March 7, 1961 S. C. BAKER 2,973,778

HYDRAULIC VALVE

Filed Nov. 3, 1958

Fig. 1.

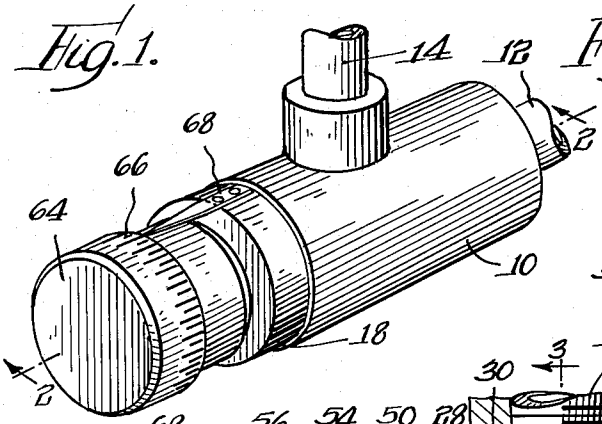


Fig. 3.

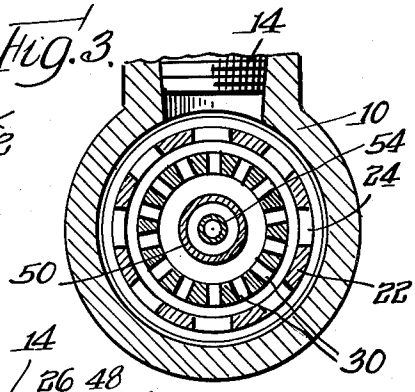


Fig. 2.

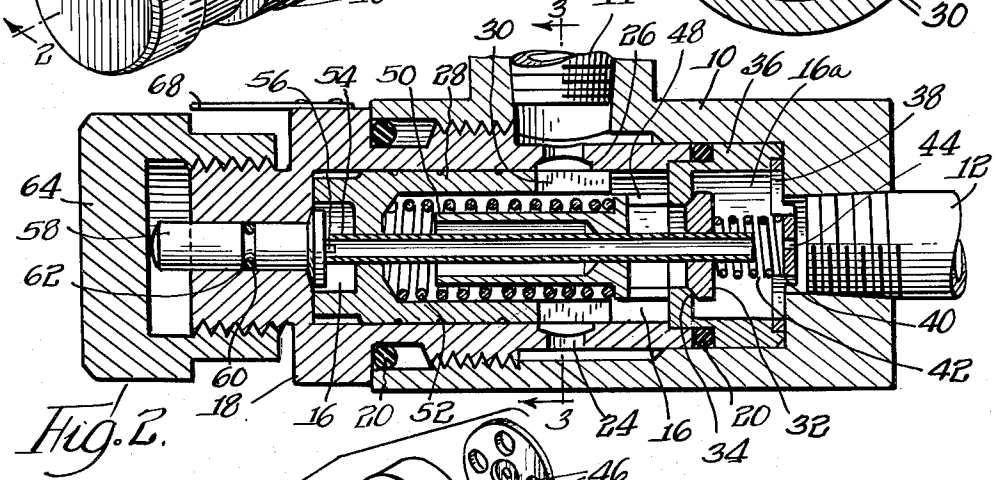


Fig. 4.

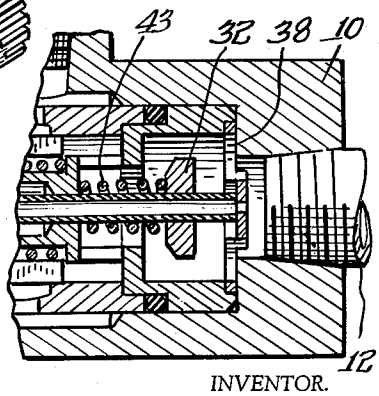
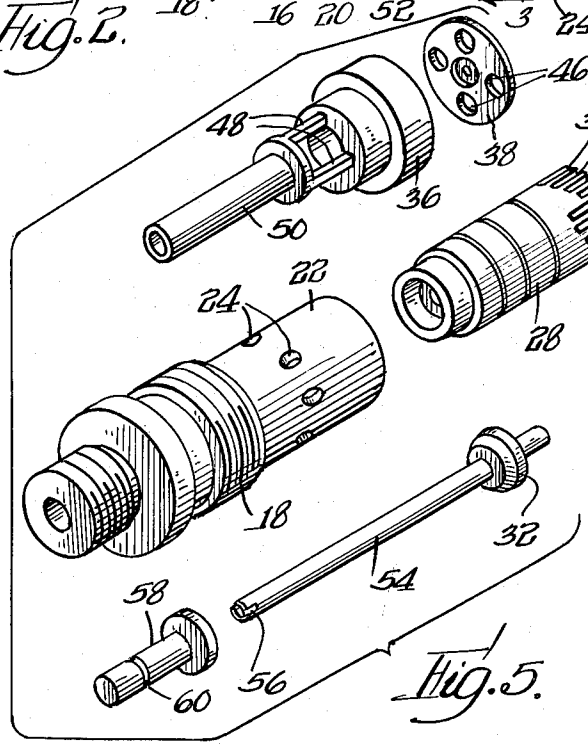


Fig. 5.



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HYDRAULIC VALVE

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9 Claims. (Cl. 137—501)

This invention relates to hydraulic valves in general and in particular to hydraulic valves intended to provide a constant rate of flow regardless of variations in the hydraulic pressure.

A number of situations exist wherein it is desirable to produce a constant rate of fluid flow regardless of the fluid pressure. One such situation arises with regard to the hydraulic lifts on fork-lift trucks. There it becomes desirable to have the forks or arms move at a constant rate irrespective of the loading and consequently irrespective of the working pressure in the hydraulic system which operates the arms.

Previous valves intended to serve this purpose have commonly included a piston slidably mounted in a valve body and adapted to regulate flow by variably obstructing a number of ports spaced radially about a sleeve surrounding the piston. These prior art valves have been beleagured by erratic performance caused by the phenomenon commonly referred to as "momentum forces." It has been found that there is a peculiar resolution of forces when fluid changes from axial flow to radial flow through a valve and is, in the process, cut off as by sliding a piston. When the edge of the piston approaches flow-cut-off position relative to the radial ports, the resolution of forces is such that the dynamic fluid pressure tends to move the piston quickly to cut off the flow. These resolved forces are referred to as "momentum forces"; and relatively large variations in the flow rate can result when they are at play.

It is therefore a general object of my invention to provide an improved hydraulic flow control valve which overcomes the prior art limitations by minimizing the results of momentum forces.

A further object of my invention is to provide a hydraulic flow control valve which is characterized by its ability to deliver a substantially constant rate of flow regardless of variations in the hydraulic pressure.

A still further object of my invention is to provide a hydraulic flow control valve which is adjustable to deliver a wide range of flow rates, each rate being substantially constant regardless of variations in hydraulic pressure.

Another object of my invention is to provide a hydraulic valve which automatically compensates for changes in the flow rate resulting from changes in the viscosity of the hydraulic fluid passing through the valve which changes in viscosity are due to changes in temperature.

Yet another object of my invention is to provide a hydraulic valve which delivers more nearly constant flow rates.

Still another object of my invention is to provide a hydraulic flow control valve which is characterized by free reverse flow.

Further objects and features of the invention pertain to the particular structure and arrangements whereby the above objects are obtained.

The structure in accordance with my invention includes a valve shell having an inlet and an outlet, flow regulating means adapted to adjust the rate of flow to desired values, and pressure compensating means including a piston having a plurality of longitudinal, varying-length slots disposed about one end, which compensating means provides throttling action in response to pressure unbalances caused by flow deviating from the desired rate.

The invention, both to its structure and mode of operation, will be better understood by reference to the following disclosure and drawings forming a part thereof wherein:

Fig. 1 shows a perspective view of a hydraulic valve in accordance with my invention;

Fig. 2 is a view through section 2—2 of the valve of Fig. 1;

Fig. 3 is a view through the section 3—3 of Fig. 2;

Fig. 4 is a detailed view of a different biasing arrangement for the poppet valve employed in my invention; and

Fig. 5 is an exploded perspective view of the internal elements of the valve of Fig. 1.

Referring now to the drawing, there is a valve shell or housing 10 having an inlet 12 and an outlet 14. These valve openings may conveniently be tapped to facilitate joining the valve shell or housing to the threaded ends of hydraulic lines. Within the housing 10 there is a valve chamber or passage interconnecting the inlet 12 and outlet 14. It should be noted that the inlet and outlet communicate with the chamber 16 at substantially right angles, the outlet being connected to the chamber 16 at substantially the mid-portion thereof.

A valve head 18 is threadedly mounted to the housing 10 opposite the inlet 12 and closing off the valve chamber 16. Sealing of the joint between head 18 and housing 10 may be effected by the employment of rubber O-rings 20 or other suitable gasketing elements.

The valve head 18 has an extended portion 22 which enters chamber 16 and acts as a sleeve. This extended portion or sleeve 22 is provided with a number of circumferentially spaced ports 24 which interconnect the chamber 16 with outlet 14. Sleeve 22 is further provided with an annular recess 26 disposed about its internal circumference in alignment with the ports 24 for purposes which will be brought out more fully hereinbelow.

A hollow piston 28 is slidably mounted in the sleeve 22 in order to regulate the fluid flow through the ports 24 as by variably obstructing the same. The piston 28 is provided with a series of longitudinal slots 30 disposed circumferentially about its open end. The length of these slots is varied in order to permit progressive closing off of the flow path. Further, the slots are varied in symmetrical fashion in order to provide a laterally balanced arrangement.

In one preferred form, the slots 30 may be varied in length according to a pair of similar helices. This configuration is best shown in Fig. 5. The slots 30 are arranged so that only the ends of two diametrically opposite slots can be closed off at the ports 24 at any one time. This arrangement of the slots 30 is provided in order to minimize the effect of momentum forces. With regard to minimizing the momentum forces, I have found it advantageous to use a large number of comparatively narrow slots.

Arranging the slots 30 in two helical configurations is important for providing a laterally balanced structure. However, configurations other than helical may be employed so long as there is a progressive closing-off of the flow through the ports 24. It may be here pointed out that the problem of aligning the slots 30 with the ports 24 is obviated by the provision of annular recess 26 which supplies a manifold-type action.

In order to adjust the flow rate, I provide a poppet valve 32 intended to close against the valve seat 34 which is carried in the collar 36. In conjunction with

the collar 36 there is shown a washer 38 having a recessed portion 40 which acts as a seat for the spring 42 employed to bias the valve 32. The strength of spring 42 is selected so that, in the absence of inlet fluid pressure, valve 32 is not closed tightly against seat 34. Washer 38 is advantageously provided with a small hole 44 and a number of larger holes 46 which permit passage of the hydraulic fluid from the inlet 12 to chamber 16.

For directing the fluid flow, a number of spaced-apart posts 48 are securely affixed to the collar 36. Posts 48 terminate in a flanged tube 50 which serves as a seat and a guide for the spring 52, spring 52 providing bias and damping for the piston 28.

The poppet valve 32 is securely fastened to a hollow tube 54, as for example by silver soldering, the hollow tube 54 being arranged to slide freely through the flanged tube 50 and the piston 28. The tube 54 is provided with a transverse slot 56 for purposes which will be brought out hereinbelow. The end of tube 54 containing the slot 56 abuts a plunger 58 slidably mounted within the valve head 18. In order to accomplish a seal, plunger 58 is provided with an annular groove 60 which is adapted to accept an O-ring 62 or some other suitable gasket.

In cooperation with the plunger 58, a cap 64 is threadedly mounted to the valve head 18. Cap 64 may be provided with a number of flow-calibrating grooves 66. An indicator 68, securely fastened to the head 18, is adapted to cooperate with the grooves 66 in providing an indication of the position of plunger 58 and therefore an indication of the position of the poppet valve 32 relative to the valve seat 34.

It should be noted that the poppet valve 32 is not limited to the biasing arrangement shown in Fig. 2 wherein the valve is biased against the valve seat. Another advantageous biasing arrangement is shown in Fig. 4. There the poppet valve 32 is biased by the spring 43 against the hydraulic fluid entering through inlet 12. In this latter arrangement, the poppet valve 32 is biased into an open position in order to ensure relatively free flow of the hydraulic fluid up to the value determined by the position of plunger 58.

Furthermore, in cases where it is desired to provide a particular pattern of fluid flow the plunger 58 need not cooperate with cap 64 as shown. Rather the plunger 58 may cooperate with a rotating cam which has been designed to program the particular flow pattern that is desired.

The temperature of the hydraulic fluid passing through my valve may change from time-to-time due to a number of causes. As the temperature of the fluid increases, the viscosity decreases and, as a result, the rate of flow increases. The situation is reversed when the temperature of the fluid decreases.

When it is desired to compensate for these changes in flow rate resulting from changes in temperature, I select the materials for fashioning the various elements of my valve to display different coefficients of thermal expansion. In one specific embodiment, I have found it advantageous to have the valve shell, the valve head, the cap, the valve seat, the collar and the piston made from aduminum while having the remaining parts made from steel.

Upon an increase in temperature, the aluminum parts expand at a faster rate than those of steel. As a consequence, the valve seat tends to close the gap between itself and the poppet valve faster than the plunger and the hollow tube tends to open the gap. Thus, the flow is somewhat restricted, compensating for the increased flow resulting from the decreased viscosity. When temperature decreases, the reversed situation holds true.

For purposes of providing an easy understanding of the invention, it is advantageous to provide at this juncture a functional description of the mode by which the component members operate. Assuming that the valve has been regulated to the desired flow rate, as by adjusting the position of poppet valve 32 relative to valve seat 34 through the action of cap 64 on plunger 58 which action is, in turn, transmitted through the tube 54 to the poppet valve 32, the flow path can be defined as follows. Fluid pasing through the inlet 12 enters the valve chamber portion shown as 16*a*, through the holes 46 and the hole 44; thence it passes around the poppet valve 32, across the valve seat 34, through the posts 48 and into the slots 30; from there it flows into the annular recess 26 and through the ports 24 into the outlet 14.

It should also be pointed out that fluid may flow from the chamber portion 16*a*, through the hollow tube 54, out of the slot 56 and into the chamber portion 16*b* defined by the piston 28. This latter fluid path enables my valve automatically to compensate for pressure unbalances by flow deviating from the desired rate. For example, if for any reason the pressure within the piston drops to a value permissive of too rapid an outlet flow, there is an accompanying pressure drop across the valve seat.

Under such circumstances, the inlet pressure which is exerted in the chamber portion 16*b* will exceed the outlet pressure manifest on the opposite side of the closed end of piston 28. As a result, the piston will be shifted in the general direction of the valve seat; and the slots 30 will partially close off the ports 24, restricting the outlet flow, thereby bringing the pressure back into balance, and re-establishing the desired rate of flow. Contrariwise, when the inlet pressure is less than the outlet pressure, this differential will appear across the closed end of the piston 28 and the piston will be moved so that the slots 30 unblock, to an appropriate degree, the ports 24. It should also be pointed out that the pressure-responsive nature of the arrangement of piston 28 permits my valve to realize free, i.e., unthrottled reverse flow.

The drawings and the above description are not intended to represent the only possible forms of my invention in regard to details of construction. Changes in form and in the proportion of parts as well as the substitution of equivalents are contemplated as circumstances may suggest or render expedient; and although specific terms are employed, they are intended in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being defined in the following claims.

The invention is claimed as follows:

1. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating with said chamber; a valve head secured to said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet; pressure compensating means including a hollow piston slidably arranged with said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston selectively obstructing said ports; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve.

2. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating with said chamber; a valve head secured to said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet; pressure compensating means including a hollow piston slidably arranged

with said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve.

3. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating at right angles with said chamber at substantially the midportion thereof; a valve head threadedly engageable with said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet; pressure compensating means including a hollow piston having a closed end and an open end slidably arranged within said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve.

4. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating at right angles with said chamber at substantially the midportion thereof; a valve head threadedly engageable with said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet, said sleeve means further having an annular recess disposed about its internal circumference in alignment with said ports; pressure compensating means including a hollow piston having a closed end and an open end slidably arranged within said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports, said slots being disposed in symmetrical configuration; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve.

5. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating at right angles with said chamber at substantially the midportion thereof; a valve head threadedly engageable with said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet, said sleeve means further having an annular recess disposed about its internal circumference in alignment with said ports; pressure compensating means including a hollow piston having a closed end and an open end slidably arranged within said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports, said slots being disposed in depth according to a pair of similar helices; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve.

6. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating at right angles with said chamber at substantially the midportion thereof; a valve head threadedly engageable with said housing and forming within said housing sleeve means including a plurality of circumferentially spaced ports communicating said chamber with said outlet, said sleeve means further having an annular recess disposed about its internal circumference in alignment with said ports; pressure compensating means including a hollow piston having an open end and a closed end slidably arranged within said sleeve means, and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports, said slots being disposed in depth according to a pair of similar helices and said tube being adapted to establish the appearance of pressure unbalances across the closed end of said piston in accordance with errors in fluid flow; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve.

7. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating at right angles with said chamber at substantially the midportion thereof; a valve head threadedly engageable with said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet, said sleeve means further having an annular recess disposed about its internal circumference in alignment with said ports; pressure compensating means including a hollow piston having a closed end and an open end slidably arranged within said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports, said slots being disposed in depth according to a pair of similar helices; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve, wherein variations in flow resulting from changes in temperature are compensated for by employing materials of different coefficient of thermal expansion.

8. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating at right angles with said chamber at substantially the mid-

portion thereof; a valve head threadedly engageable with said housing and forming within said housing sleeve means having a plurality of circumferentially spaced ports communicating said chamber with said outlet, said sleeve means further having an annular recess disposed about its internal circumference in alignment with said ports; pressure compensating means including a hollow piston having a closed end and an open end slidably arranged within said sleeve means and a hollow tube having a slotted end extending slidably through the closed end of said piston, said piston having disposed about its open end a plurality of longitudinal, varying-length slots adapted to cooperate with said ports, said slots being disposed in depth according to a pair of similar helices; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite to its slotted end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the slotted end of said tube, and a cap threadedly engageable with said valve head and adapted to cooperate with said plunger and said tube in operating said poppet valve, wherein variations in fluid flow resulting from change in temperature are compensated for by forming said housing, said valve head, said cap, said valve seat and said piston from aluminum and said tube, said poppet valve and said plunger from steel.

9. A hydraulic flow control valve comprising: a housing having an inlet, a valve chamber communicating coaxially with said inlet, and an outlet communicating with said chamber; a valve head secured to said housing and forming within said housing sleeve means having at least one radially opening port communicating said chamber with said outlet; pressure compensating means including a hollow piston slidably arranged with said sleeve means and a hollow tube having a transversely apertured end extending slidably through the closed end of said piston, said piston selectively obstructing said port; and flow regulating means including a valve seat affixed within said chamber facing said inlet, a spring-biased poppet valve mounted on said tube opposite its apertured end and tending to close said valve seat, a plunger extending slidably through said valve head and abutting the apertured end of said tube, and selectively adjustable means on said valve head adapted to cooperate with said plunger and said tube in operating said poppet valve.

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