

[54] **AUTOMATIC CHOKE**

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[51] Int. Cl. **F16k 17/10**

[58] Field of Search **137/491, 489.5, 489.3, 137/492.5, 498, 486, 487, 488, 489**

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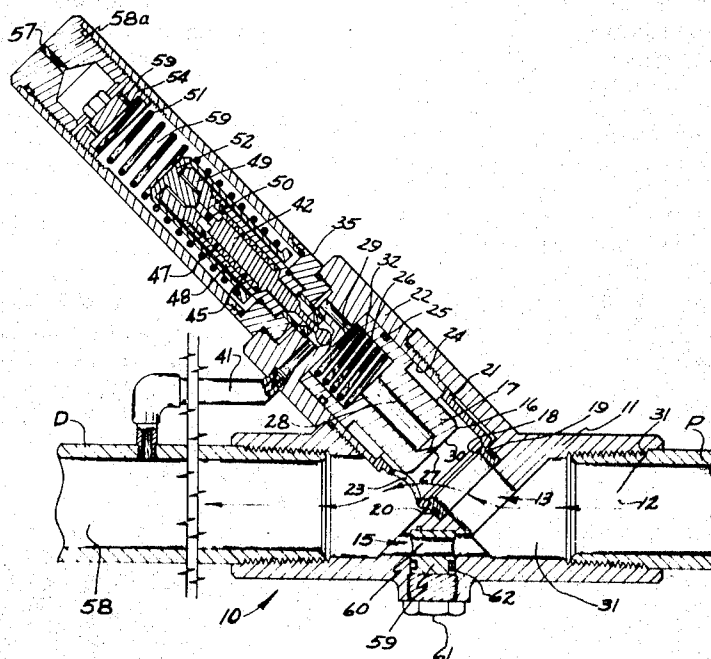
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[57] **ABSTRACT**

A valving means for automatically restricting the flow of fluids through a flow conductor until undesirably high pressures occurring in the upstream end of the

conductor return to normal. A primary valve stem closes with the advent of high pressure to force all flow through a small orifice choke. The primary valve stem is formed by a piston and is spring biased toward its seated position. Under normal conditions, the upstream pressure which acts on the front end of the piston is greater than the pressure communicated to the piston's back end and the resulting pressure differential holds the valve open against the spring force. A second pressure differential acting across a bellows disposed between the piston's back end and an external pressure area moves a control valve stem which regulates opening of a pressure outlet line extending between the back end of the piston and the downstream pressure area. When the pressure outlet line closes, a pressure inlet line extending between the upstream pressure area and the piston's back end permits pressure at the latter location to increase until it equals the upstream pressure which then permits the spring to drive the piston against the valve seat to close the primary valve opening. The small choke orifice is included as a part of a removable insert so that it may be replaced without disassembly of the entire valve. Incompressible fluid is trapped within the area confined by the bellows when bellows foreshortening exceeds a predetermined amount to prevent further foreshortening which might otherwise cause bellows damage.

9 Claims, 4 Drawing Figures



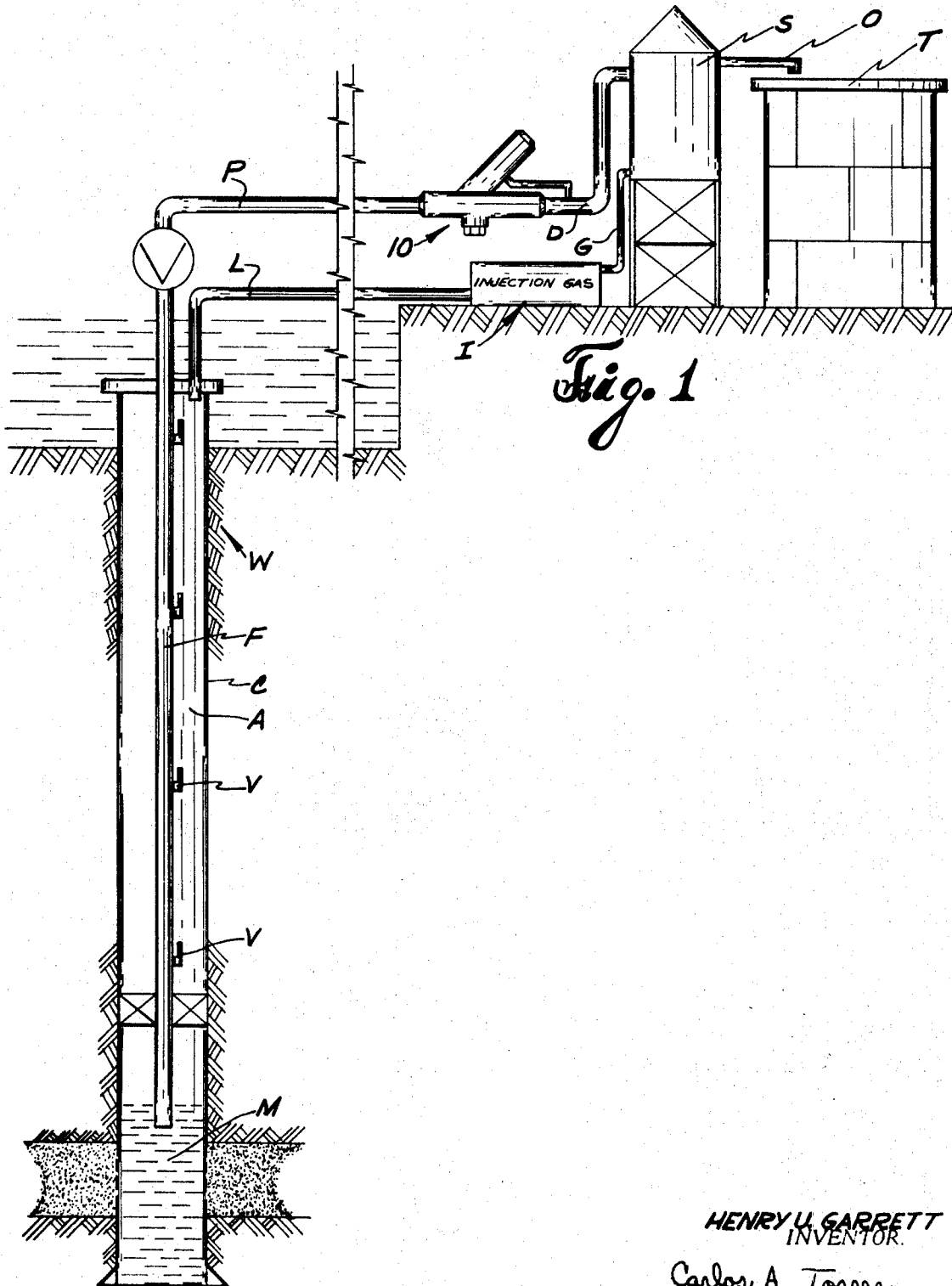
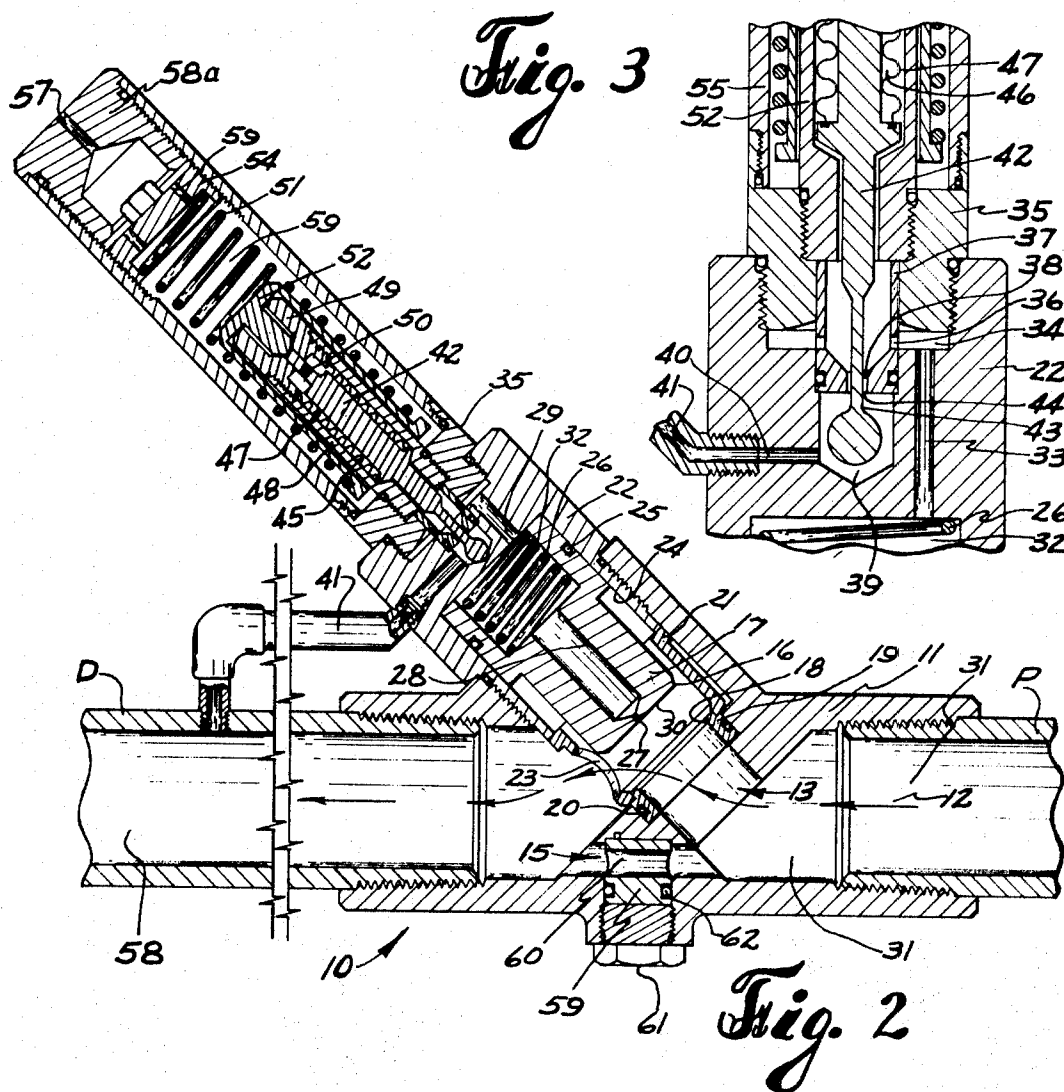


Fig. 1

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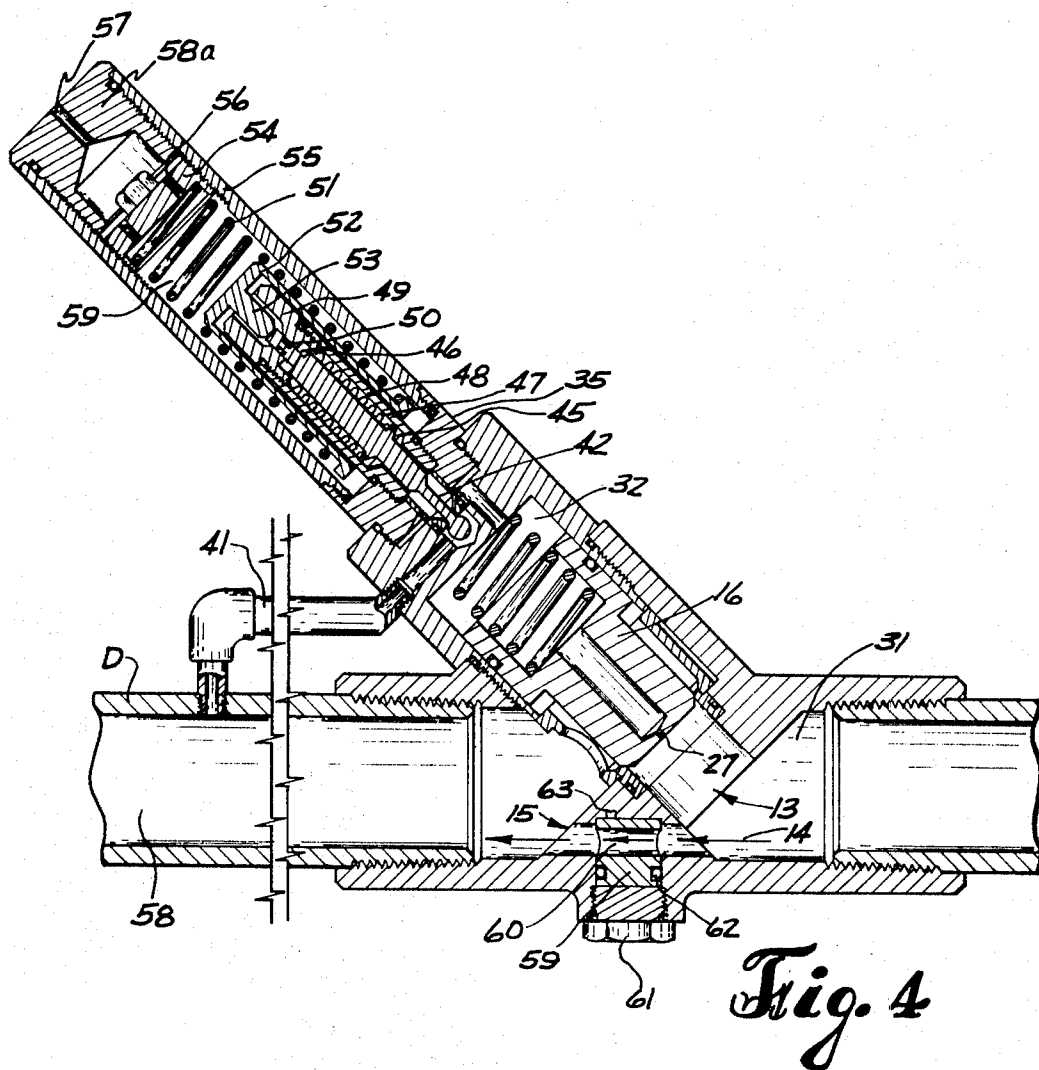
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AUTOMATIC CHOKE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to means for regulating the flow of fluids through a confining structure. More specifically, the present invention relates to an automatic valve for restricting the flow of well fluids from an oil or gas well when the well pressure increases above a predetermined maximum value. In a specific application to be described herein, the automatic valve is employed to choke down the flow of fluids from an oil well which is being produced by gas lift techniques during which relatively high pressure gases are injected into the well to elevate the oil to the well's surface. As used herein, the term "fluid" is intended to include both liquids and gases.

2. Description of the Prior Art

When the formation pressure in an oil well falls below that required to elevate the oil to the well surface at a desired rate, it is often necessary to produce the oil by artificial means such as by mechanical pumping or by gas injection. In the latter technique, high pressure gas is usually injected into the annular area between the well casing and the production tubing where gas lift valves positioned vertically along the length of the tubing automatically vent the injection gas into the column of oil contained within the production tubing. By thus mixing the injection gas with the oil column, the weight of the column is lightened so that the formation pressure can elevate the fluids to the surface at a desired rate. Control of the production rate is determined primarily by the formation pressure and the pressure of the gas injected into the fluid column. If the injection gas in the well annulus is vented into the production tubing above the level of the oil column, the high pressure gas flows upwardly through the production tubing, and out of the wellhead where it may encounter a separator used to separate oil from gas. High pressure, rapidly flowing gas can cause severe damage to the relatively expensive separation equipment. For this reason, in addition to the desire to preserve relatively expensive injection gas, it is desirable to prevent the rapid flow of high pressure gas through the production line.

One of the most common prior art techniques employed to prevent large gas flow through the production line is the use of a manually operated choke. The disadvantages inherent in the need for continuous monitoring and manual regulation are readily evident.

The prior art also includes a system in which an automatic valve moves from a fully open position to a fully closed position in response to a pressure increase in the production line. In fully closed position, no gas flows through the line. While such a system is desirable when compared with manual control, the automatic valve is relatively complex and expensive to build and maintain. Moreover, it is often desirable to choke down or restrict flow through the line rather than close off the flow completely. Automatic reopening of pressure control valves employed in gas lift systems is also desirable so that production may be automatically reinitiated when pressure conditions have returned to the desired operating ranges.

SUMMARY OF THE INVENTION

The automatic valve means of the present invention includes a piston-like primary stem closure which has

its front biased toward its seated, closed position by a coil spring acting against the stem's back end. The upstream fluid pressure acting at the front end of the valve stem acts with respect to a lower pressure area at the back end of the stem to form a pressure differential which overcomes the spring force and moves the stem away from the valve seat into fully open position. A low pressure is maintained at the back end of the stem by a pressure outlet line which communicates with the downstream pressure within the flow conduit. So long as the pressure at the stem's back end is sufficiently less than the upstream pressure, the stem remains in its up and open position. When the upstream pressure increases above a predetermined maximum value, the increased pressure moves a bellows control which seals off the pressure outlet line. A small inlet pressure line extends between front and back ends of the stem and because of the small size of the inlet line opening, a pressure differential is maintained between the front and back ends of the stem. With the outlet passage sealed off, however, the inlet line permits pressures on both ends of the stem to equalize which then permits the force of the coil spring to seat the stem closing off the valve. Once closed, all fluids in the conduit are forced to flow through a small choke orifice.

The choke orifice is formed through a removable insert which permits the orifice to be replaced without the need for disassembling the entire valve. Under those pressure conditions where the primary valve stem is closed, the large, high velocity gas flow through the choke orifice tends to cut away the orifice opening. Use of abrasion resistant material to form a removable insert permits the choke opening to be quickly and easily replaced to save maintenance cost and to reduce down time. The design of the valve of the present invention also permits the use of a fully opened, streamlined choke orifice rather than a choking orifice formed between two relatively movable valve closure elements.

In the operator portion of the present system, a low friction, reliable bellows seal ensures sensitivity and reliability of system operation. The bellows is equipped with a bellows valving means which encloses an incompressible fluid within the bellows area when bellows contraction exceeds a predetermined length. Once the bellows valve closes, further contraction of the bellows is prevented to protect the bellows from damage caused by over compression.

The foregoing and other features and advantages of the present invention will be more readily appreciated from the following specification, drawings and related claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical elevation, partly in section schematically illustrating a gas injection system for producing oil from an oil well with the automatic valve of the present invention positioned in the production line extending from the well to an oil and gas separator;

FIG. 2 is a vertical section on an enlarged scale illustrating the automatic valve means of the present invention with the primary valving means open;

FIG. 3 is an enlarged detail section illustrating the pressure responsive control means of the present invention employed to regulate opening and closing of the primary valving means; and

FIG. 4 is a view similar to FIG. 3 illustrating the primary valving means is closed position.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the automatic valve means of the present invention is indicated generally at 10 having its upstream end connected into a production line P extending from an oil well indicated generally at W. The downstream end of the valve 10 connects into a line D which carries oil and gas in the line to a separator S which separates the oil and gas and ejects the oil through an output line O into a storage tank T and recirculates the gas through a line G to an injection gas lift system indicated generally at I. The system I pressurizes gas and injects it into the well W through a line L. Gas injected into the well W flows in an annular space A formed between a well casing C and a production tubing string F where it is then injected into the tubing string through gas lift valves V. Gas injected into the production string F assists in elevating oil M through the production string and up into the production line P.

In the event the injection gas is vented into the production string F above the level of the oil or other liquids contained within the string, the pressure in production string F and line P increases causing the valve 10 to close. Once closed, the valve 10 substantially restricts the flow of gas entering the separator S. The valve remains closed to continue restricted flow through the line T and into the separator S until the well pressure drops to a predetermined value indicative of the onset of oil flow through the production line P. Once oil production is reestablished, the valve opens into its fully open position permitting the reestablishment of optimum gas injection operating conditions.

Details in the construction and operation of the valve 10 will now be described with reference to FIGS. 2-4 of the drawings. The valve means 10 includes a housing 11 which is threadedly engaged at one end to the line P and at the other end to the line D. Internally of the valve, mixed oil and gas flow in the direction of the arrows 12 illustrated in FIG. 2 from the line P through a primary flow passage indicated generally at 13 into the line B. When the valve means 10 moves into its closed position, illustrated in FIG. 4, the flow passage 13 is closed and all fluid is forced to flow in the direction of the arrows 14 through a restricted flow passage or choke opening indicated generally at 15.

Closure of the primary flow passage 13 is effected by moving a sealing surface 16 on the front end of a valve stem 17 into engagement with a seating surface 18 surrounding the flow passage 13. The seating surface 18 is formed on the edge of a seating ring 19 which is held in a receiving recess of the housing 11. An annular O-ring seal 20 between the ring 19 and housing 11 prevents leakage between the two components when the valve stem 17 is in its lower, closed position.

Seat ring 19 is held in place by a sleeve 21 which in turn is secured in position by a housing member 22 threadedly engaged to the housing 11. The sleeve 21 is ported at 23 to provide an opening for fluid flow through the primary flow passage 13.

Valve stem 17 moves axially within a stem housing component 22. A smooth internal cylindrical bore 24 formed in the stem housing component cooperates with an annular O-ring seal 25 carried on the stem 17 to provide a continuous, sliding seal between the bore and the valve stem. The stem 17 is biased towards engagement

with the seat 18 by a coil spring 26 which is confined within the bore 24 between the stem housing component 22 and the back end of the stem 17.

A small pressure inlet line 27 extends from the front end of valve stem 17 to a larger bore 28 which in turn communicates with a still larger bore 29 to provide a pressure inlet line between the front end or base 30 of valve stem 17 and the area at the back end of the stem within the bore 24. For purposes of identification, the pressure area on the upstream side of flow passage 13 is hereinafter referred to as a first pressure area 31 and the pressure area within the bore 24 at the back end of the stem is referred to as a second pressure area 32. As best illustrated in FIG. 4, when the valve stem 16 is in its lower, closed position, pressure area 31 communicates with pressure area 32 through pressure inlet line 27. Referring to FIG. 3, a pressure outlet line communicating with the pressure area 32 is provided by an axially developed bore 33 extending from the pressure area 32 to the end of valve stem housing component 22 through an annular opening 34 formed between the stem housing component and a control housing component 35, through a port 36 formed in a control seat sleeve 37, through a control valve flow passage opening 38, into a stem chamber 29, through lateral bore 40 and into a return line 41 which opens into the flow conductor D. This pressure outlet line is closed or opened by movement of a control valve stem 42 which moves a control valve sealing surface 43 into and out of engagement with a seating surface 44 formed on the valve seat sleeve 37.

Referring to FIG. 2, movement of valve stem 42 is determined by the pressure differential existing between an outer bellows area 45 and an inner bellows area 46. Areas 45 and 46 are maintained separate by virtue of the pressure tight seal provided by a movable bellows section 47. As will be seen, the described structure functions as an operator means which regulates opening and closing of the primary valve stem 17. Linear movement of the valve stem 42 and bellows 47 is confined within a supporting sleeve structure 48. The upper end of sleeve 48 is provided with a fitting 49 which includes a central opening designed to cooperate with an annular O-ring seal 50 carried at the top of control stem 42 to enclose bellows area 46 when the control stem is in its upper position illustrated in FIG. 4. Control stem 42 is urged toward its lower position illustrated in FIG. 2 by a coil spring 51 acting through an overlying cap 52. A pin 53 extending centrally from the cap 52 imparts the downwardly directed spring force to the control stem 42. The force exerted by spring 51 against valve stem 42 may be adjusted by rotating an adjustment member 54 to alter its axial position within a protective housing sleeve 55. Axially extending bores 56 permit pressure communication across adjustment member 54 and an axially extending opening 57 formed in a housing cap 58a provides pressure communication between the internal confines of housing sleeve 55 and the atmosphere. The area confined by sleeve 55 is partially filled with a non-compressible fluid, such as a lightweight oil. The level of the fluid above the opening formed through fitting 49 and the entire bellows area 45 is filled with the fluid. When O-ring seal 50 closes the opening through the fitting 49, the non-compressible fluid prevents further compression of the bellows irrespective of increasing pressure.

By this means, the bellows section 47 is protected from damaging over-compression.

For purposes of the description which is to follow, the pressure existing within the conduit D downstream of the valve 10 at the point where line 41 connects into the conduit, is referred to as a third pressure area 58 and the pressure existing within the housing sleeve 55 in the outer bellows area 45 is referred to as a fourth pressure area 59.

An important feature of the present invention is the provision of a removable choke orifice insert means 60 having a flow passage 60a employed to form the restricted flow passage 15 through which a gas is forced to flow when the primary valve stem is closed. A plug 61 is threadably engaged to the base of valve housing 11 to hold insert 59 in place and an annular O-ring seal 62 extending about the insert prevents leakage between the insert and the surrounding housing. A positioning pin 63 ensures proper alignment of the opening 60a. When replacement or repair of the insert is necessary, retaining plug 61 need merely be removed and the member 60 replaced with another insert. It will also be appreciated that with the described construction, the size of orifice opening 60 may be changed by replacing one insert with another having a different opening.

In its open position with normal pressure existing in the upstream fluids entering the valve 10, the pressure in the first pressure area 31 is higher than the pressure in the second pressure area 32 and the resulting pressure differential is sufficient to move the valve stem 17 into the position illustrated in FIG. 2 compressing the spring 26. While in this condition, the pressure outlet line connecting pressure areas 32 and 58 is open and the valve stem 42 is in the position illustrated in FIG. 2. Because of its small size, there is a pressure drop across opening 27 so that the pressure in pressure area 31 remains higher than that existing in pressure area 32 even though the two areas are connected by the small pressure inlet line. Under these same conditions, the atmospheric pressure acting in the fourth pressure area within control housing 55 and the biasing force exerted by spring 51 combine to form a force which is sufficient to overcome the pressure acting in bellows area 46 so that the valve stem 42 is retained in its lower, open position illustrated in FIG. 2. When the pressure in pressure area 31 increases above a predetermined maximum value, the increased pressure in the third pressure area 58 and the increased pressure in the second pressure area 32 are sufficient to overcome the biasing force provided by spring 51 and the force exerted by atmospheric pressure. Once these latter forces are overcome, the valve stem 42 is moved upwardly into the closed position illustrated in FIG. 4. This movement of the valve stem closes the pressure outlet line so that the second pressure area 32 is sealed except for its communication with the inlet pressure line 27. Under these conditions with the flow of fluid within area 32 being static, the pressure in pressure area 32 increases to substantially the same pressure as that existing in the first pressure area 31. When this condition prevails, no pressure differential exists across the O-ring 25 and the biasing force of spring 26 is sufficient to snap the valve stem 16 into its closed position. In closed position, the effective cross sectional area of the O-ring 25 is exposed to the pressure existing in the first pressure area 31. This area is greater than the effective cross-sectional area of the engagement between sealing

means 16 and seat means 18 so that the valve stem 17 remains in its lower, closed position so long as the pressure within pressure area 32 remains the same as the pressure in pressure area 31.

The valve will automatically reopen when the pressure acting against the bellows 47 falls sufficiently to permit the spring bias of spring 51 to reopen the pressure outlet line communicating area 32 with area 58. When the line has been reopened, the pressure in the second pressure area 32 begins to fall so that the required pressure differential is developed to open the primary valve stem 17.

From the foregoing, it will be appreciated that the valve of the present invention provides an effective, low cost means for automatically controlling the flow of high pressure gases through a production line. It will be appreciated also that the valve closure may be employed with or without a choke orifice means so that if desired, complete closure through the flow conduit may be effected upon closure of the primary valving means. In addition, while the outlet pressure passage means has been described as communicating with the downstream pressure in the flow conduit, it will be appreciated that the outlet may communicate with any pressure area having a pressure which is lower than that in the first pressure area. Moreover, if desired, the biasing force of spring 51 and atmospheric pressure may be provided by charging the area confined within the sleeve 55 with a pressurized gas and sealing the opening 57.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof, and various changes in the size, shape and materials as well as in the details of the illustrated construction may be made within the scope of the appended claims without departing from the spirit of the invention.

I claim:

1. An automatic valve means for regulating the flow of fluids flowing in an upstream to a downstream direction through a fluid flow conduit comprising:

- a. primary valving means movable between open and closed positions for permitting fluid flow through a first flow passage means when said primary valving means is in open position and for terminating such flow when said primary valving means is in closed position;
- b. operator means connected with said primary valving means for automatically moving said primary valving means to closed position when the pressure in a first pressure area in said first flow passage means upstream of said valving means exceeds a predetermined maximum value; and
- c. second flow passage means for permitting fluid flow through said valve means when said primary valving means is in closed position.

2. An automatic valve means as defined in claim 1 further including insert means removably carried in said valve means for forming a replaceable, wear resistant flow passage opening for said second flow passage means.

3. An automatic valve means as defined in claim 1 further including:

- a. biasing means tending to urge said primary valving means to closed position; and
- b. first pressure responsive control means operable in response to the pressure differential existing between said first pressure area and a second pressure

area for maintaining said closure means in opened position against the force of said biasing means when the pressure in said second area is lower than the pressure in said first pressure area and for permitting said biasing means to move said closure means to closed position when the pressures in said first and second pressure areas are substantially equal to each other.

4. An automatic valve means as defined in claim 3 wherein:

a. inlet pressure passage means connect between said second pressure area and said first pressure area for conveying pressure fluid between said first and second areas;

b. outlet pressure passage means connect between said second pressure area and a third pressure area for conveying pressure fluid between said second and third areas whereby the pressure value within said second pressure area is determined by the pressure value of the fluid moving through said inlet and outlet pressure passage means; and including

c. second pressure responsive control means operable in response to a control pressure differential between said second pressure area and a fourth pressure area to close said outlet pressure passage means when said control pressure differential exceeds a predetermined maximum value and for opening said outlet pressure passage means when said control pressure differential is below said predetermined maximum value whereby when said outlet pressure passage means is closed, the pressure in said second pressure area may increase to substantially the same value as the pressure in said first pressure area to close said primary valving means.

5. An automatic valve as defined in claim 4 further including adjustment means for adjusting the maximum valve of said control pressure differential at which said outlet pressure passage is closed.

6. An automatic valve as defined in claim 4 wherein:

a. said third pressure area is within said flow conduit downstream of said valve means; and

b. said fourth pressure area is opened to the atmosphere.

7. An automatic valve as defined in claim 4 wherein said second and fourth pressure areas are sealed from each other by bellows means.

8. An automatic valve as defined in claim 7 wherein:

a. said bellows means partially enclose a bellows area having a bellows opening through which fluids may be moved into and out of said bellows area with movement of said bellows means;

b. said bellows means includes bellows valve means operable on movement of said bellows means to open or close said bellows opening whereby fluids are confined in said bellows area when said bellows opening is closed;

c. an incompressible fluid occupies all of the fluid containable space within said bellows area; and

d. said bellows valve means is closed by movement of said bellows means beyond a predetermined maximum value in a given direction to confine said incompressible fluid within said bellows area to prevent further bellows movement in the same direction.

9. An automatic valve means for regulating the flow of fluids flowing in an upstream to a downstream direction through a fluid flow conduit comprising:

a. primary valving means movable between open and closed positions for permitting fluid flow through a first flow passage means when said primary valving means is in open position and for terminating such flow when said primary valving means is in closed position;

b. operator means connected with said primary valving means for automatically moving said primary valving means to closed position when the pressure in a first pressure area in said first flow passage means upstream of said valving means exceeds a predetermined maximum value;

c. biasing means tending to urge said primary valving means to closed position;

d. first pressure responsive control means operable in response to the pressure differential existing between said first pressure area and a second pressure area for maintaining said closure means in opened position against the force of said biasing means when the pressure in said second pressure area is lower than the pressure in said first pressure area and for permitting said biasing means to move said closure means to closed position when the pressures in said first and second pressure areas are substantially equal to each other;

e. inlet pressure passage means connecting between said second pressure area and said first pressure area for conveying pressure fluid between said first and second areas;

f. outlet pressure passage means connecting between said second pressure area and a third pressure area for conveying pressure fluid between said second and third areas whereby the pressure value within said second pressure area is determined by the pressure value of the fluid moving through said inlet and outlet pressure passage means;

g. second pressure responsive control means operable in response to a control pressure differential between said second pressure area and a fourth pressure area to close said outlet pressure passage means when said control pressure differential exceeds a predetermined maximum value and for opening said outlet pressure passage means when said control pressure differential is below said predetermined maximum value whereby when said outlet pressure passage means is closed, the pressure in said second pressure area may increase substantially to the same value as the pressure in said first pressure area to close said primary valving means;

h. bellows means sealing said second and fourth pressure areas from each other with said bellows means partially enclosing a bellows area having a bellows opening through which fluids may be moved into and out of said bellows area with movement of said bellows means;

i. bellows valve means included with said bellows means and operable on movement of said bellows means to open or close said bellows opening whereby fluids are confined in said bellows area when said bellows opening is closed; and

j. an incompressible fluid occupying all of the fluid containable space within said bellows area with said bellows valve means closed by movement of said bellows means beyond a predetermined maximum value in a given direction to confine said incompressible fluid within said bellows area to prevent further bellows movement in the same direction.