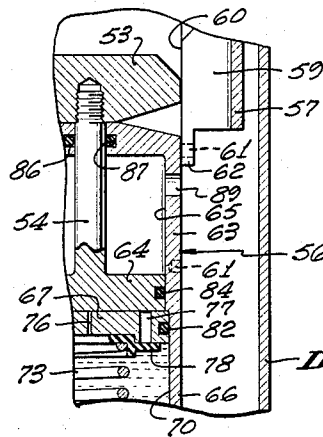


Fig. 7.



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Fig. 8.

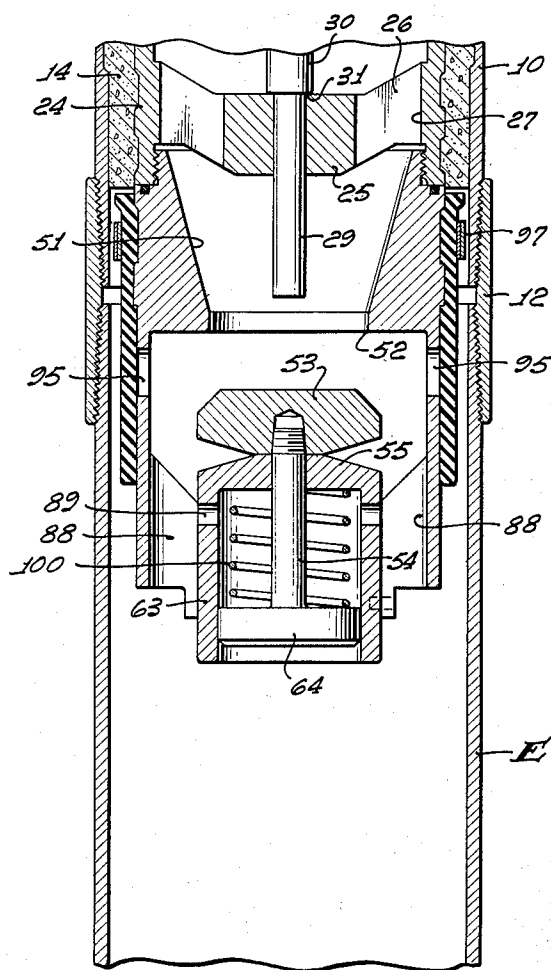
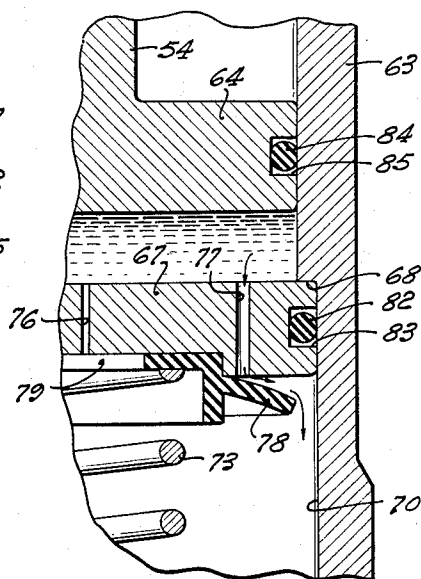


Fig. 9.



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2,962,099

BLOWOUT CONTROL VALVE

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11 Claims. (Cl. 166—224)

The present invention relates to well apparatus, and more particularly to apparatus for controlling the flow of fluids in well casing, drill pipe, tubing strings, and similar tubular strings disposed in well bores.

Apparatus has been proposed for permitting a tubular string, such as a string of well casing, drill pipe, and the like, to fill automatically with the fluid in the well bore as the tubular string is lowered therewithin. Under conditions that might be encountered in some well bores, the upward flow of fluid in the tubular string might occur at an excessive and perhaps uncontrolled rate, which could be difficult to arrest or shut off. An example of such flow is a blowout developing during the lowering of the string of casing in a well bore.

It is an object of the present invention to provide an improved control valve for automatically shutting off upward flow of fluid in the well bore when the rate of flow becomes excessive.

An additional object of the invention is to provide a control valve for automatically shutting off upward flow of fluid in the well bore when the rate of flow becomes excessive, the valve device normally remaining fully open to permit relatively free upward fluid flow therethrough, as well as free downward flow of fluid therethrough. In the event the valve closes, it is easily shifted to open position.

Another object of the invention is to provide a control valve for automatically shutting off upward flow of fluid in the well bore when the rate of flow becomes excessive, and such excessive flow rate continues for a comparatively extended period.

A further object of the invention is to provide apparatus for controllably and automatically filling a tubular string with fluid in the well bore as the tubular string is being lowered therewithin, in which the flow of the well bore fluid into the tubular string is automatically shut off in the event of the flow reaching an excessive rate. The apparatus may operate to close the tubular string only upon the continuation of the excessive flow rate for an extended period, as distinguished from excessive flow rates existing momentarily, or for only a few seconds.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a longitudinal section through an apparatus embodying the invention, with the parts in one operating condition;

Fig. 2 is a combined side elevational and longitudinal

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sectional view of the apparatus shown in Fig. 1, with the parts in another operating position;

Fig. 3 is a view similar to Figs. 1 and 2, disclosing the control valve in closed position;

Fig. 4 is a view similar to Fig. 2, illustrating the upper portion of the apparatus in another operating position;

Fig. 5 is a combined sectional and side elevational view, illustrating the shut-off valve device in another operative position;

Fig. 6 is a cross-section taken along the line 6—6 on Fig. 5;

Fig. 7 is a fragmentary longitudinal section through the lower control apparatus, with its parts occupying another relative position;

Fig. 8 is a longitudinal section through another embodiment of the invention;

Fig. 9 is an enlarged fragmentary longitudinal section through a portion of the lower control apparatus.

The apparatus is disclosed in the drawings as being incorporated in a casing collar A adapted to form part of a casing string to be disposed in a well bore. It includes an upward device B for automatically allowing fluid to flow upwardly into the casing string under control as the casing string is being lowered through the fluid in the well bore, and a lower device C for automatically shutting off such upward flow of fluid in the event its velocity exceeds a safe limit, which might be due to a blowout condition, or the like, developing in the well bore. Although the lower device C will be described in combination with the upper device B, it can be used alone or with other specific apparatus in controlling flow of fluid in well casings, drill pipe, tubing, and the like, disposed in well bores.

As shown, the casing collar A includes an outer tubular member 10 which may have an upper threaded box (not shown) threadedly secured to the lower end of an adjacent upper casing section (not shown), and a lower threaded pin 11 secured to a coupling 12 threaded onto the upper pin end of an adjoining lower casing section D. The upper valve device B is disposed within the tubular member 10. This device is of the type which will allow the fluid in the well bore to flow upwardly into the casing string while the latter is being lowered in the well bore, but when the casing string has been lowered to the desired extent in the well bore, the valve device or mechanism B can be placed in a condition in which it can preclude upward flow of fluid in the well casing, while permitting fluid to be pumped down through the well casing for discharge from a point below the valve mechanism.

The valve mechanism B is constituted by an outer housing or valve body 13 which is secured to the tubular member 10 through the agency of an intermediate cementitious plug 14. This plug is inseparably united to the tubular member by providing internal longitudinally spaced circumferential grooves 15 therein, in which the cementitious material is cast. The outer housing 13 is also provided with longitudinally spaced, circumferential external grooves 17 in which the cementitious material is cast. The upper end of the housing 13 and cement plug 14 has a passage 18 therethrough through which fluid can flow.

For convenience of assembling the apparatus, the valve housing or body 13 is made in several sections. Thus, an upper section 19 is disposed in the cementitious plug and abuts an intermediate generally cylindrical housing member 23, clamping a seal ring and seat 20 therebetween adapted to be engaged by an upwardly facing tapered surface 21 on a valve head 22 when the latter is permitted to move upwardly to a sufficient extent, as described hereinbelow. The intermediate section 23 abuts a lower housing section 24, in the form of a spider having a central hub 25 connected to the outer portion of the

lower section 24 by a plurality of circumferentially spaced ribs 26, these ribs defining openings 27 through which fluid can pass.

A valve stem or guide 28 has its lower portion 29 slidable through the spider hub 25, this stem having an intermediate enlarged portion 30 providing a downwardly facing shoulder 31 that initially rests on the upper end of the hub 24, to prevent downward movement of the valve stem or guide 28. Upward movement of the valve stem or guide is initially prevented by piloting the upper portion of the enlarged stem section within the hub 32 of a holding or stop spider 33 slidably engageable with the cylindrical walls 34 of the intermediate and lower housing sections 23, 24. An annular valve seat 35 rests upon the outer portion 36 of the holding spider, this seat being prevented from moving in an upward direction by engaging a flange 23a extending inwardly from the intermediate housing section 23.

It will be noted that the hub 32 of the holding spider rests upon an upwardly facing shearable flange 28a of the valve guide 28. In view of such engagement, the valve guide 28 is prevented from moving upwardly by the holding spider 33, and this spider, in turn, is prevented from moving upwardly within the housing 13 by virtue of its engagement with the valve seat 35, that, in turn, engages the housing flange 23a. Similarly, the valve seat 35 cannot move downwardly of the housing by engaging the holding spider 33, and the latter cannot move downwardly of the housing by virtue of its engaging the shearable flange 28a, the downwardly facing shoulder 31 of the latter engaging the lower spider 24. With the parts arranged in this fashion, the valve guide 28, upper spider 33 and valve seat 35 are initially prevented from moving in either longitudinal direction. The valve head or member 22, however, can move both in an upward and downward direction with respect to the valve guide 28 and the valve seat 35. This valve head is disposed between the upper and lower seats 20, 35 and is adapted to selectively engage these seats.

The valve head 22 has a central downwardly opening bore 39 to receive the upper piston portion 40 of the valve stem or guide 28. The bore constitutes a cylinder in which the piston is slidable, the piston preferably carrying one or more piston rings or side seals 41 sealingly engaging the inner wall 42 of the bore or cylinder, to prevent the well bore fluid from entering the cylinder 39 above the piston 40. The cylinder above the piston is thereby maintained free of well bore fluid, and will initially contain air at substantially atmospheric pressure. The upper portion of the valve head 22 is an end wall 43 constituting a closure for the cylinder or bore 39.

The valve head 22 is movable downwardly to engage its lower portion 44 with the annular valve seat 35. When so engaged, fluid is prevented from passing downwardly between the valve head 22 and seat 35. The valve head 22 can slide upwardly along the piston 40, to allow fluid to flow in an upward direction through the upper and lower spiders 24, 33, and through the valve seat 35, passing around the exterior of the valve head 22, and on up through the central passage 18 into the casing string thereabove. Initially, the valve head 22 is prevented from moving upwardly into engagement with the upper valve seat 20 by a suitable stop element in the form of a ring 45 threaded on the valve head 22 and engageable with the lower end of the piston 40.

When the valve head 22 is engaging the lower seat 35, the fluid in the well casing is acting in a downward direction over the cross-sectional area S of the valve head at its line of contact with the valve seat 35. In view of the closed cylinder 39, which contains air at substantially atmospheric pressure, the fluid under pressure below the valve head 22 is acting in an upward direction across the annular cross-sectional area R of the valve head lying between the inner cylindrical wall 42 of the head and its line of contact with the lower valve seat 35 (Fig.

1). It is evident that the fluid within the well casing above the valve head is acting over a greater pressure effective area than the fluid externally of the well casing and below the valve head 22. Accordingly, the valve head 22 will be shifted downwardly into engagement with its seat when the pressure inside the well casing is lower than the pressure externally of the well casing, the difference in pressure, which corresponds to the difference in hydrostatic heads, being proportional to the ratio of the lower pressure effective annular area R and the upwardly facing pressure effective cross-sectional area S of the valve head.

With the relationship of the parts so far described, the valve head 22 is only effective to move out of engagement from its seat 35, and back into engagement with its seat, to either permit upward flow of fluid into the apparatus or to prevent downward flow of fluid in the apparatus. Such mode of action is desirable during lowering of the casing string through the fluid in the well bore. However, following the arrival of the casing string at the desired depth in the well bore, fluid is to be pumped down through the casing and out through its lower end. When this occurs, the apparatus is operated to allow fluid to be pumped in a downward direction therethrough, and it is also placed in condition wherein the valve head 22 can move upwardly to a sufficient extent to engage the upper valve seat 20 and prevent upward passage of fluid back into the casing string.

To accomplish the purposes just noted, the flange 28a of the valve guide is made disruptable. That is to say, it can be sheared from the main portion of the guide 28, which will then allow the upper spider 33 and the lower seat 35 to drop downwardly within the intermediate and lower housing sections 23, 24 to a substantial extent. The valve head 22 cannot move downwardly as far as the lower seat 35, in view of engagement of its end wall 43 with the upper end of the piston 40. Accordingly, there will be a longitudinal space between the valve head 22 and the lower seat 35 (Fig. 4) through which fluid can pass in a downward direction, the fluid continuing on through the lower seat 35 and through the spiders 33, 24 into the lower portion of the apparatus and on out of the well casing therebelow.

In view of the shearing of the flange 28a from the main body of the guide, the valve stem 28 is no longer restrained against upward movement. Accordingly, should fluid tend to flow upwardly through the casing, it will carry the valve head 22 in an upward direction toward the upper seat 20, the stop ring 45 engaging the lower end of the piston 40 and lifting the valve stem or guide 28 with it to the extent required for the valve head 22 to engage the upper seat 20.

In the operation of the apparatus so far described, the parts are arranged in the manner disclosed in Fig. 1, in which the valve guide 28 is prevented from moving in both longitudinal directions, the lower valve seat 35 being held in its upward position. As the well casing is lowered through the fluid in the well bore, the hydrostatic head of fluid externally of the casing string can act on the downwardly facing surfaces of the valve head 22 to elevate it from its seat 35 to the extent limited by engagement of the stop ring 45 with the lower end of the piston 40. When the head is in this position, it is still prevented from engaging the upper valve seat 20. Accordingly, the fluid in the well bore can flow through the spiders 24, 33 and through the lower valve seat 35, passing around the head 22 and through the upper valve seat 20 into the central passage 18 and the casing string thereabove. When the fluid in the well casing reaches a predetermined level, which will be less than the level of the fluid in the well bore externally of the well casing, such fluid will be effective over the greater upwardly projected area S of the valve head 22, to shift it downwardly into engagement with the valve seat 35, whereupon further upward passage of fluid is precluded. However, as the well cas-

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ing is lowered to greater depths, the valve will again be opened to allow the well casing to fill with additional fluid, in order to maintain the ratio of fluid levels corresponding to the ratio of downwardly facing and upwardly facing areas R, S over which the external and internal fluid pressures are acting.

When the well casing has been lowered to the desired depth in the well bore, the casing string can be filled completely with fluid from the top of the hole, whereupon pressure is applied to this fluid. This pressure acts in a downward direction over the cross-sectional area S of the valve head 22, and also over the annular area of the valve seat 35, these parts exerting a combined downward force on the upper spider 33 and guide flange 28a. When pressure is sufficient, this downward force will shear the flange 28a from the main body of the guide 28, the fluid under pressure within the well casing then being effective to shift the head 22, seat 35 and upper spider 33 downwardly within the housing 13. The upper spider 33 and valve seat 35 can move downwardly to the extent determined by engagement of the upper spider with the lower spider 24. However, the valve head 22 cannot move this great a distance because its end wall 43 engages the upper end of the piston 40, so that a substantial longitudinal space remains between the lower portion 44 of the valve head and the lower seat 35, through which fluid can flow (Fig. 4). The fluid within the well casing can now pass downwardly through the casing collar A, discharging therefrom and then passing in an upward direction through the annulus between the exterior of the well casing and the wall of the well bore. If desired, a charge of cement slurry or corresponding cementitious material may now be pumped down the casing string, passing through and from the casing collar for deposition around and behind the string of well casing.

In the event the pressure within the well casing is relieved and fluid tends to pass back into the well casing, the force of such fluid will carry the valve head 22 and the valve stem 28 in an upward direction until the valve head engages the upper valve seat 20, thereby closing the passage 18 against upward flow of fluid therethrough. The upward movement of the valve head 22 to the extent just indicated is no longer prevented by the engagement of the stop ring 45 with the lower end of the piston 40, inasmuch as the shearing of the flange 28a on the guide 28 has removed the restraint to upward movement of the valve guide or stem 28.

At any time, fluid can be pumped downwardly through the shoe A, the valve head 22 being merely shifted off its upper seat 20, but this head will again reengage this seat in the event upward passage of fluid tends to occur.

During the lowering of the well casing through the fluid in the well bore, excessive pressure conditions, such as those incident to a blowout, might develop in the well bore, the fluid then being capable of flowing at a very high and possibly uncontrolled rate through the upper device B and to the top of the well bore. The valve head 22 might be prevented, by the great preponderance of pressure therebelow, from shifting downwardly into engagement with its companion seat 35, for the purpose of shutting off the flow. To prevent such excessive upward fluid flow, the lower device C has been incorporated in the well casing, which will automatically shut off the flow of fluid in the well casing in an upward direction in the event it becomes excessive. More particularly, the shut-off will only occur if the excessive flow continues for an appreciable period. The lower device C permits downward flow of fluid to occur at any time it is desired, and it will also allow upward flow of fluid to occur, except when such upward flow exceeds a safe and predetermined rate.

The lower device C includes a housing 50 which is threadedly secured to the lower housing section 24 of the upper device B. This housing 50 has a central passage 51 therethrough of relatively large size that is sur-

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rounded by a valve seat 52 adapted to be engaged by companion valve head 53, when the latter moves upwardly to a sufficient extent. This valve head 53 is threadedly, or otherwise, secured to the upper end of a valve stem 54 which projects through the upper end wall or head 55 of a cylinder structure 56 secured, preferably releasably, to the lower depending portion or skirt 57 of the housing 50 surrounding the valve head, with the inner wall 58 of the skirt spaced outwardly from the periphery of the valve head 53, as well as from the periphery of the cylinder structure 56, to a substantial extent. The housing 50 has a lower wall portion 59 extending inwardly from its skirt portion 57 to the cylinder structure 56, the latter being disposed within a central bore 60 in such lower wall, and being releasably secured thereto, as by means of one or more shear pins or screws 61 extending from a flange 62 depending from the lower wall and into the cylinder structure itself.

The valve stem or rod 54 extends within the upper cylinder portion 63 of the cylinder structure, being integral with, or suitably secured to, an upper piston 64 slidable along the upper cylinder wall 65. The cylinder structure also includes a lower cylinder 66 that may be integral with the upper cylinder 63 and separated therefrom by a partition or intermediate wall 67 that may engage a downwardly facing shoulder 68 of the cylinder structure. The valve head 53 is movable downwardly, limited by its engagement with the upper cylinder head 55, at which time its piston 64 will be disposed closely adjacent the partition 67.

The lower cylinder 66 of the structure 56 receives a lower piston 69 slidable along the lower cylinder wall 70, this piston being integral with a depending hollow rod 71 having a closed lower end 72 and adapted to receive a helical compression spring 73, the lower end of which engages the lower end 72 of the rod, and the upper end of which is adapted to exert its force against the partition 67, in order to hold the latter against the cylinder shoulder 68. The spring 73 urges the lower piston 69 in a downward direction within the lower cylinder 66 to the extent limited by engagement of the piston with a suitable stop member 74, such as a limit pin secured to the lower cylinder 66 and extending inwardly thereinto below the lower piston.

The lower cylinder 66 contains a liquid 75, such as oil of the desired viscosity, which preferably completely fills the space between the lower piston 69 and the intermediate partition 67, as well as the hollow rod 71. This liquid, as described hereinbelow, is adapted to be forced through a central choke orifice 76 in the partition 67 into the upper cylinder 63. The area of the choke orifice 76 is relatively small, permitting the liquid 75 in the lower cylinder to be forced through the orifice into the upper cylinder 73 at only a relatively slow rate. When moved into the upper cylinder 73 below the upper piston 64, the liquid forces the upper piston and the valve head 53 in an upward direction rather slowly. However, the liquid can return from the upper cylinder 63 to the lower cylinder 66 in a comparatively rapid manner, passing down through a plurality of relatively large size bleeder holes 77 extending through the partition 67, such liquid deflecting a rubber valve ring 78 bearing against the underside of the partition out of the way, in order to pass into the lower cylinder. The rubber valve ring 78 can seal against the underside of the partition 67 and over the by-pass passages 77 to prevent upward flow of fluid through such passages from the lower cylinder 66 into the upper cylinder 63. The rubber ring valve 78 is maintained in position by causing the upper end of the spring 73 to bear against the inner portion of the ring and hold it against the underside of the partition 67. It is to be noted that there is a full opening 79 through the central portion of the rubber valve annulus 78, to permit fluid to pass in an upward direction through the orifice 76 and into the upper cylinder 63.

Leakage of fluid from and into the lower cylinder 66 past the lower piston 69 is prevented by providing a suitable seal ring 80, such as a rubber O ring, in a ring groove 81 in the piston which slidably and sealingly engages the lower cylinder wall 70. Leakage of fluid around the periphery of the partition 67 is prevented by a suitable seal ring 82, such as a rubber O ring, in a peripheral piston groove 83, the ring sealingly engaging the cylinder wall 70. Similarly, leakage of fluid around the upper piston 64 is prevented by a seal ring 84, such as a rubber O ring, disposed in a piston groove 85 and slidably and sealingly engaging the upper cylinder wall 65. If deemed necessary, a seal may be provided around the rod 54, a suitable seal ring 86, such as a rubber O ring, being disposed in an internal groove 87 in the end wall or head 55 of the cylinder structure and slidably and sealingly engaging the valve stem or rod.

Fluid moving upwardly in the casing is capable of passing through one or a plurality of ports or passages 88 in the lower housing wall 59, such fluid flowing upwardly around the valve head 53 and into the central passage 51 through the housing 50 of the lower device, for continued upward flow through the upper valve device A into the casing sections (not shown) thereabove. These passages 88 communicate with the interior of the upper cylinder 63 through lateral ports 89 extending through the cylinder wall, and preferably disposed at the upper portion thereof.

The combined area through the passages 88 is substantially less than the area around the cylinder below such passages, so that fluid flowing through the passages 88 must move at a substantially greater velocity than the rate of flow of fluid around the lower portion 66 of the valve device. Accordingly, there will be a greater velocity in the fluid passing through the vertical passages 88 and a consequent lesser static pressure of such fluid in such passages than exists in the well casing D around the lower portion of the cylinder structure 56. Inasmuch as the well bore fluid in the upper cylinder 63 above the piston 64 is in communication with the passages 88 through the ports 89, the fluid pressure in the upper cylinder 63 above the upper piston 64 will be less than the fluid pressure acting in an upward direction over the lower piston 69 and its tubular rod 71. Accordingly, as fluid flows upwardly in the well casing around the lower device 66 and through the passages 88, there will be a pressure differential tending to move the lower piston 69 in an upward direction, such upward movement being resisted by the force of the spring 73.

When the velocity of the fluid passing through the passages 88 is sufficiently greater than the velocity of the fluid moving past the lower portion 66 of the device, the pressure below the lower piston 69 will be sufficiently greater than pressure in the upper cylinder 63 above the upper piston 64, to overcome the force of the spring 73, urging the lower piston 69 in an upward direction and forcing the liquid 75 in the lower cylinder 66 upwardly through the choke orifice 76, this liquid under pressure acting on the lower side of the upper piston 64 and moving it upwardly in the upper cylinder 63, to carry the valve head 53 upwardly toward its companion seat 52. The liquid 75 in the lower cylinder can only pass in a relatively slow manner through the choke orifice 76, in view of the small area of the latter, so that a substantial time (which may actually be of the order of several minutes) may be required, depending to some extent upon the viscosity of the liquid in the cylinder structure, before the lower piston 64 will move upwardly in the lower cylinder 63 sufficiently to force enough liquid through the orifice 76 to shift the upper piston 64 within its cylinders 63 the required distance to engage the valve head 53 with its companion seat 52, thereby preventing further upward flow of fluid through the apparatus.

If the fluid velocity in the passages 88 decreases before the valve head 53 engages its companion seat 52, then the

pressure differential acting in an upward direction on the lower piston 69 and its depending rod 71 will likewise decrease, and when it reaches a value less than the force exerted by the spring 73, the latter will shift the lower piston 69 in a downward direction, the liquid 25 in the upper cylinder 63 then flowing in a relatively free manner back through the bleeder ports 77 and orifice 76 into the lower cylinder 66, the valve head 53 moving in a downward direction toward its initial position. The extent of lowering movement of the piston 69 is limited by its engagement with the stop pin 74.

In the operation of the lower device C in conjunction with the upper valve control device B, the lower device will normally be in an open position with its valve head 53 disposed a substantial distance away from its companion seat 52. As the casing string is lowered through the fluid in the well bore, such fluid will pass upwardly through the passages 88, and so long as the velocity of such fluid is insufficient to create a pressure differential between the fluid below the lower piston 69 and the fluid in the upper cylinder 63 great enough to overcome the force of the spring 73, the valve C will remain in a fully open position. The well fluid can then flow in a comparatively unrestricted manner upwardly into and through the upper valve control device B to fill the well casing thereabove. If, however, the fluid begins flowing through the passages 88 at an excessive rate, then the pressure differential referred to will become sufficient to cause the lower piston 69 to move upwardly in the lower cylinder 66 and force the liquid 75 in the lower cylinder through the choke orifice 76 into the upper cylinder 63, to shift the upper piston 64 and the valve head 53 in an upward direction.

In view of the choke orifice 76, a substantial period is required to transfer liquid into the upper cylinder 63 and the excess flow velocity of the fluid in the passages 88 may diminish before there is very great movement of the upper piston valve head 53 in an upward direction. As an example, the excess rate of flow of the fluid through the passages 88 may result from too rapid a dropping of the casing through the fluid in the well bore, but the casing string will then be arrested, to add another casing section at the top of the hole. When the arresting occurs, fluid will continue to flow into the casing limited by the reaching of the fluid therewithin of a level which has a predetermined value lower than the external fluid level. Such level ordinarily will be reached before the lower piston 69 can force sufficient fluid 75 through the orifice 76 into the upper cylinder 63 to elevate the lower piston 64 and valve head 53 sufficiently to engage the latter with its seat 52.

When the excess fluid velocity ceases to exist, the spring 73 returns the lower piston 69 toward its initial lower position, drawing the liquid 75 in the upper cylinder 63 back through the bleeder ports 77 into the lower cylinder 66, the pressure of the liquid in the upper cylinder then forcing the upper piston 64 and the valve head 53 in a downward direction towards their initial positions.

In the event that the excess flow rate continues for a sufficient period, then the pressure differential will continue to act on the lower piston 69 for a sufficient time to shift it upwardly in the lower cylinder 66 and displace enough fluid through the choke orifice 76 into the upper cylinder 63 to cause the valve head 53 to engage its seat 52, at which time further upward flow of fluid is precluded. The predominance of fluid pressure below the valve head 53 will maintain it in engagement with the valve seat 52.

If it is again desired to open the lower valve device C by removing the valve head 53 from its seat 52, this can occur only if the pressure above the valve head 53 exceeds the pressure below. In the specific apparatus illustrated in Figs. 1 to 7 inclusive, this action can occur as a result of suddenly picking up or elevating the entire casing string in the well bore, which will have the effect

of lowering the pressure on the underside of the valve head 53 below the pressure on the upper side of this valve head. The valve head 53 need only move downwardly a slight distance from its seat 52 to equalize the pressure on both of its sides, which then permits the spring 73 to return the lower piston 69 toward its initial lower position, drawing the liquid 75 from the upper cylinder 63, through the bleeder holes 77, back into the lower cylinder 66, to cause the pressure in the upper cylinder above the piston 64 to shift the upper piston 64 and valve head 53 back to its initial position.

After the casing string has been lowered to the desired depth in the well bore, if it is desired to pump fluid in a downward direction through the apparatus, the casing string is filled with fluid and pressure is applied to the upper valve device B, for the purpose of shearing the flange 28a from the upper valve stem 28 and shift the spider 33 and the valve seat 35 downwardly to the position disclosed in Fig. 4, as described above. The upper valve head 22 engages the upper end of the stem piston 40 being prevented from moving downwardly to the same extent as the seat 35 and spider 33. Fluid can then flow around the upper valve head 22, and through the seat 35 and the spider 33 into the lower housing 50, passing around the valve head 53 of the lower device and through the flow passages 88 into the well casing D below the apparatus C.

In the event of there being insufficient area through the passages 88 to insure the proper downward pumping of fluent materials, such as cement slurry and the like, through the well casing, then additional passage area around these passages 88 can be provided. As specifically disclosed, a plurality of relatively large, circumferentially spaced ports 95 is provided through the housing skirt 57 above the passages 88. These ports are normally closed by a back pressure valve 96 in the form of a rubber sleeve, the upper end of the sleeve being suitably secured to the housing 50, as by means of an encompassing metallic band 97, and the lower end being unsecured and adapted to deflect laterally outward away from the housing 50, to permit fluids to pass from the interior of the housing through the auxiliary circulating ports 95 into the rubber sleeve 96, expanding the latter outwardly and passing on downwardly around the housing 50 into the casing D below the control passages 88.

The auxiliary circulating ports 95 will permit fluids passing downwardly of the apparatus to flow there-through, but the valve 96 will prevent fluid flowing upwardly in the apparatus from passing therethrough. Fluid passing upwardly through the well casing and around the apparatus, will cause the sleeve valve 96 to close over the port 95, such fluid being caused to pass through the vertical control passages 88, where the fluid velocity will increase with respect to the velocity of the fluid around the lower portion 66 of the cylinder structure.

As described above, the cylinder structure 56 is releasably secured to the housing wall 59 by the shear pins 61. Such shear pins can have several purposes. In the event of fluid being pumped downwardly through the well casing at a very high rate, sufficient back pressure may be built up above the valve head 53 as to act downwardly on the head and the cylinder structure 56 to shear the pin 61, ejecting the cylinder structure 56, its contents, and the valve head 53 completely out of the housing wall 59, the housing 50 then being fully open (see Fig. 7). When ejected completely from the housing 50, the cylinder structure 56 will drop downwardly in the casing and will probably come to rest upon the casing shoe (not shown). To insure that the central passage through the casing shoe will not be plugged or materially restricted by the ejected portion of the apparatus, a T bar 98 is threadedly secured to the lower end 72 of the tubular rod 71 and this bar will come to rest upon the cementitious or other plug in the shoe, to permit fluid to

pass around the ejected device 56, and then through the central passage in the cementitious shoe plug (not shown).

In the event that a blowout condition tends to occur when the shear screws 61 are still intact, the valve head 53 will move upwardly into engagement with its seat 52. The pressure acting on the cylinder structure 56 from below may be sufficient to shear the pins 61 and shift the cylinder structure in an upward direction until its upper head 55 engages the valve head 53, such as disclosed in Fig. 5. The cylinder structure will engage the head 53 and assist in holding it in leakproof engagement with its companion seat 52.

It is, therefore, apparent that the lower control valve device C of the apparatus is capable of operating to prevent upward flow of fluid in the well casing when the fluid velocity becomes excessive, and such excessive fluid velocity continues for an appreciable period of time. The cylinder structure 56 and the pistons therein, in effect, constitute a time-delay device, which will permit the valve head 53 to engage its seat 52 only when the fluid velocity exceeds a predetermined value for a particular time. Such time can be varied by several factors, including the area of the choke orifice 76, the viscosity of the oil 75, or other liquid, in the cylinder structure, and the resisting force of the spring 73.

The lower valve device C can be used by itself, and without the upper valve control device 8, serving to prevent excessive flow rates in an upward direction through the well casing. It can be incorporated in other types of tubular string disposed in well bores such as in drill pipe and production tubing. When used with drill pipe, the valve C is normally in a fully open position, to permit the drilling mud to be pumped downwardly through the drill pipe without restriction. Should a blowout condition develop, the upward passage of fluid at a sufficient velocity will cause the valve head 53 to engage its seat 52, thereby shutting off the flow of fluid in an upward direction through the drill pipe.

A similar condition may pertain when the apparatus is incorporated in a string of production tubing. In the event the well production tends to flow upwardly through the tubing at an excessive rate, as might occur in the event the connections at the top of a flowing hole are disrupted, then the valve head 53 will engage its seat 52 to stop upward flow of fluid through the tubing.

Once engaged with its seat 52, the valve head 53 can easily be shifted downwardly away from the seat, or to an open position, merely by applying sufficient pressure to the fluid in the tubular string thereabove. Upon being removed from its seat, the valve head 53 will remain in the open position until an excessive fluid flow through the tubular string again occurs.

The lower valve control device specifically shown in Figs. 1 to 7, inclusive, and specifically described above, has a time delaying action. In the event that an appreciable time delay period is not desired, then only the upper cylinder portion 63, upper piston 64, stem 54 and valve head 53 need be used, such as disclosed in Fig. 8. For that matter the seal rings 84, 86 can also be omitted. As shown in Fig. 8, the pressure of the fluid in the tubular string E is acting on the lower side of the piston 64 tending to shift it in an upward direction. At the same time, the pressure in the cylinder 63 is acting in a downward direction on the piston 64. As the velocity of the fluid in the control passages 88 increases with respect to the velocity of fluid immediately below the device, the pressure in the upper cylinder 63 above the piston decreases, producing a pressure differential below the apparatus which shifts the piston in an upward direction and moves the valve head 53 toward engagement with its seat 52. Reliance might be placed on gravity to resist the action of the pressure differential, but it is preferred to place a compression spring 100 in the cylinder 63 between the piston 64 and the upper

cylinder head 55 to require that the pressure differential exceed a value corresponding to the force exerted by the spring before the valve head 53 would be moved into engagement with its companion seat 52. Thus, when upward flow is occurring at or below a predetermined rate, the valve head 53 will remain in its lower position away from its seat 52. When the flow rate exceeds the predetermined value, then the pressure differential created will effect an upward movement of the piston 64 and the valve head 53 against the forces of the spring 100 into engagement with the companion seat 52, to prevent further upward flow of fluid to the tubular string E.

At any time, the valve can be reopened merely by applying sufficient pressure to the fluid in the tubular string above the valve head 53, to shift it downwardly away from its seat 52, the valve head remaining in a downward position until an excessive upward flow rate again is present.

The inventor claims:

1. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to resist fluid flow upwardly in said passage; a cylinder upstream of said outlet passage; means providing a plurality of restricted passages around said cylinder through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; said cylinder having ports communicating with said restricted passages and being in communication with well bore fluid upstream of said restricted passages; piston means in said cylinder between said ports and said well bore fluid upstream of said restricted passages and connected to said valve member to determine the position of said valve member with respect to said outlet passage; and means urging said valve member to a position opening said outlet passage.

2. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage therethrough surrounded by a valve seat through which well bore fluid can flow upwardly into said outlet passage; a valve head movable upwardly into engagement with said seat to restrict upward fluid flow in said passage; fluid actuated means responsive to well bore fluid pressure upstream of said seat to urge said head upwardly toward said seat; restricted passage means through which well bore fluid upstream of said seat must flow upwardly at an increased velocity before flowing into said outlet passage; said restricted passage means communicating with said fluid actuated means to provide a lesser fluid pressure than said upstream fluid pressure acting on said fluid actuated means and tending to urge said head away from said seat; time delay means for retarding the rate at which said fluid actuated means can shift said head toward said seat; and means urging said valve head away from said seat.

3. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to restrict fluid flow upwardly in said passage; restricted passage means through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; a confined chamber communicating with said restricted passage means; piston means in said chamber connected to said valve member and

subject to fluid pressure in said restricted passage means and to well bore fluid pressure upstream of said restricted passage means to determine the position of said valve member with respect to said housing and outlet passage; time delay means for retarding movement of said piston means in a direction to engage said valve member with said housing to restrict fluid flow in said outlet passage; and means urging said valve member to a position opening said outlet passage.

4. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to restrict upward fluid flow in said passage; restricted passage means through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; a confined chamber communicating with said restricted passage means; said chamber having a partition provided with a choke orifice; a first piston in said chamber on the downstream side of said partition connected to said valve member and subject to the pressure of well bore fluid in said restricted passage means; a second piston in said chamber on the upstream side of said partition and subject to well bore fluid pressure upstream of said restricted passage means; a liquid in said chamber and orifice between said pistons; and means urging said valve member to a position opening said outlet passage.

5. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to restrict well bore fluid flow in said passage; restricted passage means through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into outlet passage; a confined chamber communicating with said restricted passage means; said chamber having a partition provided with a choke orifice; a first piston in said chamber on the downstream side of said partition connected to said valve member and subject to the pressure of well bore fluid in said restricted passage means; a second piston in said chamber on the upstream side of said partition and subject to well bore fluid pressure upstream of said restricted passage means; a liquid in said chamber and orifice between said pistons; and spring means urging said second piston in an upstream direction.

6. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to restrict upward fluid flow in said passage; restricted passage means through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; a confined chamber communicating with said restricted passage means; said chamber having a partition provided with a choke orifice; a first piston in said chamber on the downstream side of said partition connected to said valve member and subject to the pressure of well bore fluid in said restricted passage means; a second piston in said chamber on the upstream side of said partition and subject to well bore fluid pressure upstream of said restricted passage means; a liquid in said chamber and orifice between said pistons; said partition having bleeder ports therethrough; check valve means preventing liquid from passing through said

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bleeder ports when said second piston moves toward said partition; and means urging said valve member to a position opening said outlet passage.

7. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to restrict well bore fluid flow in said passage; restricted passage means through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; a confined chamber communicating with said restricted passage means; said chamber having a partition provided with a choke orifice; a first piston in said chamber on the downstream side of said partition connected to said valve member and subject to the pressure of well bore fluid in said restricted passage means; a second piston in said chamber on the upstream side of said partition and subject to well bore fluid pressure upstream of said restricted passage means; a liquid in said chamber and orifice between said pistons; said partition having bleeder ports therethrough; check valve means preventing liquid from passing through said bleeder ports when said second piston moves toward said partition; and spring means urging said second piston away from said partition.

8. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to resist fluid flow upwardly in said passage; a cylinder upstream of said outlet passage; means providing a plurality of restricted passages around said cylinder through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; said cylinder having ports communicating with said restricted passages and being in communication with well bore fluid upstream of said restricted passages; piston means in said cylinder between said ports and said well bore fluid upstream of said restricted passages and connected to said valve member to determine the position of said valve member with respect to said outlet passage; and spring means resisting movement of said piston means in a direction shifting said valve member into engagement with said housing.

9. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to resist fluid flow upwardly in said passage; a cylinder upstream of said outlet passage; means providing a plurality of restricted passages around said cylinder through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing in to said outlet passage; said cylinder having ports communicating with said restricted passages; piston means in said cylinder

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between said ports and said well bore fluid upstream of said restricted passages and connected to said valve member to determine the position of said valve member with respect to said outlet passage; time delay means for retarding the rate at which said piston means can shift said valve member into engagement with said housing; and means urging said valve member to a position opening said outlet passage.

10. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in the well bore and extending to the top of the well bore and including a housing having an outlet passage through which well bore fluid can flow upwardly into the portion of the tubular string thereabove; a valve member adapted to engage said housing to resist fluid flow upwardly in said passage; a cylinder upstream of said outlet passage; means providing a plurality of restricted passages around said cylinder through which well bore fluid upstream of said outlet passage must flow at an increased velocity before flowing into said outlet passage; said cylinder having ports communicating with said restricted passages and being in communication with well bore fluid upstream of said restricted passages; said cylinder having a partition upstream of said ports and provided with a choke orifice; a first piston in said cylinder on the downstream side of said partition connected to said valve member and subject to the pressure of well bore fluid in said restricted passages; a second piston in said cylinder on the upstream side of said partition and subject to well bore fluid pressure upstream of said restricted passages; a liquid in said cylinder and orifice between said piston; said partition having bleeder ports therein; check valve means preventing liquid from passing through said bleeder ports when said second piston moves toward said partition; and spring means urging said second piston away from said partition.

11. In combination: a well bore having fluid therein; a tubular string adapted to be lowered through the fluid in a well bore and extending to the top of the well bore and including a tubular member; means in said tubular member for shutting off upward flow of fluid in the tubular string, said shutting off means including a valve and fluid actuated instrumentalities connected to said valve and responsive to the fluid flowing upwardly in the tubular member reaching a predetermined velocity for shifting said valve to closed position, time delay means for retarding movement of said fluid actuated instrumentalities in shifting said valve to closed position; and means urging said valve to open position.

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