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3,170,481

FLOW CONTROL VALVE

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Fig. 1

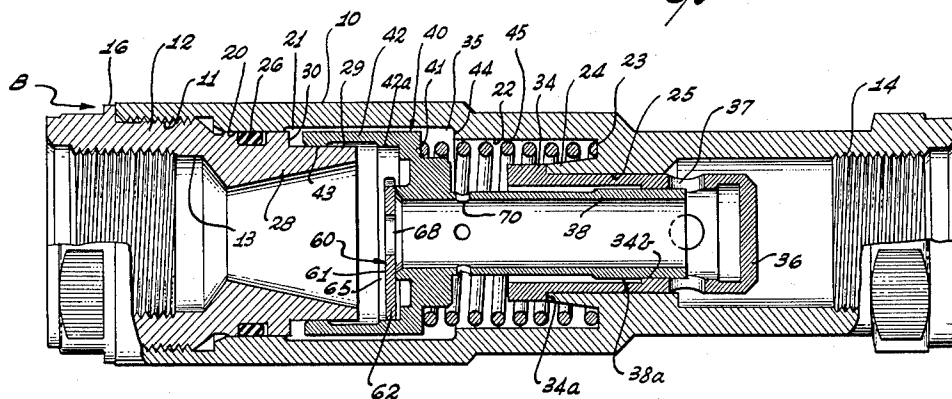


Fig. 3

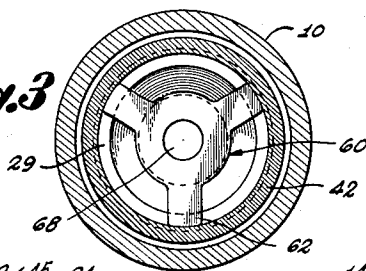


Fig. 2

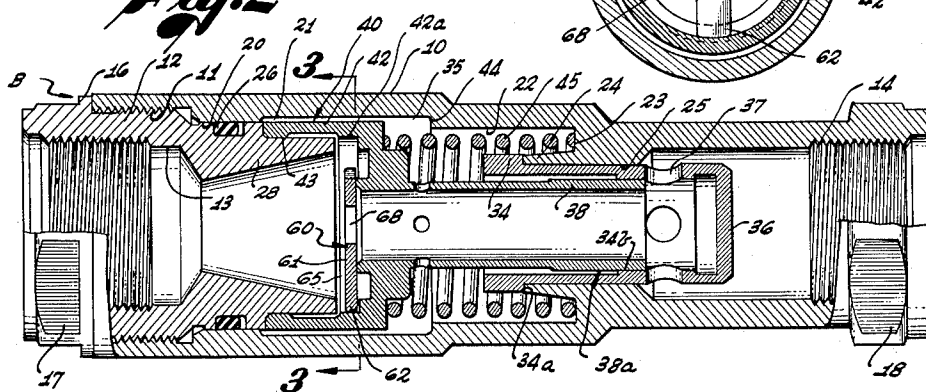
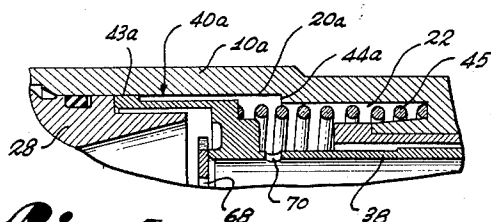


Fig. 4



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3,170,481

FLOW CONTROL VALVE

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This invention relates generally to hydraulic flow control valves of the type which limit flow to a predetermined maximum by balancing a throttling member between a spring and a force due to pressure drop across a metering orifice.

It is a general object of the invention to provide improvements in this class of valve.

An example of a prior art valve of this general class is disclosed in my prior Patent No. 2,807,279; and the present invention may be regarded as addressed to a valve of this general class, but reorganized in a number of important respects for obtainment of improved performance.

Among the objects of the invention are the following:

To provide means minimizing variations in flow due to variations in leakage past the valve's regulator piston resulting from temperature induced fluid viscosity changes and from body swell due to variations in system pressure;

To provide a combined piston and throttling member whose points of bearing are longitudinally widely spaced so as to minimize sticking and dragging due to imperfect centering of spring load;

To provide a control valve in which spring vibration and fluid turbulence are minimized by separating the spring from the main fluid flow path;

To provide a control valve wherein the spring chamber is not in the main flow path through the valve, but is used to advantage as a dash pot to insure smooth and chatter-free operation;

To provide a means limiting travel of the combined piston and sleeve and thereby preventing damage thereto and to the spring from inlet surge when the valve is empty of hydraulic fluid;

To provide a means affording relatively unobstructed reverse flow;

To provide a simple and effective means for retaining the reverse-flow poppet; and

To provide an improved means affording a bearing for an axially movable throttling sleeve and a novel arrangement of throttling ports cooperable with said sleeve.

These and other objects and the improvements comprising the invention itself may best be understood from the following detailed description of a present preferred embodiment of the invention, reference being had to the accompanying drawings, in which:

FIG. 1 is a longitudinal sectional view through a valve in accordance with the invention, shown in an operative forward flow position;

FIG. 2 is a view similar to FIG. 1, but showing the valve in an inoperative position;

FIG. 3 is a section taken on line 3—3 of FIG. 1; and

FIG. 4 is a fragmentary view showing a modification of the valve of FIGS. 1—3.

In the drawings, the numeral 10 designates a cylindrical body member or sleeve, formed in one end with a threaded bore 11 to receive an externally threaded cap 12, which completes a body generally represented by reference character B. For lightness, and for an additional reason to appear hereinafter, the body member 10 and cap 12 are preferably composed of aluminum alloy. The cap 12 is formed with a threaded inlet port 13, and the opposite end of body member 10 is formed with a threaded outlet port 14, for making up in a hydraulic line. Cap 12 has a flange 16 which abuts the end of body member 10, and is formed outside said flange with wrench

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flats 17. Similar wrench flats 18 are formed on the end of body member 10 that is remote from cap 12. These facilitate screwing of the cap 12 into body member 10, and the making up of the valve in the hydraulic line.

Bore 11 is continued inwardly into body member 10 by an unthreaded finished bore 20, beyond which is an enlarged relief bore 21, followed by a reduced bore 22. The latter extends to an annular shoulder 23, inside of which is an annular forwardly projecting annular flange or ring 24. This flange 24 bounds a reduced axial bore 25 that meets the aforementioned port 14.

The cap 12 is sealed to body member 10 by O-ring 26 in contact with the finished surface of bore 20. This cap 12 has an inward extension 28 shaped to afford an external cylindrical bearing surface 29, and at the base of surface 29, an annular stop shoulder 30. The bearing surface 29 is annularly spaced inside bore 21 to accommodate a presently described piston. The inner end of the extension 28 functions to cage a later described poppet.

A hardened tubular liner sleeve or cup 34 is pressed into and extends through bore 25 in body member 10, having its open end within the body chamber 35 formed by bores 21 and 22. The open end portion of this cup has a shoulder 34a, which engages the abutment or shoulder afforded by the end of flange 24, by which it is properly positioned. The opposite end portion or "button" of this cup extends beyond bore 25 into port 14, and is here shown as closed by wall 36. However, the wall 36 need not be a complete closure, and it is possible to provide a small port therein so as to pass a small fluid flow even though the presently described throttling ports are closed. This is a sometimes specified safety feature in a flow control valve, permitting some flow even though the valve may be stuck in a shut-off position. The cup 34 has lateral throttling ports 37 opening to port 14.

Cup 34 is formed near wall 36 with an internal cylindrical bearing surface 34b. A generally tubular throttling member or sleeve is indicated generally by the numeral 38, and this throttling member or sleeve has a cylindrical bearing surface 38a on its rearward end portion which is slidably received within and supported by cup bearing 34b. This sleeve 38, which is preferably reduced slightly forwardly of bearing surface 38a, has or includes adjacent its forward end, i.e., its end nearest cap 12, a hollow head or piston 40, comprised in this instance of an annular wall 41 extending radially outward from the end of sleeve 38, and a cylindrical wall or sleeve portion 42 projecting in the direction of the valve inlet from the periphery of wall 41. Wall 42 has, adjacent its axial extremity, an internal cylindrical bearing surface 43 which is slidably fitted on the aforementioned external cylindrical bearing surface 29 on cap extension 28. To assure desirable strength and wear resistance, and for a further reason to be described hereinafter, the throttling member 38 is preferably made of steel alloy.

The extremity of piston wall 42 is engageable against cap shoulder 30 as a stop, and the piston has a suitable range of axial travel with bearing surface 43 in sliding engagement with cap surface 29. This travel is limited by body shoulder 44 at the juncture of bores 21 and 22, and shoulder 44 may be engaged by piston 40 under certain conditions to be explained.

A coil compression spring 45 surrounds sleeve 38, seating at one end on body shoulder 23, and engaging at its opposite end behind piston 40. This compression spring urges the throttling member 38 towards the position of FIG. 2, where the piston is engaged with the cap. During regulated flow, the piston 40, under the influence of a pressure differential operating thereon, moves against spring 45 to an operating position such as illustrated in FIG. 1, where the end of sleeve 38 partially closes

throttling ports 37, and thus adjusts the flow rate through the valve.

The hollow piston 40 receives for limited movement therein a plate-like poppet valve 60, comprised of a central valve disk 61 and radially projecting arms 62 guided for sliding movement by the inner cylindric surface 42a of the outer piston wall 42 adjacent the base of the latter. The valve disk 61 is thus engageable with an annular seat 65 on the adjacent extremity of sleeve 38, this seat 65 being positioned forwardly of the front face of piston wall 41, so that the valve disk engages seat 65 rather than wall 41.

A metering orifice 68 is formed in poppet valve 60, and, excepting for leakage around the piston, passes the fluid flow from the valve inlet port to the interior of sleeve 38 when the valve is in normal operation, with the poppet valve seated (FIG. 1). When reverse flow takes place through the valve, the poppet is forced off its seat, and at such time the cap extension 28 functions to stop or cage the poppet. It will be evident that the arms 62 are of a length to engage the end of cap extension 28 at this time. It will also be clear that large fluid flow passages are at this time provided from the end of sleeve 38 through the spaces between poppet arms 62 in engagement with the cap extension 28, to the port within the latter.

Pressure equalizing ports 70 are formed in sleeve 38 immediately to the rear of piston 40, so that the pressure within sleeve 38, downstream of metering orifice 68, will be communicated to body chamber 35, whereby in normal flow controlling operation, with the poppet 60 in the position of FIG. 2, the piston is subjected to the resultant force arising from the differential of pressures upstream and downstream of the metering orifice 68.

In regulated flow, fluid enters port 13, and, impinging on poppet 60, carries said poppet into engagement with seat 65 on piston 40 (FIG. 2). Fluid pressure is exerted on the frontal area of the piston, moving the piston and sleeve assembly 40, 38 against spring 45 from the position of FIG. 2 toward that of FIG. 1. Fluid flows through orifice 68, creating a pressure differential upstream and downstream of the orifice. The upstream pressure is exerted over the total exposed frontal area of the piston, and the lower downstream pressure is exerted over the entire exposed rearward area of the piston and sleeve, including the rearward side of the piston outside the sleeve 38 by virtue of the pressure equalizing ports 70 in the sleeve. The piston and sleeve assembly is accordingly subjected to a resultant force which is exerted in a direction to compress spring 45; and spring 45 compresses until its resistance exactly balances the force owing to the pressure differential.

Fluid passing through orifice 68 into sleeve 38 discharges from the sleeve via throttling ports 37, flowing thence through outlet port 14. The position of the end of sleeve 38 relative to ports 37, as determined by the pressure differential set up as described immediately above, governs the flow rate through the valve. In overall effect, the flow rate depends upon the size of metering orifice 68 and the stiffness of spring 45. If inlet pressure increases, the piston and sleeve assembly will move to decrease the effective size of outlet ports 37, and so preserve the predetermined flow rate. If inlet pressure decreases, or outlet pressure should increase, the piston and sleeve assembly will move so as to increase the effective area of ports 37, and so preserve the predetermined flow rate.

Attention is particularly directed to the fact that the body or spring chamber 35, communicating with the interior of sleeve 38 via ports 70, functions as a dash pot to insure smooth and chatter-free operation. Thus, for example, upon a sudden rise in inlet pressure, an increased force toward the right is exerted on the piston. The piston moves smoothly to its new position, however, governed by the flow resistance offered by ports 70 to the volume of liquid necessary to be displaced from chamber 35 into sleeve 38.

Attention is also drawn to the fact that the fluid flow

through the valve, excepting for leakage, has been routed so as to avoid passing through the body or spring chamber 35, so that undesired spring vibration and fluid turbulence owing to fluid flow through or along the spring are completely avoided.

The valve has been provided with a protection against damage to the piston and sleeve assembly and to the spring arising from inlet surge when the valve is empty of hydraulic fluid. This provision constitutes the shoulder 44 between body bores 21 and 22 which is engageable by piston 40 very shortly beyond the useful travel of the latter, and thus limits the travel of the piston and sleeve assembly to a distance less than that at which it or the spring could be damaged.

With no forward flow through the valve, the piston and sleeve assembly 40, 38 is held by spring 45 in the position of FIG. 2.

When reverse flow occurs, fluid enters port 14, flows through ports 37 into sleeve 38, and, reaching poppet 60, moves the latter off its seat 65 and against the facing abutment afforded by cap extension 28. Specifically, the arms 62 of the poppet so engage cap extension 28. It will be clear that in this position of the poppet, adequate spaces are provided between the poppet disk 61 and the cap extension 28 for unrestricted passage of the reverse flow from sleeve 38 to port 13.

Attention is directed to the fact that the piston and throttling sleeve assembly 40, 38 has widely spaced slide bearing supports. Thus, the piston has bearing at its forward extremity on cap extension 28, and the sleeve 38 has bearing near the rearward end of the assembly on bearing surface 34b in cup 34. Thereby, sticking and dragging of the piston and sleeve assembly owing to imperfect centering of the spring load is minimized.

The valve preferably incorporates a special arrangement for minimizing variations in leakage past piston 40 resulting either from temperature-induced changes in the viscosity of the hydraulic fluid, or from body swell due to variations in system pressure. It is to accomplish this result that the sleeve member or piston 40 is made of steel alloy, and is made to be slidable on the outside of the aluminum alloy cap extension 28. Aluminum alloy, of course, has a greater coefficient of expansion than steel. If the steel piston were slidable in a bore in the aluminum alloy body member 10, the body member 10 would expand more than the piston with increase in temperature of the hydraulic fluid, the clearance space between the piston and body would, therefore, increase, and because of this increased clearance space, and because also of the lowered viscosity of the hydraulic fluid at higher temperatures, leakage flow would increase very materially. Swelling of the body member under high system pressures would also increase the clearance, and the leakage flow.

However, by having the steel piston slidable on the outside of an aluminum alloy body member, in this case, on the aluminum alloy body cap extension 28, increase in temperature results in more expansion of the cap extension 28 than of the steel piston 40, so that whatever initial working clearance was provided is then reduced. However, the hydraulic fluid, being warmer, and less viscous, flows easier. The tendency is thus for the leakage flow rate to remain fairly constant, rather than increasing markedly with temperature. In addition, in the arrangement described, swelling of the body member 10 with increase in system pressure has no effect on piston clearance. Cap extension 28 and hollow piston 40 are exposed to no pressure differential except that due to pressure drop across orifice 68, which, typically on the order of 2 percent of full system pressure, is too small to effect appreciable expansion of either cap extension 28 or hollow piston 40.

While it is generally preferred to have the piston work on the outside of a cap extension, the invention broadly contemplates situations wherein the piston may work

in a bore in the body member, as illustrated in FIG. 4, and a modification such as suggested in FIG. 4 is, therefore, within the scope of the invention in a number of its aspects. In FIG. 4, the bore 20a in body member 10a extends rearwardly to shoulder 44a, without relief, as in FIGS. 1-3, and affords bearing for a cylindric exterior bearing surface 43a on the outside of the forward end of piston 40a. Otherwise, the valve may be identical with the valve of FIGS. 1-3, and corresponding parts are identified by corresponding reference numerals. The modification of FIG. 4 is adequate in case temperature variations and/or system pressure changes are not large enough to produce leakage flow rate changes which are troublesome.

It will be understood that the drawings and description are of present preferred illustrative embodiments of the invention, and that various changes in design structure, and arrangement may be made without departing from the spirit and scope of the appended claims.

I claim:

1. In a flow control valve, a hollow valve body having an inlet at one end and an outlet at the other, a tubular throttling member longitudinally movable in said body and including, at the inlet end of the body, a co-axial head portion with a cylindrical bore therein affording an interior cylindrical bearing surface, means on said body at the inlet end thereof affording an exterior cylindrical tubular bearing inside and in sliding and sealing engagement with said interior cylindrical bearing surface of said head portion, a spring urging said tubular throttling member toward the inlet end of said valve body, means affording a metering orifice between said inlet and an interior region of said throttling member, and throttling port means providing a port arranged to receive fluid from said interior region of said throttling member and to pass fluid to said outlet, said throttling member including a portion for varying the effective size of said throttling port in response to longitudinal movement of said throttling member.

2. The subject matter of claim 1, wherein said means on said body affording said exterior cylindrical bearing is composed of material of higher coefficient of thermal expansion than the material of said tubular throttling member.

3. In a flow control valve, a hollow valve body having an inlet at one end and an outlet at the other, a tubular throttling member longitudinally movable in said body and including, at the inlet end of said body, a co-axial head portion with a cylindrical bore therein affording an interior cylindrical bearing surface, inlet cap means included in said valve body fitted into said body at the inlet end thereof and having a port therethrough which constitutes said inlet of said body, a cylindrical extension on said cap means around said port projecting inside and slidably and sealingly fitting said interior cylindrical bearing surface of said head portion of said throttling member, a spring urging said tubular throttling member toward the inlet end of said valve body, means affording a metering orifice between said inlet and an interior region of said throttling member, throttling port means providing a port arranged to receive fluid from said interior region of said throttling member and to pass fluid to said outlet, and means on said throttling member for varying the effective size of said throttling port in response to longitudinal movement of said throttling member.

4. In a flow control valve, a hollow valve body having an inlet at one end and an outlet at the other, a tubular

throttling member longitudinally movable in said body and including, at the inlet end of said body, a piston with an axial cylindrical bore therein opening toward said inlet end of said valve body, inlet cap means included in said valve body fitted into said body at the inlet end thereof and having a port therethrough which constitutes said inlet of said body, a cylindrical extension on said cap means around said port projecting inside said cylindrical bore of said piston and having bearing and sealing engagement therewith, a poppet valve received in the base of said piston, confined by said cylindrical extension of said cap, there being a metering orifice through said poppet valve, and said poppet valve and the forward end of said tubular throttling member being adapted for seating interengagement by virtue of inflow of hydraulic fluid through said inlet, said metering orifice communicating with an interior region of said tubular throttling member in such position, and said poppet valve being adapted for unseating movement upon reverse flow through the valve, a spring urging said throttling member in the direction of said inlet, throttling port means providing a port arranged to pass fluid between said interior region of said throttling member and said outlet, and means on said throttling member for varying the effective size of said throttling port in response to longitudinal movement of said throttling member.

5. In a flow control valve, a hollow valve body having an inlet at one end and an outlet at the other, a tubular throttling member longitudinally movable in said body, the end of said throttling member proximate to said inlet having a cylindrical bearing surface, a complementary cylindrical bearing surface on the inlet end of said body in sliding and sealing engagement with said bearing surface on said throttling member, a transverse partition wall in said body, a liner sleeve in the form of a cup seated in said wall, with its bottom end proximate to said outlet, arranged to receive and surround the end portion of said tubular throttling member that is proximate to said outlet, and to afford an exterior slide bearing therefor, there being a chamber in said body outside said throttling member between said partition wall and said complementary engaging bearing surfaces on said body and throttling member, a spring lodged in said chamber urging said throttling member toward said inlet, means affording a metering orifice between said valve inlet and the interior of said tubular throttling member, said liner sleeve comprising a tubular wall having therein, between said partition wall and said outlet, a throttling port opening laterally from the interior to the exterior thereof, said throttling port being partially covered by said throttling member so as to be controlled thereby, said throttling port leading from the interior of said throttling member to said outlet, whereby to complete a flow path from said inlet through said metering orifice to the interior of said tubular throttling member, and thence through said throttling port to said outlet, and said throttling member having a port establishing communication between its interior and said chamber.

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