United States Patent

[11] 3,599,675

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[21] Appl. No. 9,201
[22] Filed Feb. 6, 1970
[45] Patented Aug. 17, 1971
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[54] **PROPORTIONAL VALVE**
18 Claims, 7 Drawing Figs.

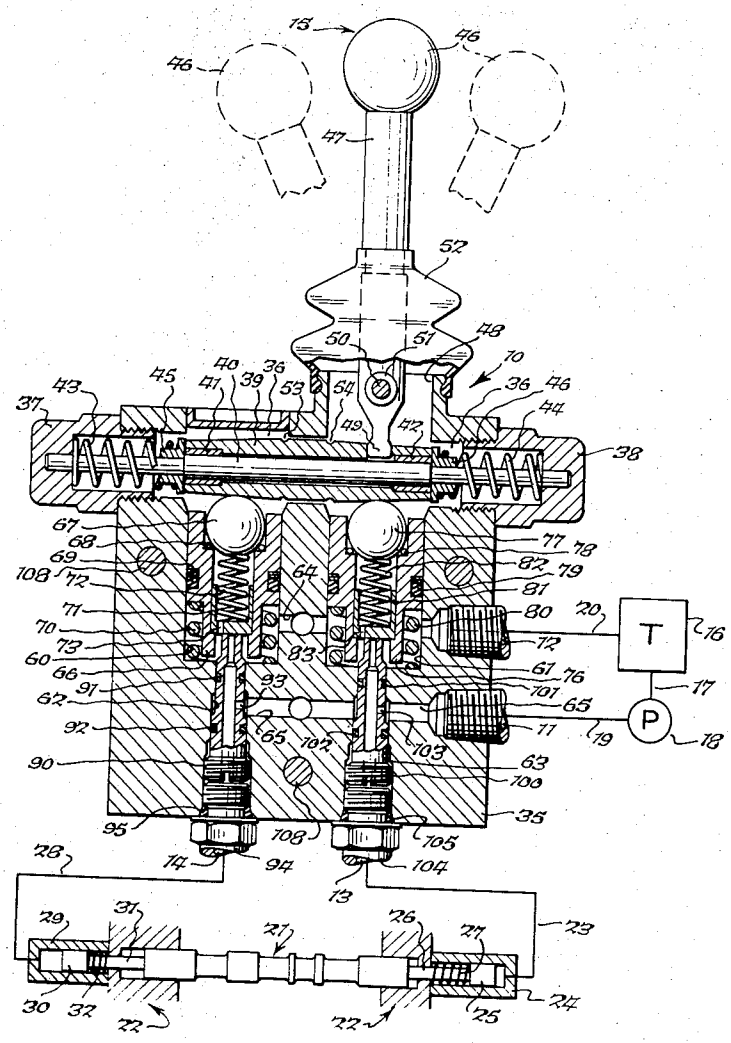
[52] U.S. Cl. 137/636.1, 137/596.2, 137/625.6
[51] Int. Cl. F16k 11/10
[50] Field of Search 137/625.6, 625.63, 625.64, 625.66, 636.1, 596.2

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ABSTRACT: A control valve adapted to be connected in an hydraulic circuit including two cylinders movable against corresponding linear springs and connected to opposite ends of a mechanical load, such as the spool of a master valve in a relatively high-pressure circuit. Fluid from either of two chambers in the control valve connected to corresponding ones of the hydraulic cylinders is bled to a tank or reservoir in proportion to the movement of a control valve handle. The resulting pressure unbalance creates proportionate movement of the mechanical load. Flow controlling means in the form of a first poppet member and a second poppet carried in the first poppet and axially movable therein are in each of the valve chambers and moved from a seated to an unseated position allowing bleedoff of fluid. The poppets are spring-biased and operatively connected through a ball or roller-type follower to a tapered, elongated cam member axially movable and operatively connected to the valve handle. Two additional chambers and corresponding flow controlling means can be included and to which are transmitted additional movements of the valve handle whereby a single hydraulically movable load can be controlled in a plurality of directions or two loads controlled separately or interdependently.



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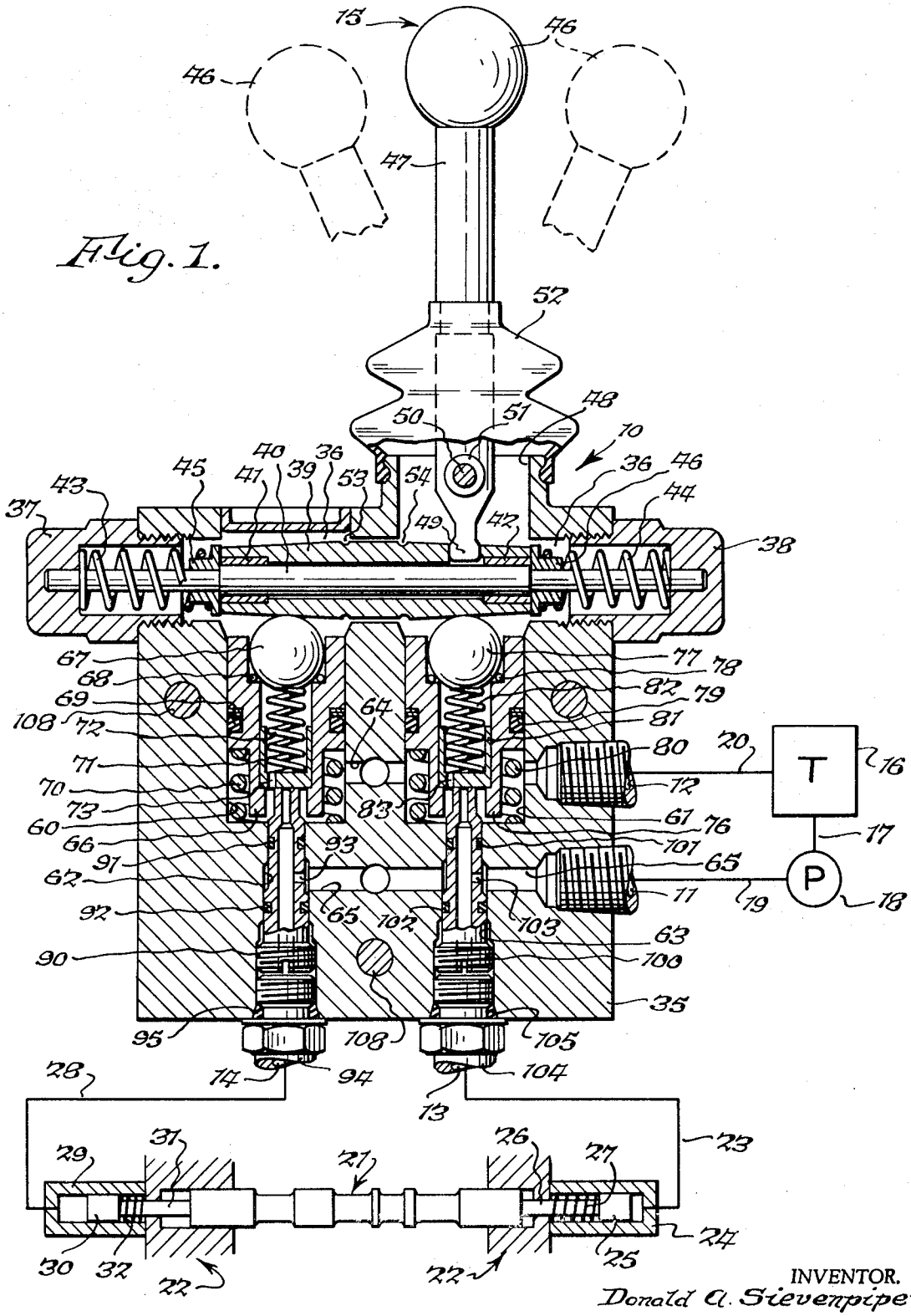


Fig. 1.

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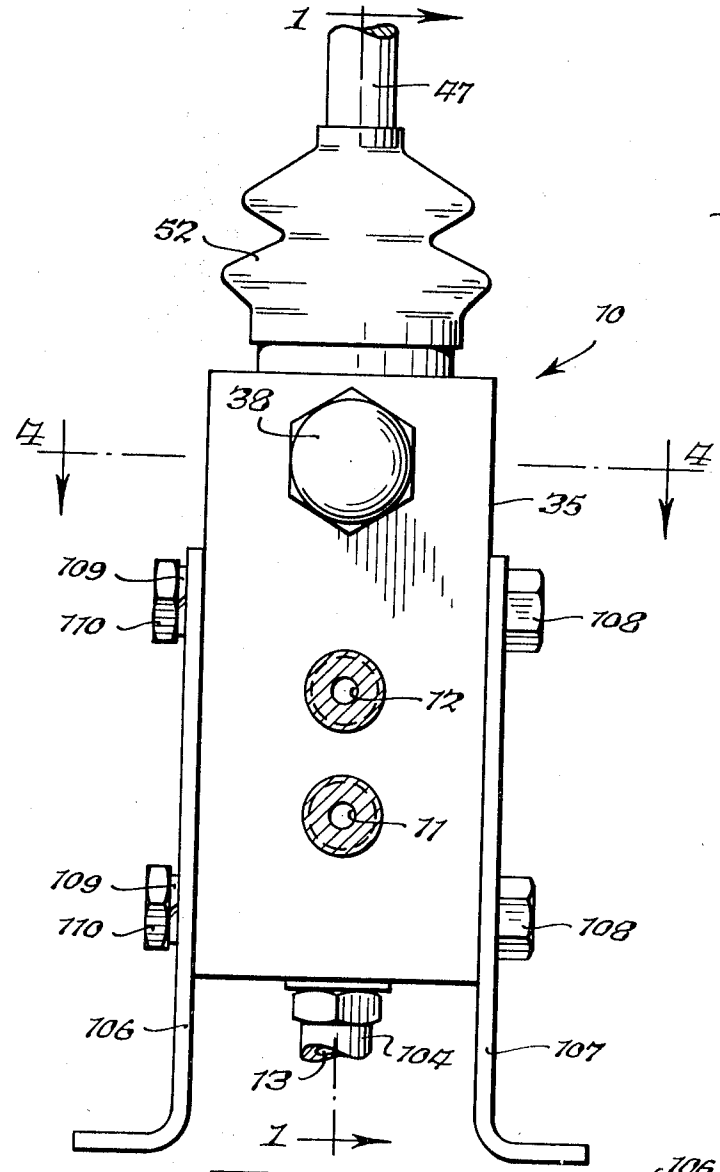


Fig. 2.

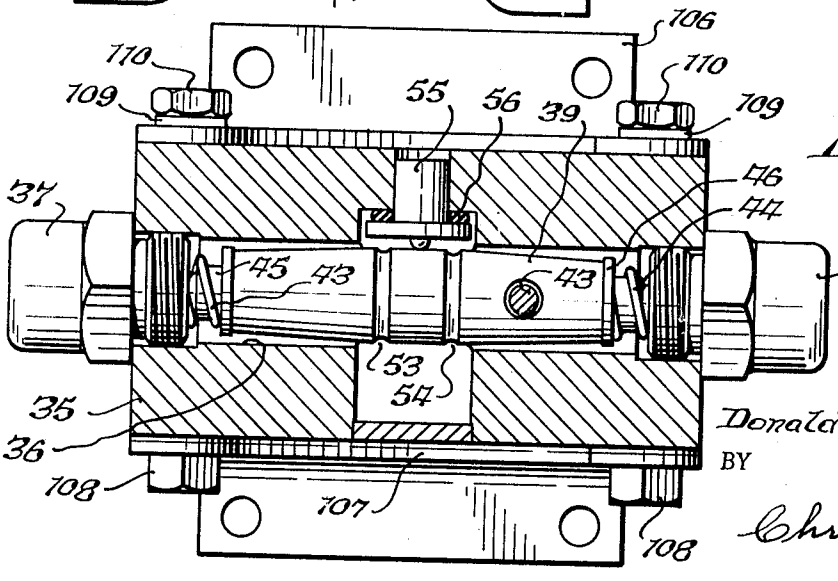


Fig. 4.

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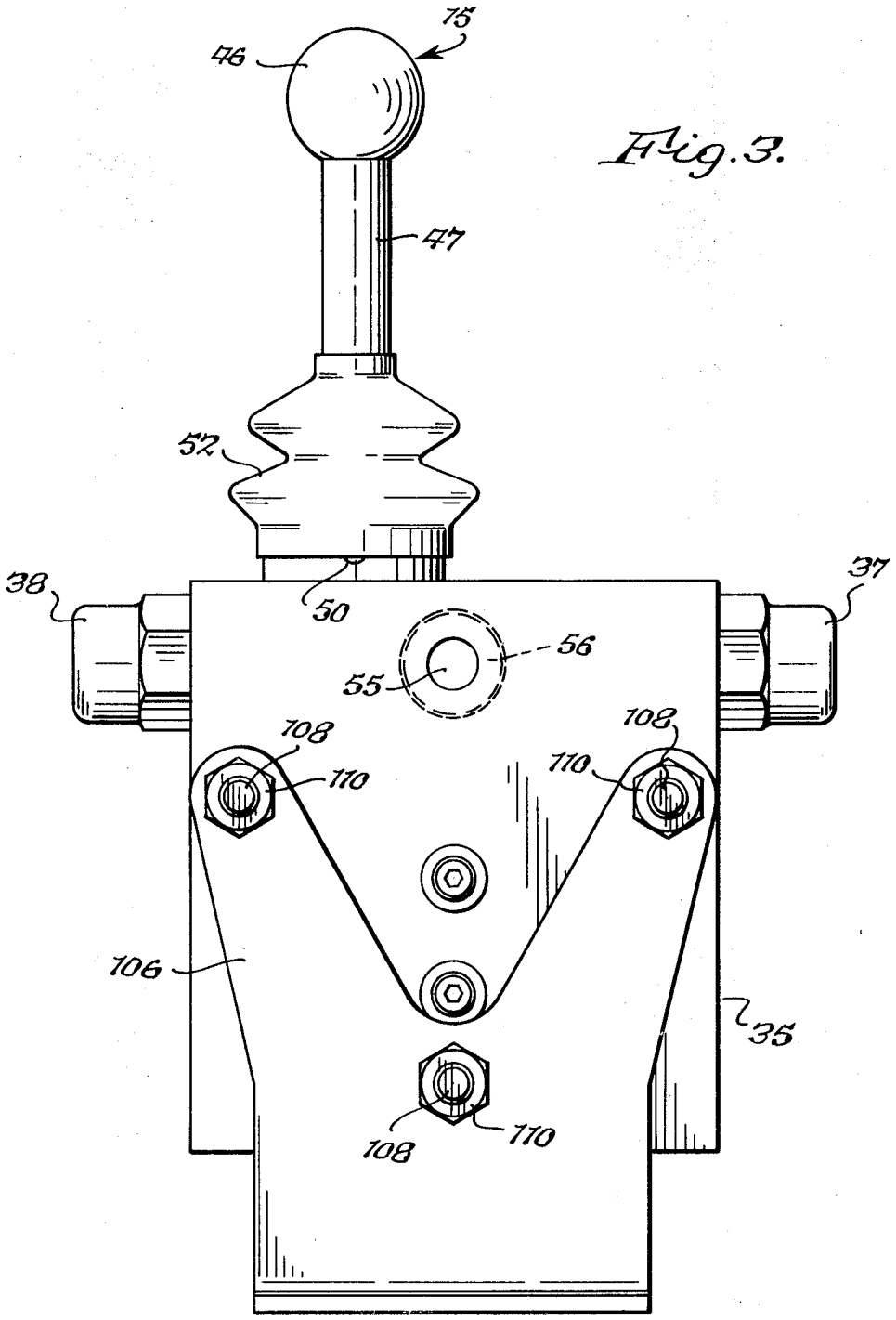


Fig. 3.

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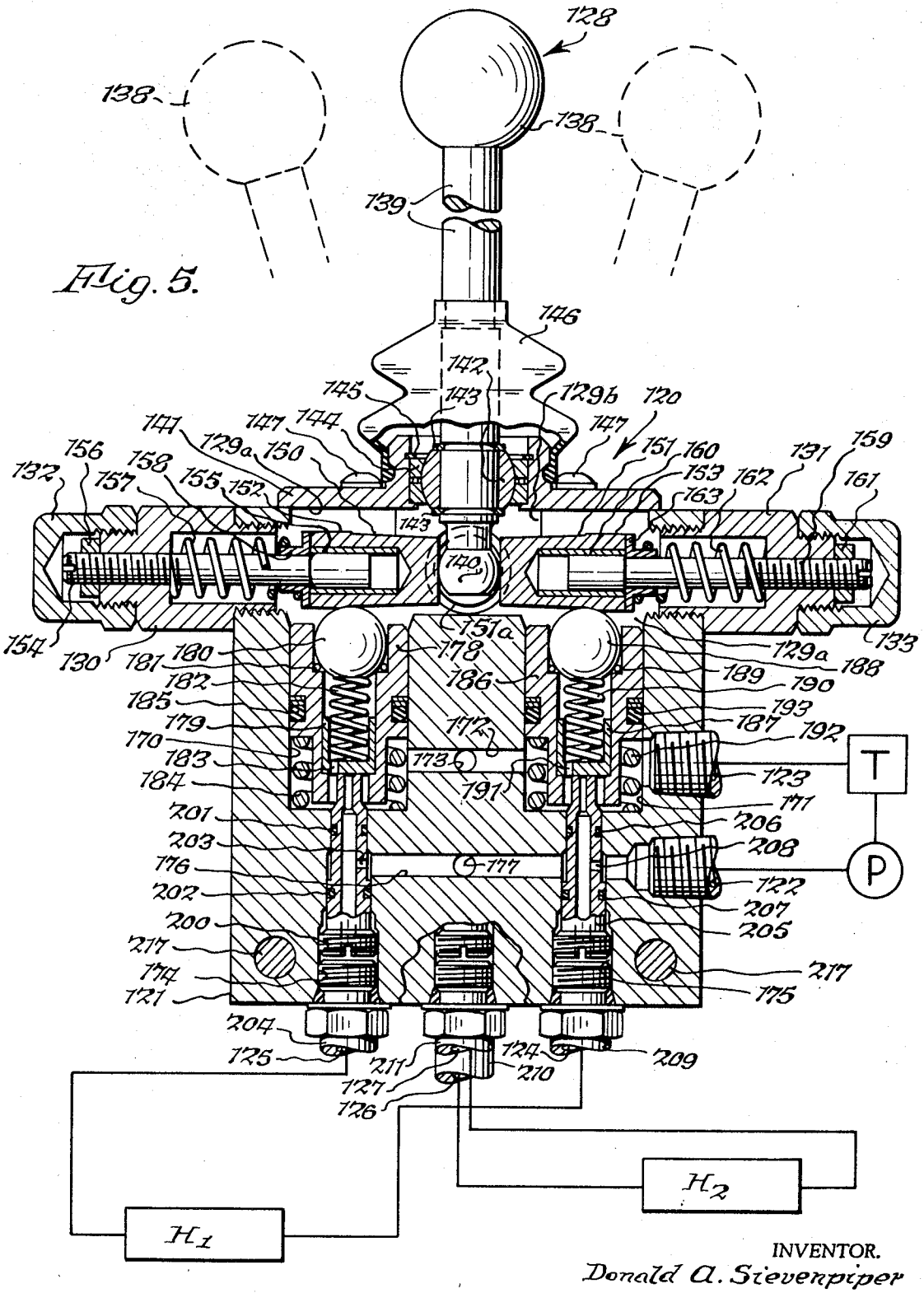
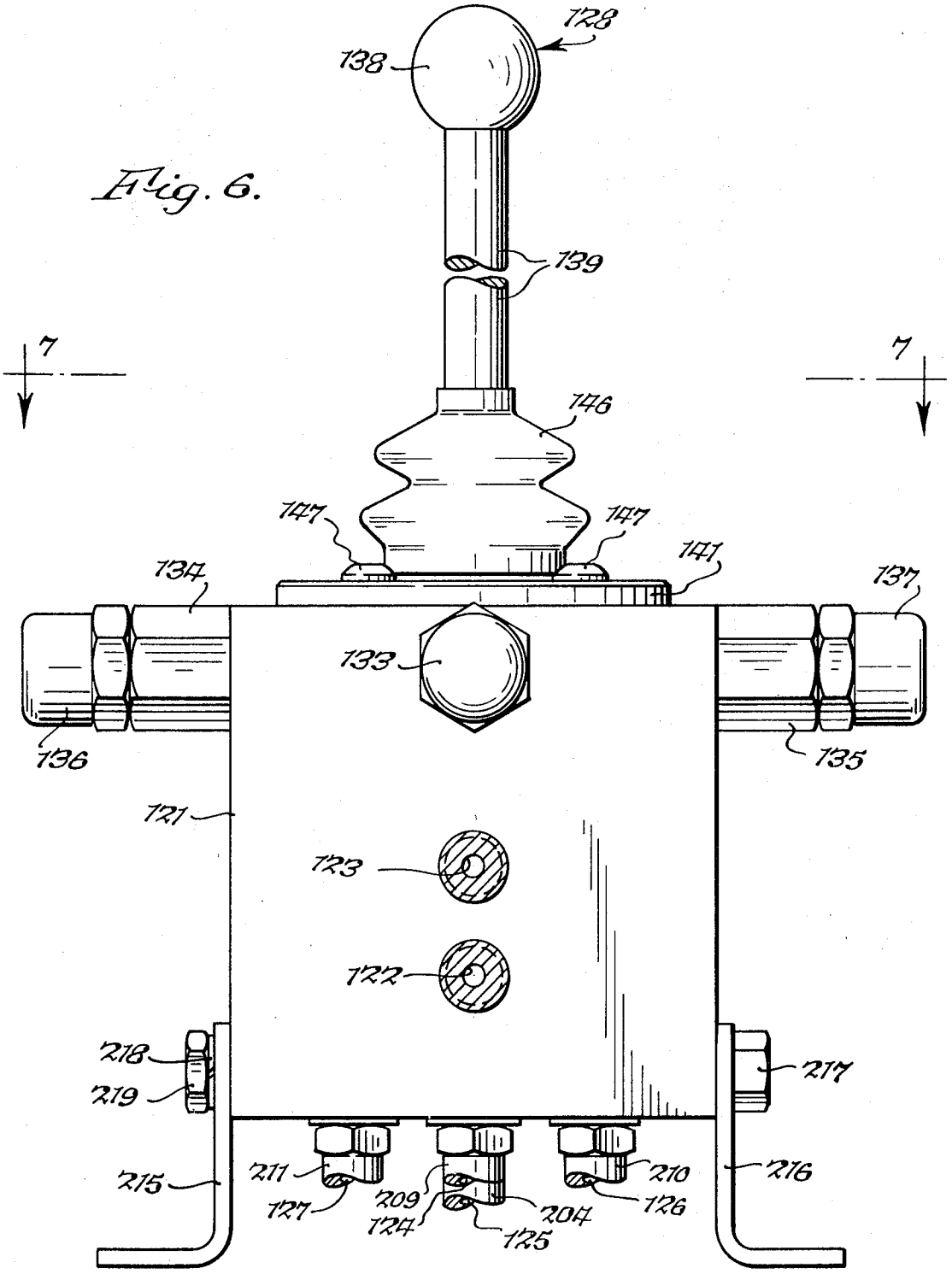


Fig. 5.

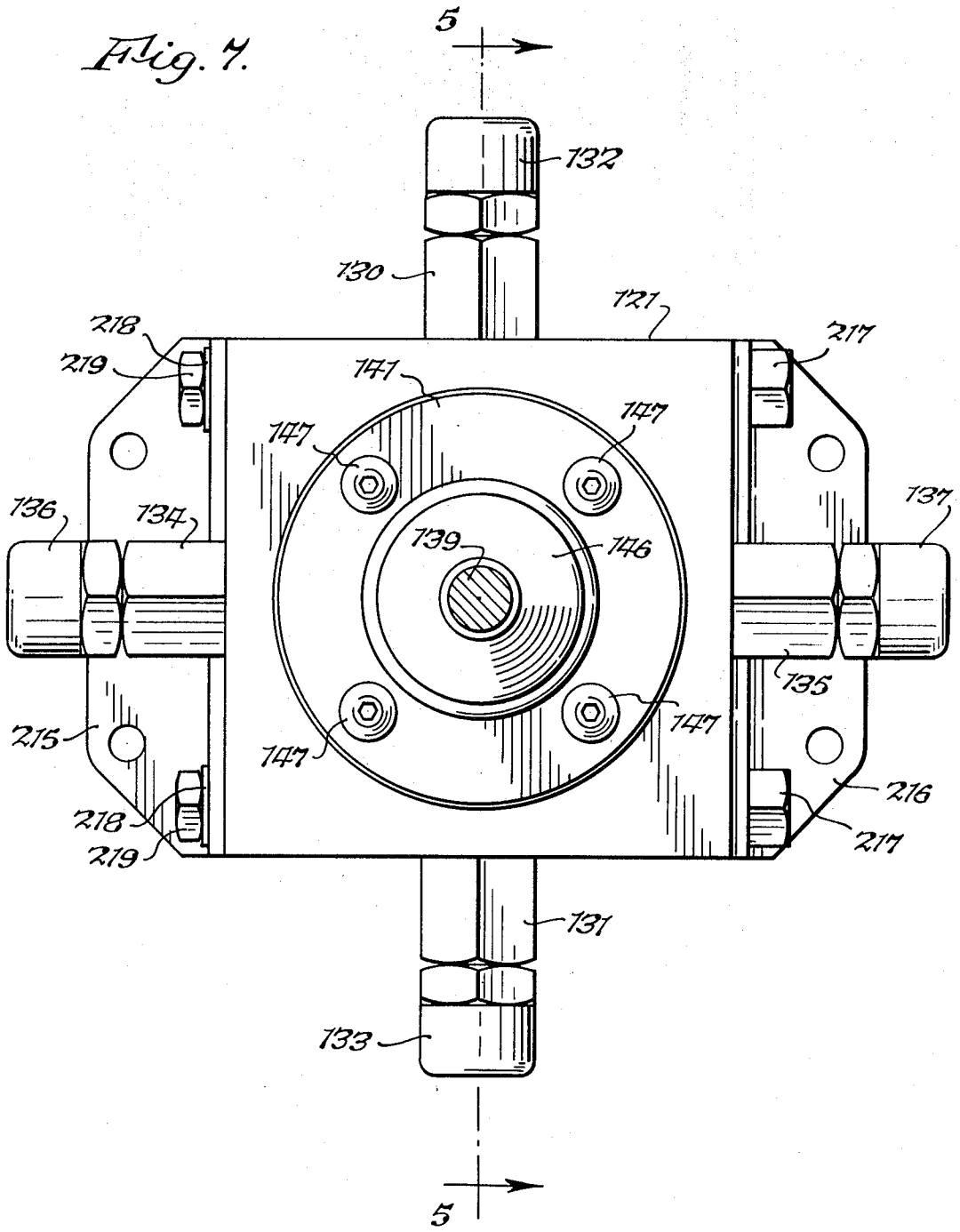
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Fig. 6.



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Fig. 7.



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PROPORTIONAL VALVE

BACKGROUND OF THE INVENTION

The present invention relates to the valve art and, more particularly, to a valve for controlling the position of a fluid-actuated device or component proportionally in response to a manual input.

The control of high-pressure hydraulic power by a manually operated control valve connected in the main or primary hydraulic circuit undesirably requires excessive human effort and frequently precludes an accurate correspondence between movement of the valve handle and movement of the hydraulically actuated device. A proposed solution is the addition of a low pressure, secondary or pilot hydraulic circuit under control of a manually operated pilot valve, which circuit would power a main or master valve connected in the high-pressure circuit. For this arrangement to be most effective in many situations, the pilot valve should provide a proportional control whereby movements of the pilot valve handle produce proportionate movements of the hydraulically actuated device. Moreover, this should occur with little required manual effort in moving the valve handle. In addition, practical considerations often dictate that such results be obtained with a quick response time and with a valve construction which is reasonably simple to manufacture and maintain.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an improved valve for controlling the position of a fluid-actuated device proportionally in response to a manual input.

It is a more particular object of this invention to provide such a control valve wherein movements of the valve handle produce proportionate movements of the hydraulically actuated device and with little required manual effort in moving the handle.

It is a further object of this invention to provide such a control valve operable with a relatively short response time and of a construction which is relatively simple to manufacture and convenient to maintain.

It is a further object of this invention to provide such a valve for controlling either a single fluid-actuated component in a plurality of directions or a plurality of components separately and interdependently.

The present invention provides a control valve adapted to be connected in an hydraulic circuit including two cylinders movable against corresponding linear springs and connected to opposite ends of a mechanical load such as the spool of a main valve in a relatively high pressure and high flow hydraulic circuit. Fluid from either of two chambers in the control valve which are connected to corresponding ones of the hydraulic cylinders is bled to a tank or reservoir in proportion to the movement of a handle of the control valve. The resulting pressure unbalance creates proportionate movement of the external device. Flow controlling means in each of the valve chambers are selectively and independently moved from a seated to an unseated position allowing bleedoff of fluid response to movements of the valve handle which are transmitted to the flow controlling means. Alternatively, two additional chambers and corresponding flow controlling means can be included to which are transmitted additional movements of the valve handle whereby a single hydraulically movable load can be controlled in a plurality of directions or two loads controlled separately or interdependently.

The foregoing and additional advantages and characterizing features of the present invention will become clearly apparent upon a reading of the ensuing detailed description of two illustrative embodiments thereof together with the included drawing depicting the same.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a longitudinal, cross section view of one embodiment of the control valve of the present invention taken about on line –1 of FIG. 2 and showing the manner whereby it is connected in an hydraulic circuit for moving the spool of a separate valve;

FIG. 2 is an end elevational view of the control valve shown in FIG. 1;

FIG. 3 is a side elevational view thereof;

FIG. 4 is a sectional view taken about on line 4–4 in FIG. 2;

FIG. 5 is a longitudinal, cross section view of another embodiment of the control valve of the present invention taken about on line 5–5 of FIG. 7 and showing the manner whereby it is connected to two hydraulically movable loads for controlling movements of the same;

FIG. 6 is a side elevational view of the control valve shown in FIG. 5; and

FIG. 7 is a plan view taken about on line 7–7 in FIG. 6.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

FIG. 1 shows one embodiment of the present invention connected in an illustrative fluid system wherein it is advantageously employed. A control valve 10 constructed in accordance with the present invention is provided with an inlet port 11, a bleed or exhaust port 12 and first and second outlet ports 13 and 14, respectively. Manual operation of valve 10 is effected through a lever or handle designated generally at 15 in FIG. 1. Operating fluid for the circuit in which valve 10 is connected is stored in a tank or reservoir 16 and supplied through a line or conduit 17 to a pump 18 which, in turn, delivers operating fluid under pressure to valve 10 through a line 19 connected to pump 18 and to valve inlet port 11. A line 20 connects bleed port 12 of valve 10 to the inlet of reservoir 16 for a purpose to be described presently.

Valve 10 functions to control the position of a fluid-actuated device or component and the control is effected proportionately in response to movement of valve handle 15 with minimal manual effort. In this particular illustration the hydraulically movable load is the spool 21 of a valve 22 shown schematically in FIG. 1. Valve 22 would be connected in controlling relation to another fluid system or circuit and in most instances this system is characterized by a significantly high operating pressure and high flows relative to the pressure and flows controlled by valve 10. Valve 22 is of well-known construction wherein a plurality of axially spaced lands on spool 21 open and close internal passages communicating with various ports in response to axial movement of spool 21 in valve 22. A detailed description of the construction and operation of valve 22 therefore is believed unnecessary.

Spool 21 is moved axially relative to valve 22 by means of two hydraulic cylinders which, in turn, are controlled by valve 10. As shown in FIG. 1, outlet port 13 of valve 10 is connected by a line 23 to the interior of a cylinder 24 which houses a piston 25 movable axially therein. Piston 25 is operatively connected to one end of spool 21 by a rod 26, and a biasing spring 27 coaxial with rod 26 urges against piston 25 and the housing of valve 22. In a similar manner, outlet port 14 of valve 10 is connected by a line 28 to the interior of a cylinder 29 which houses a piston 30 movable axially therein. Plston 30 is operatively connected to the opposite end of spool 21 by a rod 31, and a biasing spring 32 coaxial with rod 31 urges against piston 30 and the housing of valve 22. The arrangement of springs 27 and 32 is shown schematically in FIG. 1, and in practice it is necessary to provide a shouldering arrangement for the springs whereby any tendency of the springs to offset each other is prevented and positive centering of spool 21 is assured.

Valve 10 comprises a body 35 of cast iron or similar material which is generally rectangular in shape. Valve body 35 is provided with a longitudinal chamber 36 therein extending through the entire length and located near the side or surface

into which handle 15 extends. Chamber 36 is closed at opposite ends thereof by axially spaced cap members designated 37 and 38 in FIG. 1. Chamber 36 houses an axially movable cam member 39 which is operatively connected to handle 15 and to the flow controlling elements included in valve 10. In particular, cam 39 comprises a generally hollow cylindrical element having a constant diameter axial bore therethrough and an outer diameter which is the same at both ends thereof but which increases slightly in opposite axial directions from both ends of cam 39 toward the middle where the diameter is a maximum. Expressed equivalently, the outer diameter of cam member 39 is a maximum about midway of the axial ends thereof and gradually decreases in opposite axial directions. In effect, the outer surface of cam member 39 is tapered from each end thereof outwardly toward the midpoint along the axis thereof.

Cam member 39 is supported for axial movement in chamber 36 in the following manner. A guide rod 40 extends through the inner bore of cam 39 and the opposite ends thereof are received in corresponding bores provided in cap members 37 and 38. The outer diameter of rod 40 is slightly less than the diameter of the inner bore of cam member 39. The inner bore of cam 39 is enlarged slightly and for a short axial distance at each end thereof to receive corresponding bushings 41 and 42 snugly fitted therein which, in turn, are axially movable along rod 40. Cam member 39 is biased to a neutral position, such as that shown in FIG. 1, by means of springs 43 and 44 each of which is located in a corresponding recess of cap members 37 and 38, respectively, and acts against an end of cam member 39. In particular, one end of spring 43 contacts or urges against an inner surface of cap 37, and the other end of spring 43 urges against a retainer element 45 slidably connected on rod 40 and abutting one axial end face of cam 39. Similarly, one end of spring 44 contacts or urges against an inner surface of cap 38, and the other end of spring 44 urges against a retainer element 46 slidably connected on rod 40 and abutting the opposite axial end face of cam 39. Retainers 45 and 46 also butt against shoulders included on rod 40 to provide a definite centered location.

Handle or lever 15 comprises a ball 46 to facilitate grasping thereof connected to one end of a rod 47, the other end of which extends into a bore 48 provided in valve body 35. This end of rod 47 terminates in a relatively smaller, generally bulbous portion 49 which is received in an opening provided in the surface of cam 39. Rod 47 is pivotally connected near this same end to valve body 35 by suitable means, for example a pin 50 extending through rod 47 generally perpendicular to the axis thereof and received at corresponding ends thereof in bushings, one designated 51 in FIG. 1, supported in valve body 35. A bellows member or boot 52 is attached in sealing engagement to handle rod 47 and to valve body 35. In addition, cam 39 is provided with circumferential grooves 53, 54 around the outer surface thereof which are axially spaced in opposite directions a short distance from the midpoint along the axis of cam 39. Each of the grooves 53, 54 is adapted to engage a detent member 55 supported in a transverse bore in valve body 35 and which is spring-biased toward cam 39 by means of an O-ring 56. This arrangement is shown in FIG. 4 and functions to releasably lock cam 39 in this particular example at each of two outer limits of axial movement, although the exact number and location of grooves can vary depending upon the particular application of valve 10.

Cam member 39 is operatively connected to flow controlling means in valve 10 in the following manner. Valve body 35 is provided with bores extending perpendicular with respect to the longitudinal axis of chamber 36 and communicating therewith. In particular, each bore comprises a first portion extending from chamber 36 to a point slightly beyond the axis of exhaust or bleed port 12 which first portions each define chambers 60 and 61. Preferably the axes of chambers 60, 61 lie in the same plane. Each bore further comprises a second, relatively smaller diameter portion extending from chambers 60 and 61, respectively, and defining chambers 62 and 63 communicating with valve outlet ports 14 and 13, respectively, in a manner which will be described presently. Valve body 35 is provided with two additional bores, the axes of which are disposed perpendicular with respect to the axes of chambers 60 and 61 whereby valve inlet port 11 and exhaust or bleed port 12 each communicate with the flow controlling means. In particular, a bore 64, the axis of which is substantially coincident with that of port 12, extends through valve body 35 as shown in FIG. 1 in a manner whereby it defines a passage connecting chambers 60 and 61 with each other and with exhaust port 12. In a similar manner a bore 65, the axis of which is substantially parallel with respect to the axis of bore 64, extends from valve inlet port 11 into valve body 35 to both of the smaller diameter chambers 62 and 63 thereby defining a passage connecting them together and to inlet port 11.

Included within chamber 60 is a first poppet member 66 which is generally hollow cylindrical in shape and adapted to move axially within chamber 60. A ball or roller-type follower 67 is seated within poppet 66 at one axial end thereof, and the surface of ball 67 contacts the outer surface of cam member 39 at one end thereof as shown in FIG. 1. An O-ring 68 is positioned between ball 67 and a surface of the interior of poppet 66 to provide a fluidtight seal between valve chambers 36 and 60. Another O-ring 69 is positioned in a circumferential groove in the outer surface of poppet member 66 and contacts the wall of chamber 60 for the same purpose. Poppet member 66 has a smaller outer diameter portion at the other end thereof around which is positioned a spring 70. One end of spring 70 urges against the end wall of chamber 60 and the other end of spring 70 urges against an outer surface of poppet member 66 whereby it is urged in a direction toward cam member 39 and ball 67 thus is urged into contact with the tapered outer surface of cam member 39 on one side of the midpoint thereof.

Seated within poppet member 66 is a second poppet member 71 in the form of a hollow cylinder closed at one end. The outer diameter of poppet 71 is slightly less than the diameter of the inner bore through poppet 66 over a major portion of the axial length of poppet 66 whereby poppet 71 is axially movable therein. Poppet 71 is retained in poppet 66 at one end thereof, so as to be carried therein, by an annular seat defined at the juncture of the relatively larger diameter portion of the inner bore through poppet 66 and the remaining portion which is of a diameter less than the outer diameter of poppet 71. The open end of poppet 71 is a disposed toward ball 67 and a spring 72 is received in poppet 71, contacting a portion thereof, and extends axially into contact with ball 67. A small diameter, laterally offset bore 73 is provided in the end wall of poppet 71 whereby the interior thereof is in fluid communication with the chamber 60.

An identical arrangement of poppets, springs and ball is located within chamber 61. In particular, a first generally hollow cylindrical poppet member 76 is movable axially within chamber 61, and a ball or roller-type follower 77 is seated within poppet 76 at one axial end thereof so that the surface of ball 77 is in contact with the outer surface of cam member 39 at the other end thereof. An O-ring 78 is positioned between ball 77 and a surface of the interior of poppet 76, and another O-ring 79 is received in a circumferential groove in the outer surface of poppet 76 and is in contact with the wall of chamber 61. A spring 80 positioned around a smaller diameter portion of poppet 76 at the other end urges against the end wall of chamber 61 and against an outer surface of poppet 76 whereby it is urged in a direction toward cam member 39 and ball 77 thus is urged into contact with the tapered outer surface of cam member 39 on the other side of the midpoint thereof. Seated within poppet 76 is a second poppet member 81 in the form of a hollow cylinder closed at one end. Poppet 81 is movable axially within poppet member 76 toward ball 77 and is limited in opposite axial movement and thus carried in poppet 76 by an annular seat defined by a smaller diameter inner portion of poppet 76 at the end near spring 80. The open

end of poppet 81 is disposed toward ball 77, and a spring 82 is received in poppet 81 and extends axially into contact with ball 77. A small diameter laterally offset bore 83 is provided in the end wall of poppet 81 whereby the interior thereof is in fluid communication with the chamber 61.

Positioned within chamber 62 is a nozzle member or jet 90 which is generally hollow cylindrical in shape. One end of nozzle 90 extends into chamber 60 within poppet 66 and in contact with the end wall of poppet 71. In the position shown in FIG. 1, poppet 71 is seated on the one end of nozzle 90 thereby closing off the interior thereof, which can be considered a chamber, from fluid communication with chamber 60. First and second O-rings 91 and 92, respectively, are received in corresponding axially spaced, circumferential grooves provided in the outer surface of nozzle member 90 and are in fluidtight contact with the wall of chamber 62. Along a portion of the region between O-rings 91 and 92, the outer diameter of nozzle member 90 is less than the diameter of chamber 62 thereby defining an annular space or passage which, as can be seen in FIG. 1, also is in fluid communication with the passage defined by bore 65. A small diameter bore or aperture 93 extends through the wall of nozzle member 90 and is axially located thereon so that the interior of nozzle 90 is in fluid communication with bore 65 through aperture 93. Nozzle 90 is positioned within chamber 62 so as to leave a small portion of chamber 62 vacant and thus adapted to receive one end of a 90° flare fitting 94, a portion of which is shown in FIG. 1, the other end of which defines valve outlet port 14. An O-ring 95 provides a fluidtight seal between fitting 94 and the wall of chamber 62. The chamber defined by the interior of nozzle 90 thus is in fluid communication with valve outlet port 14.;

A similar arrangement of nozzle and fitting is included in chamber 63. In particular, a generally hollow cylindrical nozzle member or jet 100 is positioned within chamber 63, and one end of nozzle 100 extends into chamber 61 within poppet 76 and in contact with the end wall of poppet 81. In the position shown in FIG. 1, poppet 81 is seated on the one end of nozzle 100 thereby closing off the interior thereof, which can be considered a chamber, from fluid communication with chamber 61. First and second O-rings 101 and 102, respectively, are received in corresponding axially spaced, circumferential grooves provided in the outer surface of nozzle member 100 and are in fluidtight contact with the wall of chamber 63. Along a portion of the region between O-rings 101 and 102, the outer diameter of nozzle member 100 is less than the diameter of chamber 63 thereby defining an annular space or passage which, in addition, is in fluid communication with the passage defined by bore 65. A small diameter bore or aperture 103 extends through the wall of nozzle member 100 and is located axially thereon so that the interior of nozzle 100 is in fluid communication with bore 65 through aperture 103. Nozzle 100 is positioned within chamber 63 so as to leave a small portion of chamber 63 vacant and thus adapted to receive one end of a 90° flare fitting 104, the other end of which defines valve outlet port 13. The chamber defined by the interior of nozzle 100 thus is connected to valve outlet port 13. An O-ring 105 provides a fluidtight seal between fitting 104 and the wall of chamber 63.

Valve 10 can be mounted at a desired location and to this end mounting brackets 106 and 107 are provided as shown in FIGS. 2—4 and are secured to valve body 35 by suitable means, such as bolts 108 extending therethrough and anchored by lockwashers 109 and jam nut 110.

The system of FIG. 1 is in a standby or neutral operating condition when handle 15 of valve 10 is in a position which maintains poppets 71 and 81 seated on the corresponding ends of nozzles 90 and 100, respectively, thereby preventing the flow or bleedoff of any fluid from the interiors of nozzles 90 and 100 into chambers 60 and 61, respectively. In the preferred arrangement shown in FIG. 1, handle 15 is in a vertical position when the valve is in this condition. Operating fluid for valve 10 is supplied by pump 18 at a desired pressure, for example 500 p.s.i., and enters through port 11 into bore 65. From bore 65 some fluid enters the interior of nozzle 100 through aperture 103 and the remainder circumvents aperture 103 through the annular passage in proximity thereto, travels further along the remaining portion of bore 65, whereupon the fluid enters the interior of nozzle 90 through aperture 93.

Poppets 71 and 81 carried in poppets 66 and 76, respectively, prevent any flow of fluid out of the corresponding ends of nozzles 90 and 100, respectively, in the neutral condition illustrated in FIG. 1. In other words, the poppets when seated seal chambers 60 and 61 from the chambers defined by the interiors of nozzles 90 and 100, respectively. Therefore, all of the operating fluid flows out from the other ends of nozzles 90 and 100, respectively, into the corresponding fittings 94, 104 and thence out of valve 10 through outlet ports 14 and 13, respectively. Fluid is conducted from valve outlets 13 and 14 through corresponding lines 32 and 28 to the interiors of cylinders 24 and 29, respectively. Operating fluid thus acts on both pistons 25 and 30 which are connected rigidly to spool 21 of valve 22. Since the pressure in both lines 23, 28 is equal during this condition, a standby or neutral position of valve stem 21 is maintained. This position of valve stem 21 would, of course, correspond to a particular desired operating condition in the separate hydraulic circuit (not shown) in which valve 22 is connected in controlling relation. When springs 27, 32 are of equal elasticity, which is often the case, the springs are in the same condition and thus valve stem 21 is midway of its axial path or thus displaced slightly to the left from its illustrative position in FIG. 1.

Assume now that a given desired change in the operating characteristics of this separate hydraulic system can be obtained by a slight axial movement of valve spool 21 to the left from its neutral or standby position. This movement is effected by a pressure unbalance between lines 23 and 28, more specifically by a reduction in the pressure in line 28, which pressure unbalance is created by valve 10 in the following manner. Handle 15 is moved manually so as to be pivoted about pin 50 a small distance to the left in FIG. 1. Cam member 39 as a result is moved to the right, it being axially movable along guide rod 40. Ball 67 is in contact with a progressively decreasing diameter portion of cam member 39, and the assembly of poppet 66, ball 67 and poppet 71 is moved axially in chamber 60 toward cam 39 by the force of spring 70. The axial movement of poppet 66 moves the end wall of poppet 71 away from the corresponding end of nozzle 90. In other words, the movement of handle 15 and cam 39 unseats poppet 71 from nozzle 90. As cam member 39 is moved to the right to unseat poppet 71, poppet 81 remains seated on the corresponding end of nozzle 100. This is because ball 77 is in contact with a progressively increasing diameter portion of cam member 39 thereby causing poppet 76 and ball 77 to move axially toward the end wall of chamber 61 against the force of spring 80 and, as a result, maintaining the end wall of poppet 81 in contact with the corresponding end of nozzle 100.

The unseating of poppet 71 from nozzle 90 causes a bleedoff or exhaust of operating fluid from the interior of nozzle 90 and, hence, from line 28. The amount of fluid exhausted depends upon the extent to which poppet 71 is unseated which, in turn, is proportional to the extent of axial movement of cam 39 and arcuate movement of handle 15. Fluid exhausted from the interior of nozzle 90 enters chamber 60 from which it is conducted by bore 64 to chamber 61 and from there through the remaining portion of bore 64 to valve exhaust port 12 and through line 20 to reservoir 16.

The bleeding of operating fluid from line 28 causes a pressure drop therein, and the pressure in line 23 remains at the relatively higher standby level. As a result, the force acting on piston 25 and against spring 27 is momentarily greater than the force acting on piston 30 and against spring 32. Valve spool 21 thus will be moved a distance to the left in FIG. 1 until the force provided by the pressure of operating fluid in line 23 is balanced by the force of spring 27 and the force pro-

vided by the pressure in line 28. A new equilibrium position of valve spool 21 is reached and will be maintained as long as handle 46 is held in position.

Springs 27 and 32 connected to pistons 25 and 30, respectively, have linear force-displacement characteristics. The amount of operating fluid exhausted from the system is proportional to the extent of movement of handle 15. As a result, a proportional relationship between the extent of movement of valve spool 21 and handle 15 results within the limits of movement of the handle. In the illustrative example of FIG. 1, handle 15 is movable through an angle of about 24° in either direction from its standby or vertical position. Valve 10 can be releasably locked at preselected locations along the arcuate path of handle 15 by means of the cooperative engagement between detent 55 and either of the grooves 53, 54 in cam member 39.

The pairs of corresponding poppets 66, 71 and 76, 81 together with the associated biasing springs comprise first and second flow controlling means positioned in chambers 60 and 61, respectively. Handle or lever 15 connected to cam member 39 spring biased in the valve body together comprise a motion transmitting means which is operatively connected to the first and second flow controlling means through balls 67 and 77, respectively.

By proceeding through a similar analysis, one can see that when a movement of valve spool 21 to the right is desired, handle 15 of valve 10 is pivoted to the right. Poppet 71 remains seated on nozzle 90, but poppet 81 is unseated from the corresponding end of nozzle 100. A proportional amount of operating fluid is bled or exhausted from the interior of nozzle 100 and line 23 to chamber 61 through port 12 and into reservoir 16. As a result, the pressure in line 23 drops and the force acting on piston 25 is less than the force acting against piston 30 and spring 32 provided by operating fluid in line 28. Valve spool 21 is then moved to the right until the force of fluid in line 28 equals the force of spring 32 and of fluid in line 23. A new equilibrium position of valve spool 21 is reached such as that illustrated in FIG. 1.

Movement of handle 15 in either direction is against the elastic force of the springs 43, 44, and handle 15 is returned to a definite centered location by the springs in cooperation with the aforementioned retainers 45, 46 which abut corresponding shoulders on rod 40. Springs 72 and 82 positioned within poppets 71 and 81, respectively, hasten the closing of a previously opened one of the corresponding nozzles 90, 100 when handle 15 is returned toward the standby position thereby shortening the valve response time. This is because the force of each spring 72, 82 is greater than any force developed by fluid in valve 10. In addition, the provision of spring-biased inner poppets 71, 81 movable within corresponding outer poppets 66, 76, accommodates the variations which can occur in the length of nozzle members 90, 100 and which could otherwise cause improper seating of poppets 71, 81 on the nozzle ends. The location of the inner annular seat in poppet members 66, 76 will be determined, in part, by the known tolerance in the length of nozzles 90, 100. Bores 73 and 83 in poppets 71 and 81, respectively, maintain a pressure equality between the interiors of poppets 71, 81 and chambers 60, 61 for the purpose of eliminating chatter between inner and outer poppets. Being offset, they do not interfere with closing of the nozzles.

FIGS. 5—7 shown another embodiment of the present invention whereby the axial movements of two or more fluid-actuated devices or components can be controlled separately or interdependently or whereby the movement of a single load can be controlled in a plurality of directions. A control valve 120 constructed in accordance with this embodiment of the present invention includes a body or housing 121 provided with an inlet port 122, a bleed or exhaust port 123 and four outlet ports 124—127 as shown in FIG. 5. Manual operation of valve 120 is effected through a lever or handle designated at 128. Valve 120 would be supplied with operating fluid in a manner identical to that in which valve 10 of FIG. 1 is supplied. In particular, valve inlet port 122 would be connected through a line to a pump P, and valve exhaust port 123 would be connected through another line to a tank or reservoir T which, in turn, would be connected to the pump.

Valve 120 can be employed to control the movement of a single hydraulically actuated device or component in four mutually perpendicular directions or vectors therebetween. Alternatively, and as illustrated in FIG. 5, valve 120 can be employed to control the axial movements of two hydraulically actuated devices either independently or in combination. To this end, valve outlet ports 124 and 125 are connected through corresponding lines to hydraulic cylinders each operatively connected through springs to a load for causing movement thereof in two opposite directions. In particular, block H_1 shown in FIG. 5 connected to valve ports 124, 125 schematically represents the combination of valve spool, two hydraulic cylinders and corresponding springs as shown in FIG. 1. In a similar manner, valve outlet ports 126, 127 are connected through corresponding lines to a second load, designated generally at H_2, which can comprise another valve spool, two hydraulic cylinders and corresponding springs like those of FIG. 1.

Valve body 121 can be formed from cast iron or similar material and be generally rectangular in shape. A first longitudinal chamber 129*a* is provided in valve body 121 and extends through the entire length thereof and is located near the side or surface into which handle 128 extends. Chamber 129*a* is extended in length beyond the dimension of valve body 121 by axially spaced bushings 130, 131 connected in valve body 121, and chamber 129*a* is closed at each end by axially spaced cap members 132 and 133 connected to bushings 130 and 131, respectively. A second longitudinal chamber 129*b* communicating with chamber 129*a* is provided in valve body 121, the axis of which is disposed at right angles relative to the axis of chamber 129*a*. Chamber 129*b* is extended at opposite ends thereof by axially spaced bushings 134, 135 connected to valve body 121 and is closed by cap member 136 and 137 connected to bushings 134 and 135, respectively, as shown in FIGS. 6 and 7.

Handle or lever 128 comprises a ball 138 to facilitate grasping thereof connected to one end of a rod 139, the other end of which extends into the space common to chambers 129*a* and 129*b* whereupon the end of rod 139 terminates in a generally bulbous portion 140. A cover member 141 closes the chambers 129*a* and 129*b* along one common side thereof which cover 141 is provided with a central opening through which rod 139 of handle 128 extends. An annular member 142 having a semispherical outer surface is fixedly secured on rod 139 near portion 140 by means of retainer rings 143, which member 142 is journaled in a spherical bearing 144 which, in turn, is seated in the opening of cover member 41 against an annular, inwardly extending shoulder or ridge and held therein by a retainer ring 145. A boot or bellows member 146 is attached at one end thereof to rod 139 and at the other end thereof to cover member 141.

Chamber 129*a* houses first and second axially movable cam members 150 and 151, respectively, each of which is in operative contact with handle 128 and each of which is operatively connected to corresponding flow controlling means in valve 120. Chamber 129*b* likewise houses identical first and second axially movable cam members, one of which is shown at 151*a* in FIG. 5, each of which is in operative contact with handle 128 and each of which cam members is operatively connected to the flow controlling means in valve 120. Referring now to FIG. 5, cam member 150 in preferred form comprises a generally cylindrical element having a constant diameter internal bore extending along a major portion of the length thereof. The outer diameter of cam 150 increases slightly over the axial length thereof, the smaller diameter end being in contact with handle 128. In effect, the outer surface of cam 150 is tapered slightly over the length thereof. The outer surfaces of cams 150, 151 moreover, each can be provided with a slight step or rise 152, 153, respectively, and near the larger

diameter end for a purpose to be described. Cam **151** and the other two cam members in chamber **129***b* are of identical shape and size. While the cam members are of generally cylindrical shape having a tapered outer surface, the cams can be of other shapes which will provide the needed operating surfaces thereon.

Cam **150** is supported for axial movement in chamber **129***a* in the following manner. A guide rod **154** extends at one end thereof into the inner bore of cam **150** and is axially movable within a bushing **155** fitted in the bore. The other end of guide rod **154**, which is of a slightly smaller diameter, extends through bushing **130** into the interior of cap member **132** where it is held against axial movement by a nut **156**. A spring **157** is positioned on rod **154**, one end of which spring abuts the end surface of bushing **130** and the outer end of which urges against a retainer member **158** which is axially movable on guide rod **154** and which is in contact with the axial end face of cam **150**. Retainer **158** also butts against a shoulder on rod **154** to provide a definite centered location. Cam **151** is supported for axial movement in chamber **129***a* by an identical arrangement including a guide rod **159**, one end of which extends into the inner bore of cam **151** and is axially movable within a bushing **160** fitted in the bore. The other, slightly smaller diameter end of rod **159** extends through bushing **131** into the interior of cap **133** where it is anchored by a nut **161**. A spring **162** is placed on rod **159**, one end of which urges against an inner surface of bushing **131**, and the other end of which urges a retainer member **163**, axially movable on rod **159**, into contact with the axial end face of cam **151**. Retainer **163** also butts against a shoulder on rod **159** to provide a definite centered location. An identical supporting arrangement is provided for each of the two cams which are axially movable in chamber **129***b*.

The flow controlling means included in valve **120** are four in number and each is of a construction identical with that of the flow controlling means included in valve **10** shown in FIGS. **1—4** and each is in operative contact with a corresponding one of the four cam members. Valve body **121** is provided with first and second chambers **170** and **171**, respectively, each of which communicates with chamber **129***a* and has an axis generally perpendicular with respect to the axis of chamber **129***a*. In like manner, two other chambers are provided in valve body **121** communicating with chamber **129***b* and extending generally perpendicular with respect to the axis of chamber **129***b*. The four chambers are connected to each other and to bleed port **123** through passages defined by mutually perpendicular bores **172** and **173** shown in FIG. **5**. The chambers **170** and **171** are in fluid communication with outlet ports **125** and **124**, respectively, through relatively smaller diameter chambers **174** and **175**, respectively. Likewise, outlet ports **126** and **127** are connected through two small diameter chambers to the two chambers extending from chamber **129***b*. The four smaller diameter chambers are connected to each other and to valve inlet port **122** through passages defined by mutually perpendicular bores **176** and **177**.

Valve chamber **170** houses a first poppet member **178** axially movable therein and generally hollow cylindrical in shape. A second, generally cup-shaped poppet member **179** is movable within poppet member **178** along a major portion of the axial length of poppet **178**, and the end wall of poppet **179** normally seats against an annular seat defined in the interior of poppet **178**. A ball **180** seated in one end of poppet **178** is in operative contact with cam member **150**, and an O-ring **181** provides a fluid seal between ball **180** and the interior of poppet **178**. A spring **182**, one end of which contacts ball element **180**, is received at the other end in poppet member **179** and urges against the end wall thereof whereby the outer end wall of poppet **179** is urged into contact with the annular seat defined on the inner surface of poppet member **178**. A small diameter, laterally offset aperture **183** is provided through the end wall of inner poppet member **179**. A spring **184**, one end of which urges against the bottom wall of chamber **170**, and the other end of which urges against a portion of the outer surface of poppet member **178**, maintains ball **180** in operative contact with cam member **150**. An O-ring **185** is received in a circumferential groove in poppet **178** and is in fluid sealing contact with the wall of chamber **170**.

The other three chambers included in valve body **121** house similar arrangements of flow controlling components. For example, chamber **171**, also shown in FIG. **5**, houses a first poppet member **186** which is axially movable within the chamber. A second, generally cup-shaped poppet member **187** is movable within poppet member **186** along a major portion of the axial length thereof, and the end wall of poppet **187** normally rests against an annular seat defined in the interior of poppet **186**. A ball **188** is seated against one end of poppet member **186** and is in operative contact with cam **151**. An O-ring **189** is positioned between poppet **186** and ball element **188**. A spring **190** is in contact at one end thereof with ball element **188** and urges against the inner end wall of poppet member **187**. A small diameter, laterally offset aperture **191** is provided in the end wall of poppet member **187**. Ball **188** is maintained in operative contact with cam element **151** by means of a spring **192**, one end of which urges against the bottom wall of chamber **171** and the other end of which urges against a portion of the outer surface of poppet member **187**. A fluid seal between the outer surface of poppet **186** and the wall of chamber **171** is provided by an O-ring **193** received in a circumferential groove provided in poppet member **186**. As previously stated, a similar arrangement of poppets, ball and springs is included in each of the other two chambers which extend from chamber **129***b*.

Positioned within chamber **174** is a nozzle member or jet **200** which is generally hollow cylindrical in shape. One end of nozzle **200** extends into chamber **170** within poppet **178** and in contact with the end wall of poppet **179**. In the position shown in FIG. **5**, poppet **179** is seated on the one end of nozzle **200** thereby closing off the interior thereof, which can be considered a chamber, from fluid communication with chamber **170**. First and second O-rings **201** and **202**, respectively, are received in corresponding axially spaced, circumferential grooves provided in the outer surface of nozzle **200** and the diameter of nozzle member **200** is less than a portion of the diameter of chamber **174** between the O-rings thereby defining an annular passage or space which is in fluid communication with bore **176**. The interior of nozzle **200** is in fluid communication with this passage by means of a small diameter aperture **203** extending through the wall of nozzle **200**. The other end of nozzle **200** is in fluid communication with a 90° flare fitting **204** connected in valve body **121**, the external end of which fitting **204** defines outlet port **125**.

A similar arrangement is included in each of the other three chambers in valve body **121**. For example, chamber **175** includes a nozzle **205**, one end of which extends into chamber **171** within poppet **186** and in contact with the end wall of poppet **187**. First and second O-rings **206**, **207** are received in corresponding axially spaced circumferential grooves in nozzle **205**, and an annular passage or space is defined between nozzle **205** and the wall of chamber **175** between O-rings **206**, **207**. The interior of nozzle **205**, which may be considered a chamber, is in fluid communication with this annular space and hence bore **176** by means of a small diameter aperture **208** extending through the wall of nozzle **205**. The other end of nozzle **200** is in fluid communication with a 90° flare fitting **209** connected in valve body **121**, the external end of which fitting **209** defines outlet port **124**. A similar nozzle is included in each of the other two chambers extending from chamber **129***b*, the interior of each nozzle communicating with a corresponding one of the flare fittings **210**, **211** connected in valve body **121**.

Valve **120** can be mounted at a desired location and for this purpose mounting brackets **215**, **216** are provided as shown in FIGS. **6**, **7** and are secured to valve body **121** by suitable means, such as bolts **217** extending therethrough and anchored by lockwashers **218** and jam nuts **219**.

Valve **120** operates in the following manner to control the movements of loads H_1 and H_2 connected thereto as shown in FIG. 5. Movements of handle or lever **128** in the plane of the drawing result in movement of the valve spool or similar component in load H_1 in one of two directions depending upon the direction of movement of handle **128**. Movements of handle **128** along a plane perpendicular to the plane of the drawing cause movements of the valve spool or similar component of load H_2 depending upon the direction of movement of handle **128**. In particular, movement of handle **128** to the left and in the plane of the drawing moves cam **151** to the right against spring **162**. Cam **150** is moved to the right by the force of spring **157** and thereby maintained in operative contact with handle **128**, specifically with enlargement **140**. As a result ball **188** is contacted by an increasingly smaller surface portion of cam **151** thereby allowing movement of poppet **186** toward cam **151**. Poppet **187** is carried upwardly and unseated from the end of nozzle **205** so as to allow a bleedoff or exhaust of operating fluid from the interior of nozzle **205** into chamber **171** and out from port **123** into reservoir T. Ball **180**, on the other hand, is contacted by an increasingly larger surface portion of cam **150** thereby maintaining poppet **179** seated on the end of nozzle **200** and thus sealing the interior thereof from fluid communication with chamber **170**.

Operating pressure in the line connected to valve outlet port **124** is lowered relative to the pressure in the line connected to valve port **125**, and the component in load H_1 is moved to the right until an equilibrium position is reached. The amount of operating fluid exhausted from the system is proportional to the extent of movement of handle **128**, and when load H_1 includes two hydraulic cylinders connected through corresponding linear springs to a component, such as the load shown in FIG. 1, movements of the component are proportional to movements of valve handle **128**. By proceeding through a similar analysis, it is apparent that a movement of handle **128** to the right will cause a proportionate movement of the component of load H_1 to the the right. Poppet **187** remains seated on nozzle **205**, but poppet **179** is unseated from the end of nozzle **200** thus allowing operating fluid to be bled or exhausted from the interior thereof to chamber **170** and thence through bore **172** and port **123** to tank T. The pressure in the line connected to outlet port **125** is lowered relative to port **124** and a movement to the right accordingly results until an equilibrium position is obtained.

An identical series of movements of the components of load H_2 occurs in response to movements of handle **128** along a path in a plane perpendicular to the plane of the drawing. The operating pressure is reduced in either of the two lines connecting valve outlet ports **126**, **127** to load H_2 depending upon the direction of movement of handle **128**. The pressure reduction, in turn, results from selective bleedoff or exhaust from the interiors of nozzles connected to ports **126**, **127** corresponding chambers through bore **173** and then through bore **172** and valve port **123** to reservoir T.

The fact that handle or lever **128** is journaled in spherical bearing **144** allows universal movement thereof, and this universal mounting permits movement along either quadrature axes or any vector therebetween. As a result, both loads H_1 and H_2 can be caused to move in unison in response to a single movement of handle **128**. For example, a movement of handle **128** from left to right at an angle to the plane of the drawing and from rearwardly to forwardly of the plane would unseat poppet **187** from nozzle **205** and the poppet from the corresponding nozzle located in valve body **121** forwardly of the plane of the drawing whereby a pressure reduction would occur in the line connection valve outlet port **124** to load H_1 and in the line connecting outlet port **127** to load H_2.

From the foregoing, it should be apparent that a single load movable in four mutually perpendicular directions could be operatively connected to four hydraulic cylinders which, in turn, are connected through corresponding lines to valve outlet ports **124—127**. Corresponding linear springs would be connected between pistons and load, as in the arrangement of FIG. 1, and proportionate movements in the load would be caused by movements of handle **128**.

The four pairs of corresponding poppets, including poppets **178**, **179** and **186**, **187** together with the associated biasing springs comprise flow controlling means each positioned in a corresponding one of four chambers in valve body **121**. Handle or lever **128** operatively connected to the four cam members, including cams **150**, **151** spring-biased in valve body **121** comprise motion transmitting means operatively connected to flow controlling means through balls, two of which are shown at **180**, **188** in FIG. 5.

Movements of handle or lever **128** are against the elastic force of the various springs which bias corresponding ones of the cam members in a manner analogous to that of valve **10**, and handle **128** is returned to a definite centered location by the springs in cooperation with the aforementioned retainers which abut corresponding shoulders on the rods. Valve response time is shortened by the provision of springs within the inner poppets, such as springs **182**, **190** in poppets **179**, **187**, respectively. Variations in nozzle length are accommodated by the arrangement of spring-biased inner poppets movable within corresponding outer poppets in a manner identical to that of valve **10**. The inner poppets are provided with offset bores for the purpose of eliminating chatter, such as bores **183** and **191** in poppets **179** and **187**, respectively. Each of the cam members is provided with a step or rise, such as that shown at **152** and **153** on cam members **150** and **151**, respectively, for the purpose of enabling valve **120** to respond quickly to movement of handle **128** away from the neutral or standby position and thereby overcome mechanical inertia present in the system.

It is therefore apparent that the present invention accomplishes its intended objects. While two specific embodiments of the present invention have been described in detail, this has been done by way of illustration without though of limitation.

I claim:

1. A fluid control valve comprising:

a. a body having an inlet port, an exhaust port and a pair of outlet ports;

b. first and second chambers in said body;

c. passage means connecting said first and second chambers to said exhaust port;

d. means in said valve body defining third and fourth chambers connecting said first and second chambers, respectively, with a corresponding one of said outlet ports;

e. passage means connecting said third and fourth chambers to said inlet port;

f. first and second flow controlling means in said first and second chambers, respectively, each of said flow controlling means being movable in its chamber from a seated position sealing its said chamber from a corresponding one of said third and fourth chambers to an unseated position wherein said flow controlling means allows fluid flow between the two chambers, and

g. motion transmitting means operatively connected to each of said first and second flow controlling means and including a linearly movable element, said motion transmitting element having a neutral position wherein said first and second flow controlling means both are maintained in said seated position, and said motion transmitting element being movable out of said neutral position in directions unseating either of said flow controlling means while maintaining the other of said flow controlling means in said seated position.

2. The fluid control valve defined in claim **1** wherein each of said flow controlling means comprises:

a. a first poppet member axially movable in a corresponding one of said first and second chambers;

b. a second poppet member carried by said first poppet member so as to be moved thereby from a seated position blocking a corresponding one of said third and fourth chambers to an unseated position; and

c. a spring urging said first poppet into operative contact with said motion transmitting means.

3. The fluid control valve defined in claim 2 wherein said second poppet is axially movable within said first poppet and wherein said valve further comprises:

a. a follower positioned in operative contact between said first poppet and said motion transmitting element; and

b. a spring contacting said follower and said second poppet.

4. The fluid control valve defined in claim 1 wherein said motion transmitting element comprises an elongated, generally cylindrical cam member supported in a chamber in said valve body for axial movement in both directions along a line perpendicular to the direction of movement of each of said first and second flow controlling means, said cam member having equal diameters at opposite ends thereof and a relatively larger diameter about midway from the ends thereof.

5. The fluid control valve defined in claim 4 further including a manually operable lever pivotally connected to said valve body and operatively connected at one end to said cam.

6. The fluid control valve defined in claim 1 wherein said means defining third and fourth chambers each comprises a generally hollow cylindrical nozzle member, one end of which extends into a corresponding one of said first and second chambers, the other end of which is in communication with a corresponding one of said valve outlet ports, said nozzle having a bore therethrough intermediate the ends thereof whereby the nozzle interior is in fluid communication with said passage connected to said valve inlet port.

7. In combination with the fluid control valve defined in claim 1:

a. a source of operating fluid under pressure connected to said valve inlet port;

b. first and second fluid cylinders each having a piston reciprocable therein;

c. means connecting said first and second fluid cylinders to corresponding ones of said valve outlet ports;

d. a mechanical load adapted for reciprocal movement along an axis, said load being connected at opposite ends thereof to corresponding ones of said cylinder pistons; and

e. first and second elastic members each having linear force-displacement characteristics and each connected at one end to a corresponding one of said cylinder pistons and at the other end to a rigid body.

8. The combination defined in claim 7 wherein said mechanical load comprises a spool movable in the body of a master valve connected in a separate fluid circuit.

9. The combination defined in claim 8 wherein each of said elastic members comprises a spring comprises a spring positioned on the rod of a corresponding one of said cylinder pistons and connected at one end to the piston and at the other end to the body of said master valve.

10. A fluid control valve comprising:

a. a body having an inlet port, an exhaust port and a pair of outlet ports;

b. a generally cylindrical cam member supported for limited axial movement in a chamber in said valve body, the outer diameter of said cam member being a maximum about midway of the axial ends thereof and gradually decreasing in opposite axial directions;

c. a manually operable lever pivotally connected to said valve body and operatively connected at one end thereof to said cam member;

d. first and second chambers in said valve body extending from the chamber in which said cam member is movable;

e. passage means connecting said first and second chambers to said bleed or exhaust port;

f. a first, generally hollow cylindrical poppet member positioned in each of said first and second chambers;

g. a follower seated in one end of said first poppet member and in operative contact with the outer surface of said cam member;

h. a spring positioned in each of said first and second chambers urging said first poppet toward said cam member;

i. a second poppet member carried in said first poppet member and axially movable therein;

j. a spring positioned in said first poppet member, one end of said spring being in contact with said second poppet member and the other end in contact with said follower;

k. first and second generally hollow cylindrical nozzle members positioned in said valve body so that one end thereof extends into a corresponding one of said first and second chambers and so that the interiors of said first and second nozzles are in communication with corresponding ones of said valve outlet ports, said second poppet members normally sealing the interiors of corresponding ones of said first and second nozzles from said first and second chambers; and

l. passage means connecting the interiors of said first and second nozzles each to said valve inlet port.

11. A fluid control valve comprising:

a. a body having an inlet port, an exhaust port and four outlet ports;

b. four chambers in said body;

c. passage means connecting each of said four chambers to said bleed or exhaust port;

d. four hollow generally cylindrical nozzle members in said body each of said nozzle members being positioned so that one end is in fluid communication with a corresponding one of said four chambers and so that the opposite end of said nozzle is connected to a corresponding one of said four outlet ports;

e. passage means connecting the interiors of said nozzles each to said inlet port;

f. flow controlling means in each of said four chambers, each of said flow controlling means being movable in the chamber wherein it is located from a seated position sealing the chamber from the interior of a corresponding one of said nozzle members to an unseated position wherein said flow controlling means allows a flow of fluid from the nozzle interior to the chamber;

g. four motion transmitting elements each axially movable in said valve body and positioned so as to be operatively connected to a corresponding one of said flow controlling means, each of said elements having a tapered outer surface whereby in response to axial movement thereof the corresponding flow controlling means is moved between seated and unseated positions; and

h. a manually operable lever journaled in said valve body for universal movement and operatively connected at one end to each of said motion transmitting elements.

12. The fluid control valve defined in claim 11 wherein the axes of said motion transmitting elements are disposed in mutually perpendicular relation.

13. The fluid control valve defined in claim 11 wherein each of said motion transmitting elements is provided with a slight step or rise in the outer surface intermediate the ends thereof.

14. The fluid control valve defined in claim 11 wherein each of said flow controlling means comprises;

a. a first poppet member axially movable in the corresponding chamber;

b. a second poppet member carried by said first poppet member so as to be moved thereby from a seated position on the end of a corresponding one of said nozzles to an unseated position; and

c. a spring urging said first poppet member into operative contact with a corresponding one of said cams.

15. The fluid control valve defined in claim 14 wherein said second poppet is axially movable within said first poppet and wherein said valve further comprises:

a. a follower positioned in operative contact between said first poppet and a corresponding one of said motion transmitting elements; and

b. a spring contacting said follower and said second poppet.

16. In combination with the fluid control valve defined in claim 11:

a. a first hydraulic circuit connected to two of said outlet ports and including a mechanical load movable in two directions;

b. a second hydraulic circuit connected to the remaining two of said outlet ports and including a mechanical load movable in two directions; and

c. a source of operating fluid under pressure connected to said valve inlet port.

17. The combination defined in claim 16 wherein each of said first and second hydraulic circuits further includes:

a. first and second fluid cylinders each having a piston reciprocable therein in response to the flow of said operating fluid;

b. said mechanical load being connected at opposite ends thereof to corresponding ones of said cylinder pistons; and

c. first and second elastic members each having linear force-displacement characteristics and each connected at one end to a corresponding one of said cylinder pistons and at the other end to a rigid body.

18. In combination with the fluid control valve defined in claim 11:

a. a single mechanical load reciprocable along two independent axes;

b. two pair of hydraulic cylinders, each pair operatively connected to said load with the two cylinders comprising the pair at opposite ends of said load along one of the axes;

c. an hydraulic circuit connecting each pair of hydraulic cylinders to a corresponding pair of said valve outlet ports;

d. a source of operating fluid under pressure connected to said valve inlet port; and

e. two pair of elastic members each having linear force-displacement characteristics, each of said elastic members being connected at one end to the piston of a corresponding one of said hydraulic cylinders and at the other end to a rigid body.