United States Patent [19]

Young

[11] **3,831,632**

[45] **Aug. 27, 1974**

[54] **REMOTE CONTROLLED SAFETY VALVE**

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[22] Filed: **Sept. 14, 1973**

[21] Appl. No.: **398,260**

Related U.S. Application Data

[63] Continuation of Ser. No. 235,988, March 20, 1972, abandoned.

[52] **U.S. Cl.** **137/624.13**, 137/39, 137/460, 137/514.7, 137/599, 166/224, 251/16

[51] **Int. Cl.** **F16k 17/34**, E21b 33/00

[58] **Field of Search** 137/460, 514.3, 514.5, 137/514.7, 517, 624.13; 251/16; 166/224

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[57] **ABSTRACT**

An illustrative embodiment of a downhole safety valve apparatus to control a well in the event of a surface disaster, includes a valve actuator moved in one direction toward valve closing position in response to the normal rate of flow of production fluids, a metering system to retard movement of the valve actuator so that a predetermined time interval must lapse before closure occurs, and a spring that operates during a temporary reduction in flow rate below the normal rate to move the valve actuator in the opposite direction, so that successive reductions in flow rate, one during each predetermined time interval, maintain the safety valve in open position, and the absence of a reduction in flow rate during said time interval enables the valve to close.

13 Claims, 3 Drawing Figures

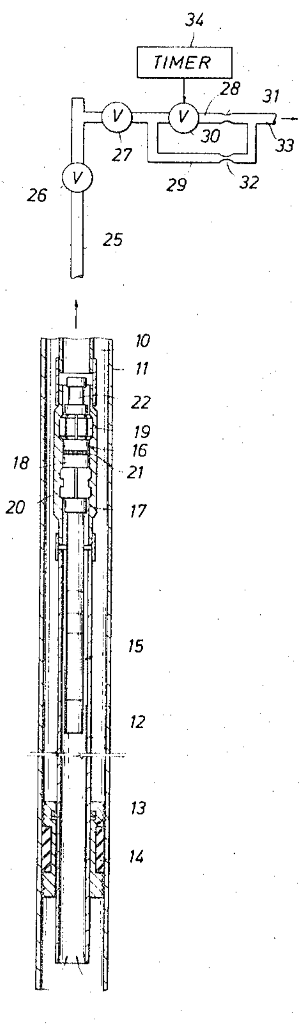


FIG. 1

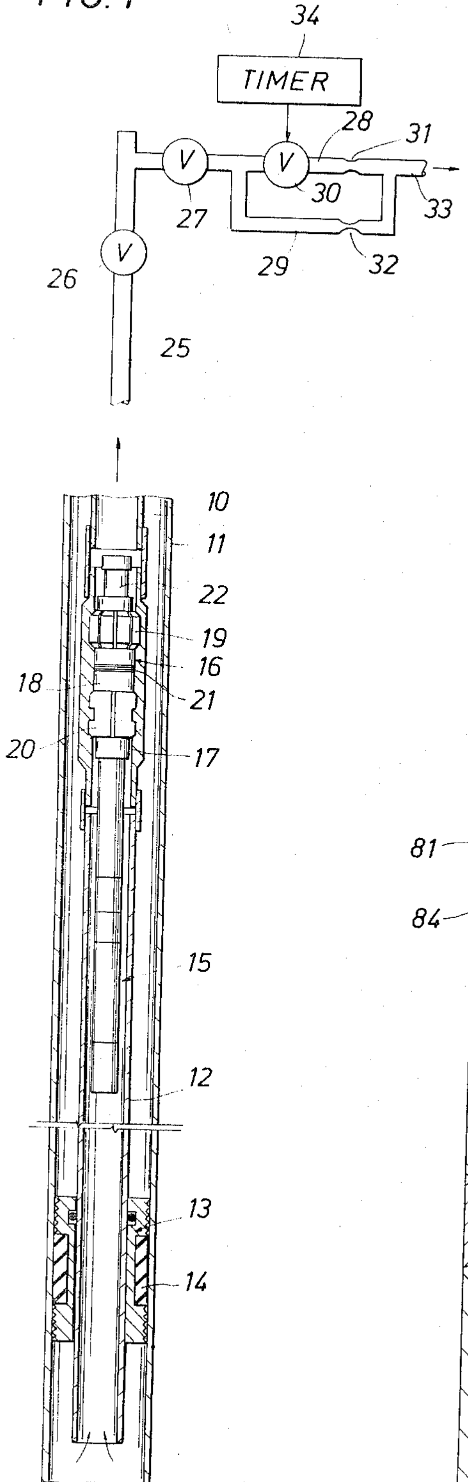


FIG. 2A

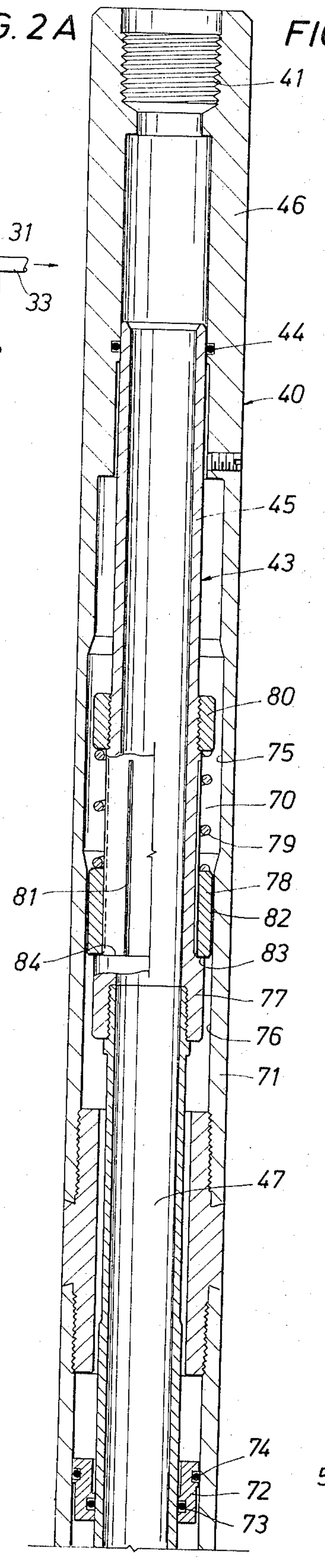
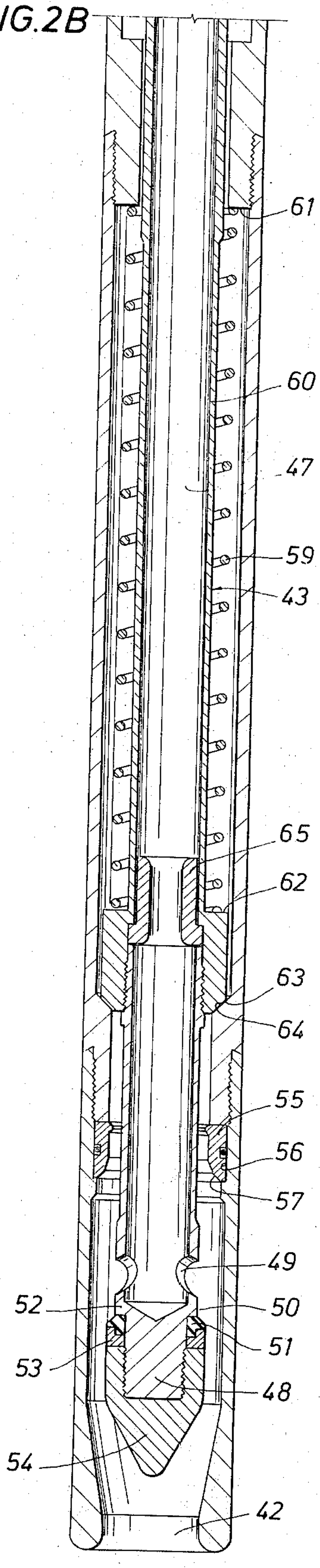


FIG. 2B



REMOTE CONTROLLED SAFETY VALVE

This application is a continuation of application Ser. No. 235,988, filed Mar. 20, 1972 now abandoned.

This invention relates generally to well control valves, and move specifically to a downhole safety valve for automatically shutting in a producing well in the event of surface disaster.

Existing safety valve systems for the prevention of catastrophic blowouts and pollution in offshore wells are generally considered to be inadequate. The so-called velocity sensitive safety valve is a spring loaded device that senses the condition of excessive flow rate due to disruption or leakage of flow lines at the surface, and closes in response to such excessive flow rate. These devices, although having the feature of simplicity in structure and operation, are not usable where the normal flow rate of a formation is at or near its maximum, since an excess of flow rate over and above this value is required to operate the valve. Moreover, where a well has been produced for some period of time the bottom hole pressure may be reduced to a point where the maximum flow under blowout conditions develops insufficient pressure drop across the valve to cause closure. Of course this type of safety valve is useless if the valve element fails to close. Another fairly common system is the surface controlled, hydraulically actuated subsurface safety valve which is more reliable than the velocity sensitive device, since it can be controlled directly from the surface. However, the cost of installation of this system in existing wells can be quite prohibitive in many cases, due primarily to the necessity for killing the well, pulling the tubing and installalling a separate piping string for pressure communication to the valve to enable hydraulic actuation thereof. Furthermore, in so-called "tubingless" completion wells, it is impossible to install this type of a system because the production string cannot be removed.

The principal object of this invention is to provide a new and improved downhole safety valve system that is simple and reliable and can be controlled from the surface without the use of a separate pressure control line.

This and other objects are attained in accordance with the concepts of the present invention through the provision of a safety valve apparatus that includes a valve means adapted for downhole installation in the production string of either a new or an existing well. The valve means comprises a valve element that moves upwardly toward closed position against the force of a spring, upward movement being due to a net upward force developed by the flow of production fluids through a flow restriction in the valve element. A hydraulic means is provided to retard or delay movement of the valve element, so that under normal flow conditions a known period of time is required for the valve to close. A control system is provided at the surface for periodically reducing the flow rate at a set time interval of lesser duration than the above-mentioned time period, whereupon the spring force exceeds the upward force due to the reduced flow rate, and shifts the valve element to its lowermost position. Then normal flow rates are resumed. As long as the flow rate is periodically reduced at the surface, the safety valve remains open. However, if due to surface disaster the flow is not periodically reduced, the valve element will continue to move upwardly until it reaches the closed condition and shuts in the well.

The present invention has other objects and advantages which will become more clearly apparent in connection with the following detailed description of a preferred embodiment, taken in conjunction with the appended drawings in which:

FIG. 1 is a schematic view of a safety valve installed in a well with surface control equipment; and

FIGS. 2A and 2B are longitudinal sectional views, with portions in side elevation, of a safety valve apparatus in accordance with the present invention, FIG. 2B forming a lower continuation of FIG. 2A.

Referring initially to FIG. 1, both the downhole and surface installations are shown schematically. The well bore 10 is lined with casing 11 and traverses the earth formation being produced. A production string of tubing 11 extends from the top of the well bore downwardly through a typical production packer 13 having a packing element 14 that seals off the producing interval from the well casing thereabove. Well fluids enter the casing 11 below the packer 13 through perforations (not shown) and pass upwardly through the tubing string 12. At a suitable downhole location in the tubing string 12, usually above the packer 13, a safety valve 15 in accordance with the principles of the present invention is shown attached to the lower end of a conventional wireline setting and retrieving mandrel assembly 16 that is seated in a landing nipple 17. The mandrel 18 carries locking dogs 19 and locator keys 20 to either side of seal packing rings 21, and the upper end of the mandrel 18 is provided with a running and retrieving neck 22. The details of construction of the setting mandrel assembly 16, as well as the procedures for running and retrieving the assembly on wireline, are well known to those skilled in the art and form no part of the present invention. Moreover, the safety valve of the present invention can be readily installed in a production string where a landing nipple has not been previously positioned, through use of a small size hook-wall packer of conventional construction. Of course it will be appreciated that the manner and means by which the valve is installed are not limitive.

The upper portion of FIG. 1 is a schematic representation of one arrangement of surface equipment that can be used to remotely control the safety valve 15 of the present invention. The flow conduit 25 may be visualized as a portion of a conventional Christmas tree installation having a master valve 26 and a wing valve 27. Downstream of the wing valve 27 the flow conduit has separate branches 28 and 29 with one branch being provided with a flow control valve 30 and a flow choke 31, the other branch 29 also having a flow choke 32 of smaller orifice size than the choke 31. Downstream on the two chokes 31 and 32 the conduit branches are joined to a flow line 33. The control valve 30 is arranged to be automatically closed at periodic intervals of time in response to the action of a timer 34 as will be more fully described hereafter. When the valve 30 is in closed position, all of the production flow from the well is directed through the small choke 32 to substantially reduce the rate of flow from the formation. While the valve 30 is open, however, flow from the well is through both chokes at a cumulative normal rate.

Turning now to FIGS. 2A and 2B for a detailed presentation of a preferred embodiment of a safety valve apparatus is in accordance with the present invention, and outer housing member 40 is generally tubular in form and has internal threads 41 at its upper end for connection with the lower end of the setting mandrel 18. The lower end of the housing member 40 is open to fluid flow at 42. An elongated tubular inner member 43 is sealingly slidable within the housing member 40 between a lower position as shown, and an upper position, fluid leakage being prevented by a seal ring 44 located between the upper portion 45 of the inner member and the upper end section 46 of the housing member. The lower end of the central bore 47 of the member 43 is closed by a transverse section 48, and several side ports 49 communicate the bore 47 with the annular space 50 outside. A suitable valve seal 51 is mounted externally of the member 43 below an outwardly directed shoulder 52 thereon, the seal ring being held in place by a retainer 53 and a nose piece 54 that is screw threaded onto the lower end of the member 43.

A valve seat ring 55 is retained within an internal annular recess 56 in the housing member 40. The seat ring 55 provides a seat surface 57 that faces downwardly and is arranged to be engaged by the seal ring 51 upon upward movement of the inner member 43 within the housing member 40. A coil compression spring 59 surrounds a portion 60 of the member 43 and reacts between a downwardly facing internal shoulder 61 on the housing member 40 and an upwardly facing shoulder 62. The spring 59 is selected to have a known spring force and continuously presses the valve member 43 toward its lower position shown in FIG. 2 where stop shoulders 63 and 64 limit downward movement.

To provide an upward force for moving the inner member 43 upwardly to a position where the valve seal 51 engages the seat 57, a flow restriction in the form of a choke bean 65 is fixed within the bore 47 of the member 43. As production fluids pass through the bean 65, a pressure drop is developed and the greater pressure below the restriction acts upwardly on the member 43 tending to force it upwardly. It will be appreciated that when the upward force due to pressure drop across the bean 65 is greater than the downward force afforded by the spring 59, the inner member 43 will move upwardly toward closed position. Upward movement is delayed or retarded, however, by a hydraulic metering system shown in detail in FIG. 2A.

An annular enclosed chamber 70 is provided between the upper portion 45 of the inner member 43 and the surrounding portion 71 of the housing member 40, the chamber being sealed at its upper end by the seal ring 44 and at its lower end by a floating balance piston 72 carrying internal and external seals 73 and 74. The chamber 70 is adapted to be filled with a suitable hydraulic fluid such as silicone oil, and the balance piston 72 functions to transmit the pressure of well fluids to the hydraulic fluid. The outer wall of the chamber has stepped diameter wall surfaces 75 and 76 with the lower wall surface being formed on a lesser diameter as shown. The upper portion 45 of the inner member 43 has an outwardly directed shoulder 77 above which an annular metering piston 78 is movably arranged, the piston 78 being pressed downwardly against the shoulder 77 by a coil spring 79 whose upper end engages a nut 80 threaded onto the member 43. One or more grooves 81 extend longitudinally in the outer wall surface of the inner member 43 from a location just above the shoulder 77 to a location just below the nut 80.

In the lower position of the inner member 43 within the housing member 40, the metering piston 78 is within the lower portion of the chamber 70 and is sized and arranged to provide with the wall surface 76 a restricted leak path 82 for the passage of hydraulic fluid from above the piston into the chamber therebelow. The lower face 83 of the piston 78 seats against the upper face 84 of the shoulder 77 to prevent passage of hydraulic fluid downwardly through the grooves 81. Thus the inner member 43 can move upwardly within the housing member 40 only at a very slow and controlled rate as fluid leaks past the metering piston 78, the delay or retardation of upward movement being effective until the metering piston passes into the larger diameter upper portion of the chamber 70, whereupon there is substantial clearance between the outer surface of the metering piston 78 and the chamber wall 75. Then the inner member 43 can move quickly upwardly over the final portion of its movement toward closed position. On the other hand, the inner member 43 can move downwardly quite rapidly to open position without retardation because the metering piston 78 moves away from the shoulder 77 to allow flow of hydraulic fluid through the grooves 81.

In operation, the safety valve apparatus 15 is assembled and arranged as shown in the drawings and is positioned in the production tubing 12 by wireline or other well known running and positioning techniques. The well is put on production, and the production flow passes through the end opening 42 of the housing member 40 and into the bore 47 of the inner member 43 via the annular space 50 and the side ports 49. As the flow passes through the choke bean 65, an upward force is produced due to pressure drop thereacross, the magnitude of the force being a function of the pressure drop and the difference between the cross sectional area circumscribed by the seal ring 44 and the area through the throat of the choke bean 65. The spring 59 is selected to provide a spring force such that under the desired or normal flow rate from the well, the upward force due to flow exceeds the spring force, providing a net upward force that causes the inner member 43 to move upwardly. Upward movement, however, is at a slow and controlled rate due to the action of the hydraulic metering system as previously described. By way of example, and not limitation, the time period during which the inner member 43 would move completely upwardly to a position where the valve seal 51 engages the seat 57 might be 8 to 10 minutes.

At the surface, the production flow downstream of the wing valve 27 passes through the branch conduits 28 and 29 with their respective chokes 31 and 32 and into the flow line 33, the valve 30 being normally open. At periodic time intervals however, for example every 4 to 5 minutes, the timer 34 causes the valve 30 to close, forcing all the production flow through the branch 29 and the smaller choke 32. This reduces the rate of flow substantially, and correspondingly reduces the rate of flow of production fluids through the safety valve 15. At reduced flow rates, the upward force on the inner member 43 is reduced to a value less than the force of the spring 59, whereupon the inner member 43 moves downwardly to its lowermost position, such downward movement occuring rather quickly since the metering system does not impede movement in this direction. After an appropriate time lapse, say 10 to 20 seconds, the timer causes the valve 30 to open again so that normal flow resumes. The foregoing cycle is continuously repeated during normal production operations for the well.

It will be apparent that should the timer 34 fail to close the valve 30 for any appreciable time interval in excess of the normal open period, the inner member 43 will move completely upwardly to a position where the valve seal 51 engages the seat 57 to shut in the well. The timer itself is coupled to various surface sensors (not shown) that sense various disaster conditions such as heat due to fire, acceleration due to collision, and pressure loss due to leakage, pursuant to which the timer is disabled and will fail to initiate closing of the valve 30. Of course if the timer itself is obliterated, or the entire wellhead assembly, in any such event the safety valve 15 will close in a short time and kill the well.

It will also be appreciated that the operability of the safety valve 15 can be checked at any time by purposely disabling the timer 34. After closure, the safety valve 15 is reopened by applying pressure to the tubing string 12 sufficient to create a balanced condition, whereupon the spring 59 forces the inner member 43 downwardly to open position. Then normal production operations are resumed.

Certain changes or modifications may be made in the disclosed embodiment without departing from the inventive concepts involved. For example, a ball valve that opens and closes in response to longitudinal movement of the inner member 43 can be used. Other obvious modification will also be apparent to those skilled in the art. Therefore it is the aim of the appended claims to cover all such changes or modifications falling within the true spirit of the present invention.

I claim:

1. A safety valve apparatus comprising: a valve actuator movable longitudinally within a housing member, said valve actuator and housing member defining a fluid flow passage; normally open valve means responsive to movement of said valve actuator in one longitudinal direction for closing said flow passage; first means responsive to a normal rate of fluid flow through said passage for moving said valve actuator in said one direction; means for controlling the rate of movement of said valve actuator in said one direction so that movement to closed position occurs during a predetermined time interval; second means active during a reduction in fluid flow rate below said normal rate for causing movement of said valve actuator in the opposite longitudinal direction to maintain said valve means open; and means for periodically reducing the rate of flow of fluids through said passage to a rate less than said normal rate, each time period between rate reductions being of lesser duration than said predetermined time interval to enable cyclical movement of said valve actuator in alternate opposite directions, whereby said valve means is maintained open unless and until there is an absence of a reduction in flow rate for a time period greater in duration than said predetermined time interval.

2. The safety valve apparatus of claim 1 wherein said controlling means includes piston means coupled to said valve actuator and disposed within cylinder means in said housing member, and a flow course for metering the flow of a hydraulic fluid from one side of said piston means to the other side thereof during movement in said one direction.

3. The safety valve apparatus of claim 2 wherein said flow course is provided by an annular clearance space between an outer peripheral surface of said piston means and an adjacent wall surface of said cylinder means; and further including means for enabling unrestricted flow of hydraulic fluid from said other side of said piston means to said one side during movement in said opposite direction.

4. The safety valve apparatus of claim 1 wherein said first means comprises a flow restriction in said valve actuator for creating a pressure drop, said pressure drop developing a force tending to move said valve actuator in said one longitudinal direction, and wherein said second means comprises a spring with a selected spring force tending to shift said valve actuator in the opposite longitudinal direction.

5. The safety valve apparatus of claim 1 wherein said valve means comprises an annular seat surface on said housing member and a companion seal element on said valve actuator, said valve actuator having at least one laterally extending flow port located upstream of said seal element.

6. A safety valve apparatus comprising: an inner member movable within an outer member between first and second longitudinally spaced positions, said members providing a fluid passageway; valve means on said members for closing said passageway in said second position; means responsive to a predetermined normal rate of flow of fluids through said passageway for causing movement of said inner member from said first position toward said second position; delay means to retard said movement over a preselected time period; shifting means active during a temporary reduction in flow rate to a value below said predetermined normal rate for moving said inner member back to said first position; and means for periodically reducing the rate of flow of fluids through said passageway to a rate less than said normal rate, the time periods between flow rate reductions each being normally of lesser duration than said preselected time period to enable said shifting means to continue to intermittently move said inner member back to said first position and thereby prevent closure of said valve means, the absence of a periodic reduction in flow rate for a time of greater duration than said preselected time period enabling said inner member to be moved to said second position where said valve means closes said passageway.

7. The safety valve apparatus of claim 6 wherein said delay means comprises a piston means on said inner member movable within an enclosed cylinder means in said outer member, said cylinder means being filled with a hydraulic fluid, and a flow course for metering hydraulic fluid from one side of said piston means to the other as said inner member moves toward said second position.

8. The safety valve apparatus of claim 7 further including means for enabling unretarded movement of said inner member toward said first position.

9. The safety valve apparatus of claim 7 wherein said flow course for metering hydraulic fluid is provided by an annular clearance space between the outer peripheral surface of said piston means and the adjacent wall surface of said cylinder means.

10. The safety valve apparatus of claim 6 wherein said movement causing means includes a flow restriction means within said inner member, said flow restriction means creating a pressure drop, the greater fluid pressure upstream of said flow restriction developing longitudinally directed force to cause movement of said inner member toward said second position.

11. The safety valve apparatus of claim 10 wherein said shifting means includes a coil spring pressing between opposed shoulders on said outer member and said inner member, said coil spring exerting a bias force on said inner member tending to cause movement thereof back to said first position.

12. The safety valve apparatus of claim 6 wherein said inner member has one end thereof closed by a transverse section, said valve means comprising an annular seat surface on said outer member, a companion seal element of said inner member, and a flow port extending through the wall of said inner member downstream of said seal element and said transverse section.

13. A safety valve apparatus comprising: a valve actuator movable longitudinally within a housing member, said valve actuator and housing member defining a fluid flow passage; normally open valve means responsive to movement of said valve actuator in one longitudinal direction for closing said flow passage; first means responsive to a predetermined normal rate of fluid flow through said passage for moving said valve actuator in said one direction; second means active during a reduction in fluid flow rate to a valve below said predetermined normal rate for reversing the direction of movement of said valve actuator to maintain said valve means in its normally open condition; and one way delay means for controlling the rate of movement of said valve actuator in said one direction so that movement to closed position occurs during a predetermined interval, said delay means including a metering piston carried by said valve actuator and arranged for movement within an enclosed cylinder means in said housing member, said cylinder means containing a hydraulic fluid, said metering piston having a high pressure side and a low pressure side, the metering of said hydraulic fluid from said high pressure side to said low pressure side controlling the rate of movement of said valve actuator in said one direction, and further including means providing for the unrestricted passage of said hydraulic fluid from said low pressure side to said high pressure side during movement of said valve actuator in said opposite direction.

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