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[54] **PRESSURE-ACTUATED VALVE**
7 Claims, 1 Drawing Fig.

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[50] **Field of Search** .... 137/87, 514.5, 514, 469, DIG. 5

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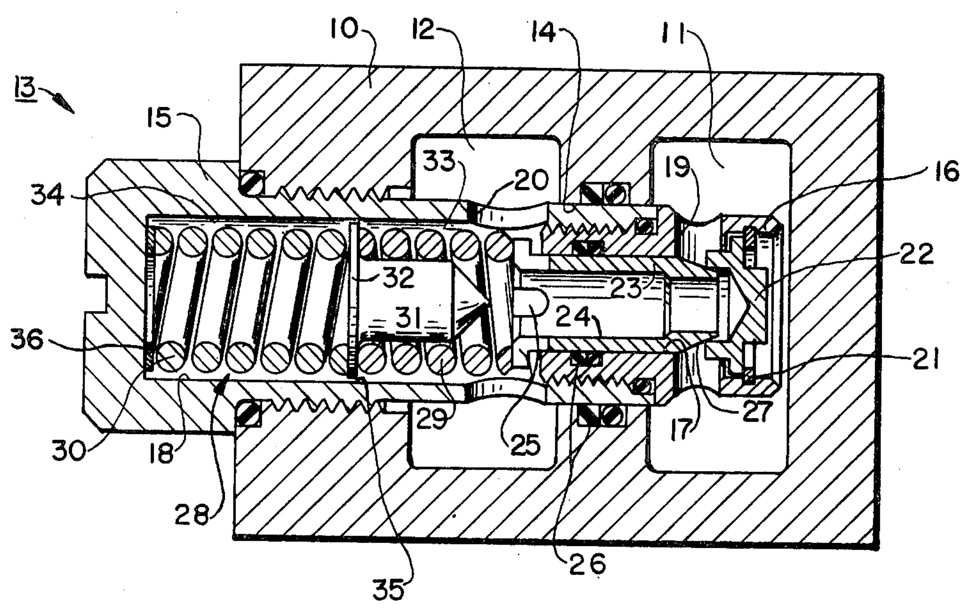
ABSTRACT: A pressure-actuated relief valve is disclosed having biasing means urging the poppet to a closed position which biasing means includes a damped and an undamped member cooperating to provide fast response while controlling poppet oscillation. The damped member includes a spring within a hydraulic dashpot and serves as a reaction seat for the undamped member. Fast pressure increases compress only the undamped member while longer duration pressure signals will also compress the damped member.



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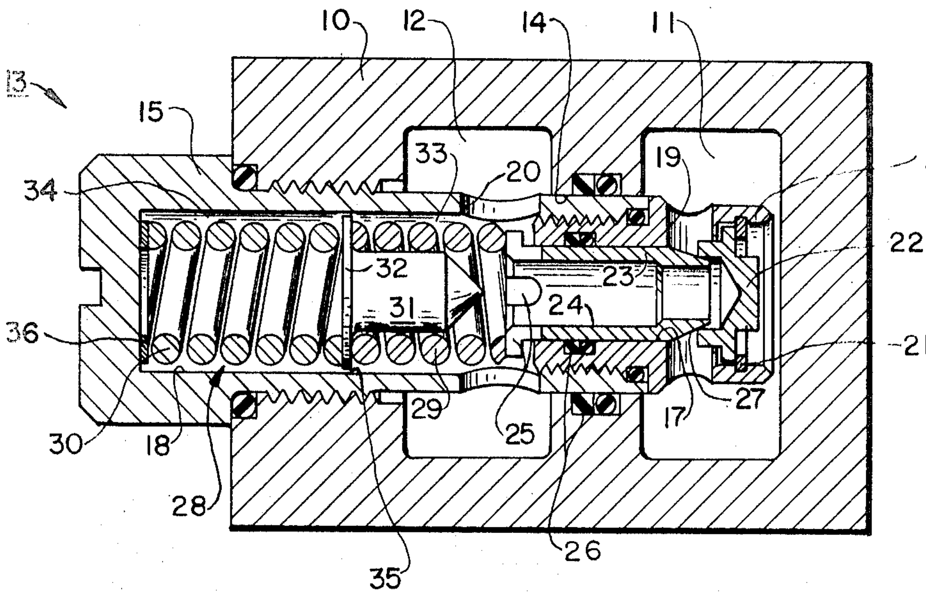

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PRESSURE-ACTUATED VALVE

This invention relates to pressure-actuated fluid flow control valves and relates more particularly to improved biasing means providing improved performance characteristics for such valves.

Flow control valves of the pressure relief type are actuated in response to a predetermined increase in hydraulic pressure to regulate and maintain system pressure of a desired level. As is well known, such valves generally include a control member or poppet variably positioned by a hydraulic actuating pressure to meter, control and direct fluid flow to a low pressure outlet. Biasing means act against the control member in opposition to the pressure forces so that the control member is positioned by the balance between the force exerted by hydraulic pressure and the biasing means. A problem common to such control valves is obtaining proper response to the pressure actuating force to produce the desired control of fluid. Improper action of the control member, such as too slow or too fast responsive movement to the pressure applied, may result in uncontrolled oscillation, chatter, excessive flow and pressure fluctuations and generally unacceptable performance. By correctly damping movement of the control member, proper and acceptable performance of the control valve can be achieved.

The present invention is directed toward an improved biasing member construction for pressure actuated valves providing improved damping and generally better valve performance characteristics. The improved damping characteristics produce stable operation, fast response and reduce operational noise of the valve without introducing sluggishness or insensitivity in its operation.

The invention contemplates at least a two-stage resilient biasing member within the valve arranged to exert a biasing closing force on the control member or poppet. One stage of the biasing member is damped while the other is undamped. Compression of the damped stage requires longer duration pressure signals, while the other undamped stage is capable of moving quickly in response to pressure surges acting on the control member.

In the preferred embodiment, a relief valve is provided with two springs which are compactly arranged with the damped spring acting through and with the undamped spring to bias the control member to a closed position. Movement of the control member through pressure actuation sequentially causes compression of the undamped spring and then the damped spring. The damped spring acts as the seat or reaction member to the undamped spring during its compression. Damping of the one spring is achieved through the use of a hydraulic dashpot.

A primary advantage of my invention resides in providing a relief valve which retains the responsiveness of a valve having undamped biasing while eliminating the instability normally associated with undamped biasing means. The valve of the present invention has particular application in systems where the exhaust or discharge is at some predetermined back pressure above atmospheric. These advantages are achieved while still retaining a flat pressure versus flow characteristic desirable in such valves.

Further advantages and features of the invention are set forth in the following detailed description and accompanying drawing which is a longitudinal section of a fluid pressure relief valve embodying the invention.

More particularly, the drawing illustrates a portion of a fluid pressure device **10** having a high pressure chamber **11** and a low pressure fluid return chamber **12** communicating with a reservoir of low pressure fluid. For example, **10** may be a portion of a control valve having supply duct **11** and return passageway **12**. Cartridge-type relief valve **13** embodying the present invention is threadably secured to the device **10** and extends through bore **14** to hydraulically communicate with chambers **11** and **12** and functions to selectively divert fluid from chamber **11** to chamber **12** and prevent overpressurization of chamber **11**.

Relief valve **13** has a two-piece housing including casing **15** which receives closure member **16**. Interior bores **17** and **18** are provided in members **15** and **16**, respectively. Cross bores **19** and **20** in valve housing sections **15** and **16** are open to the high and low pressure chambers **11** and **12**, respectively, and serve as inlet and outlet openings through the valve. Held within closure **16** by snap ring **21** is seat **22** which is bored to sealingly receive the frustoconical outer surface **27** of poppet **23** in the valve closed position as illustrated. Poppet **23** is movable within internal bore **17** of member **16** and has a central bore **24** extending through the poppet. The left end of poppet **23** is provided with outlet openings **25** which place bores **24** and **18** in communication and permit selective communication between chambers **11** and **12** through bore **24** and opening **25**. Appropriate sealing members **26** retard leakage from chamber **11**.

The outer portion of conical face **27** of poppet **23** is exposed to the associated pressure in chamber **11** through passage **19**. Sufficient imposed pressure tends to urge the poppet leftwardly away from seat **22** to an open position permitting fluid flow to be relieved from passage **19** through bore **24** to low pressure chamber **12**. This hydraulic opening force is opposed by the biasing means, designated generally at **28**, contacting the poppet to urge it to the closed seating position.

The improved biasing means **28** of the present invention comprise two helical compression springs **29** and **30** situated in passage **18** and sequentially arranged to extend between the closed end of cartridge **15** and poppet **23**. Interiorly located pin **31** having an enlarged diameter flange **32** is interposed between the springs, and a conically ended body portion extends forwardly toward poppet **23**. The conical end on pin **31** acts as a flow deflector to assist and redirect fluid flowing from chamber **11** axially through bore **24**, outwardly through the coils of spring **29**, which compresses and reduces flow area as the poppet opens, and notches **25** to crossbores **20** and chamber **12**.

Flange **32** is circular conforming to bore **18** and defines at its periphery, in cooperation with the internal diameter of bore **18**, an annular restriction at **35**. Two variable volume fluid chambers **33** and **34** are in communication through restricted passage **35** formed between flange **32** and the wall of bore **18**. A sufficient number of outlet apertures **20** are included in cartridge **15** so that chamber **33** openly communicates with low pressure passage **12**. On the other hand, fluid can escape from chamber **34** only through annular restriction **35**, thereby creating a hydraulic damping chamber or dashpot **34** limiting the speed of compression of spring **30** and speed of movement of poppet **23**. Annular restriction **35** is sized to provide the desired damping characteristics and speed of movement of poppet **23**. The restricted hydraulic communication between chambers **33** and **34** can be provided through other constructions such as one or more properly sized orifice holes extending through pin **31**, or orifices directly communicating chamber **34** with low pressure passage **12**.

In the closed position shown, springs **29** and **30** are set to a predetermined compression by inclusion of one or more shims **36** to establish the desired closing bias force upon poppet **23**. As pressure in chamber **11** reaches the predetermined limit, the force exerted on poppet **23** overcomes the bias of springs **29** and **30** and moves the poppet leftwardly individually, an open position. Initially, spring **29** compresses slightly against flange **32** as the dashpot chamber **34** prevents sudden and immediate compression of spring **30**. Alone, spring **29** exhibits a relatively high spring gradient due to its relatively short length (that is, a closing force increasing very rapidly with spring compression) so that this initial movement, and the consequent flow relieved from chamber **11**, is limited. If the excessive pressure continues to be applied against poppet **23**, fluid in chamber **34** is given sufficient time to flow through restriction **35** to undamped chamber **33** and low pressure chamber **12**, allowing spring **30** to compress and flange **32** to move leftwardly. Moving together, the separate springs of biasing means **28** exhibit a lower gradient than either spring **29** or 30 individually, the gradient of biasing means 28 being approximately equivalent to that of a single spring of equal length. As a result, poppet 23 in a normal manner continues to open as far as necessary to relieve sufficient flow from chamber 11 to limit pressure therein, this continued poppet movement being damped and governed by fluid flow out of dashpot chamber 34.

Consequently, the spring biasing and damping means permit rapid, but limited, undamped movement of the poppet control member as well as a hydraulically damped and well controlled major opening response of poppet 23. The damping afforded by chamber 34 and the dual spring arrangement permits valve 13 to relieve large flows from chamber 11 without inducing poppet instability, pressure overshoot and oscillation and attendant disadvantages typical of underdamped valves. The damping creates smoother, quieter operation, eliminates poppet chatter, reduces vibration and generally improves the valve operation and life.

The quick opening feature of this valve is particularly adapted to instant response to sudden, but brief, pressure surges and shocks experienced in chamber 11. In such instances, spring 29 compresses slightly against flange 32 and permits a limited flow out of chamber 11 and allows poppet 23 to quickly return to the closed position as pressure in chamber 11 is relieved. Such operation is distinctly advantageous over previous designs where such pressure surges created improper poppet response. Prior valves, having damping characteristics similar to that exhibited by the present valve during compression of spring 30, would be so slowly responsive that the poppet would not react at all to the momentary pressure surge, resulting in excessively high pressure peaks and accompanying stress upon the pressure system. On the other hand, previous valves designed to respond to such pressure surges have inherently been underdamped and unstable; when responding to normal pressure forces and not to surges, the poppet would move open too far, relieve too much fluid and cause consequent drop in pressure in chamber. Such action in many instances induced oscillation of the poppet member. The present valve, however, provides quick opening to prevent high pressure peaks in chamber 11 without inducing poppet oscillation and chatter.

It can thus be seen that the present invention provides a novel biasing means that is provided with intermediate damping staging the biasing effect. The one stage is undamped and sensitive to high frequency movements while the damped stage is sensitive to lower frequency, longer duration poppet movements. Such biasing more nearly matches the requirements of pressure chamber 11 and reduces poppet chatter and unwanted oscillation.

The present invention has been found capable of being incorporated in standard valves to replace a conventional single-spring bias, since the length of springs 29 and 30 together are approximately equivalent to the length of a corresponding single spring. This is due to the sequential arrangement of springs 29 and 30 whereby both are compressed to provide the control member biasing force. In fact, it has been found suitable in certain valves to split an existing spring into two sections, a smaller section 29 and larger section 30 to produce the improved biasing members.

To prove the effectiveness of the improved relief valve design, a valve according to the invention was designed and tested in comparison to a conventional valve identical in design save for a conventional single spring biasing means. The conventional valve had excellent response characteristics to shock loading as determined by a very low peak pressure overshoot, about 2,000 p.s.i. peak pressure when adjusted to "crack" or open at 1,750 p.s.i. As inherent to many such fast response valves, the conventional valve was underdamped and oscillated creating excessive wear and undue noise. This was reflected in the wide band of pressure variation, about 1,000 p.s.i., occurring in the high pressure chamber.

The improved valve incorporated helical coil springs 29 and 30, both having a wire diameter of 0.103 inches. Spring 30 had a spring rate of 772 pounds/inch and was 0.780 inches long, while spring was 0.615 inches long having a spring rate of 1,080 pounds/inch. Bore 18 was nominally 0.519 inches in diameter with circular flange 32 being nominally 0.512 inches leaving an annular restricted passage 35 of 0.07 inches in width. In the test, the relief valve was installed and adjusted so that 1,750 p.s.i. opening pressure force in chamber 11 was required to "crack" the poppet open with a back pressure of 150 p.s.i. being maintained in exhaust chamber 12 by an appropriate needle valve. Pressure in chamber 11 was continually monitored as a shock load having a pressure rate of about 100,000 p.s.i./second was created in chamber 11. Upon opening in response to the shock loading, my improved valve maintained a variation in pressure in chamber 11 of only about 250 p.s.i. with a peak pressure of about 2,000 p.s.i., substantially duplicating the fast response performance of the conventional valve under the same conditions. The increased stability, as evidenced by the reduced pressure fluctuation, eliminated the poppet chatter, oscillation and excessive operational noise prevalent in operation of the conventional valve. Thus, the test illustrated the effectiveness of this invention in providing adequate damping for a fast response valve without introducing sluggishness or increasing pressure peaks and overshoot.

The invention has been specifically shown and described as it is incorporated in a high pressure relief valve to provide proper damping without introducing sluggishness or insensitivity to its operation. The invention may be similarly utilized in other types of pressure-actuated, spring-biased valves, and accordingly, the foregoing specification is to be considered exemplary in nature and not limiting to the scope and spirit of the invention as set forth in the appendaged claims.

I claim:

1. A fluid relief valve comprising:

a. a body member defining a chamber therein and having an outlet and inlet, said body adapted to be connected to a housing with said inlet being exposed to fluid at high pressure,

b. an interior seat within said chamber,

c. an axially movable pressure-responsive poppet in said chamber, said poppet in a closed position abutting against said seat and adapted to move away from said seat upon establishing predetermined high pressure at said inlet thereby placing said inlet and outlet in hydraulic communication; and

d. biasing means in said chamber urging said poppet to a normally closed position, said biasing means being comprised of an undamped member and a damped member, said undamped member being responsive to initial application of predetermined pressure to permit limited undamped opening of said poppet and said damped member being responsive to continued application of said predetermined pressure to permit further damped opening of poppet thereby substantially reducing instability of said valve.

2. The relief valve of claim 1 wherein said first and second members of said biasing means comprise helical compression springs.

3. The relief valve of claim 1 wherein said first and second members of said biasing means comprise compression springs separated by a slidable partition dividing the chamber into first and second fluid chambers respectively containing said first and second biasing means, said partition adapted to restrict fluid flow from said first chamber whereby compression of said first biasing means is hydraulically damped.

4. A fluid relief valve comprising:

a. a body member defining a chamber therein and having an outlet and inlet communicating with said chamber, said body adapted to be connected to a housing with said inlet being exposed to fluid at high pressure,

b. an annular interior seat within said chamber,

c. an axially movable pressure-responsive poppet in said chamber having a passageway therein coaxial with said bore, said poppet in a closed position abutting against said seat and adapted to move away from said seat upon establishing predetermined high pressure at said inlet thereby placing said inlet and outlet in hydraulic communication through said passageway, and

d. biasing means extending between said body and said poppet urging said poppet to a normally closed position, said biasing means being comprised of a damped member adjacent said body member and an undamped member adjacent said poppet, said undamped member being initially responsive to initial application of predetermined pressure to permit movement said poppet from said seat and said damped member being responsive to continued application of predetermined pressure whereby both said members sequentially compress to permit further opening of said poppet thereby substantially reducing instability of said valve.

5. A pressure relief valve comprising:

a. a housing member defining a central chamber closed at one end and having a fluid inlet communicating with said bore and a fluid outlet communicating with said bore intermediate the inlet and said closed end,

b. a poppet member movably disposed in said bore and cooperating with a seat to control flow therethrough from the inlet to the outlet, said poppet having a surface portion arranged whereby predetermined fluid pressure associated with the inlet exerts an opening force on said poppet urging same to an open position permitting flow from the inlet to the outlet,

c. a divider plate in said bore intermediate said closed end and said poppet closely cooperating with the bore wall to define in said bore first and second fluid chambers respectively extending axially from the closed end to said plate and from said plate to said poppet, said second chamber being in open communication with said outlet,

d. flow restriction means permitting restricted fluid flow from the first to the second chamber,

e. first resilient means arranged in said first chamber between the closed end and dividing plate, and

f. second resilient means spring in said second chamber extending between said damping plate and said poppet, said first and second resilient means exerting a biasing force on the poppet to urge same to a normally closed flow-blocking position and normally cooperatively compressing upon actuation of the poppet by sufficient inlet pressure wherein poppet movement is hydraulically damped and whereby said second resilient means is capable of limited compression against said damping plate independent of first spring compression to permit undamped opening movement of said poppet.

6. The relief valve of claim 5 wherein said flow restriction means are formed as an annular restriction defined by said chamber and the periphery of said divider plate.

7. The relief valve of claim 5 wherein said damping plate includes a protuberant portion extending axially into said second chamber toward said poppet and having a conically formed end for diverting axially directed fluid flow from the inlet through said poppet central bore radially outwardly toward said outlet.

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