Jan. 27, 1959

V. BILAISIS

PNEUMATICALLY OPERATED CONTROL VALVE FOR HYDRAULIC ACTUATORS

2,870,789

Filed Jan. 11, 1956

2 Sheets-Sheet 1

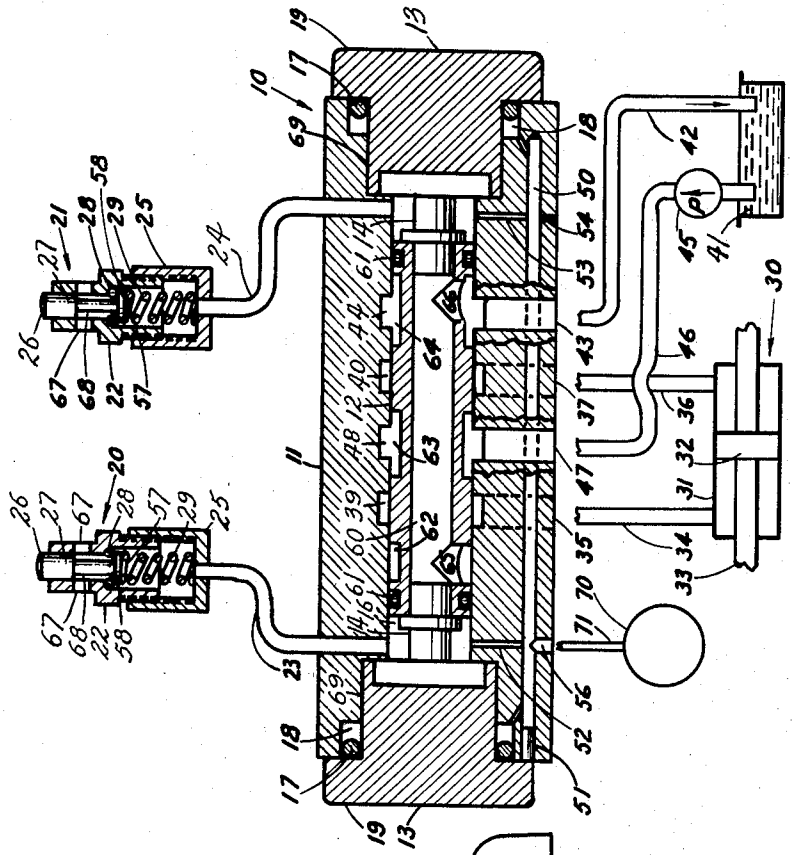


Fig. 1

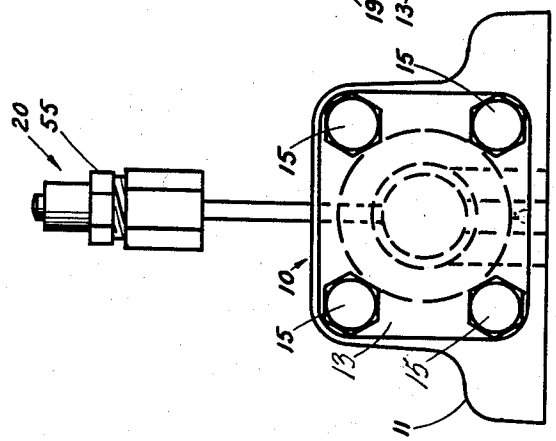


Fig. 2

VIKTORAS BILAISIS
INVENTOR.

BY Paul J. Rose Jr.
HIS ATTORNEY

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2 Sheets-Sheet 2

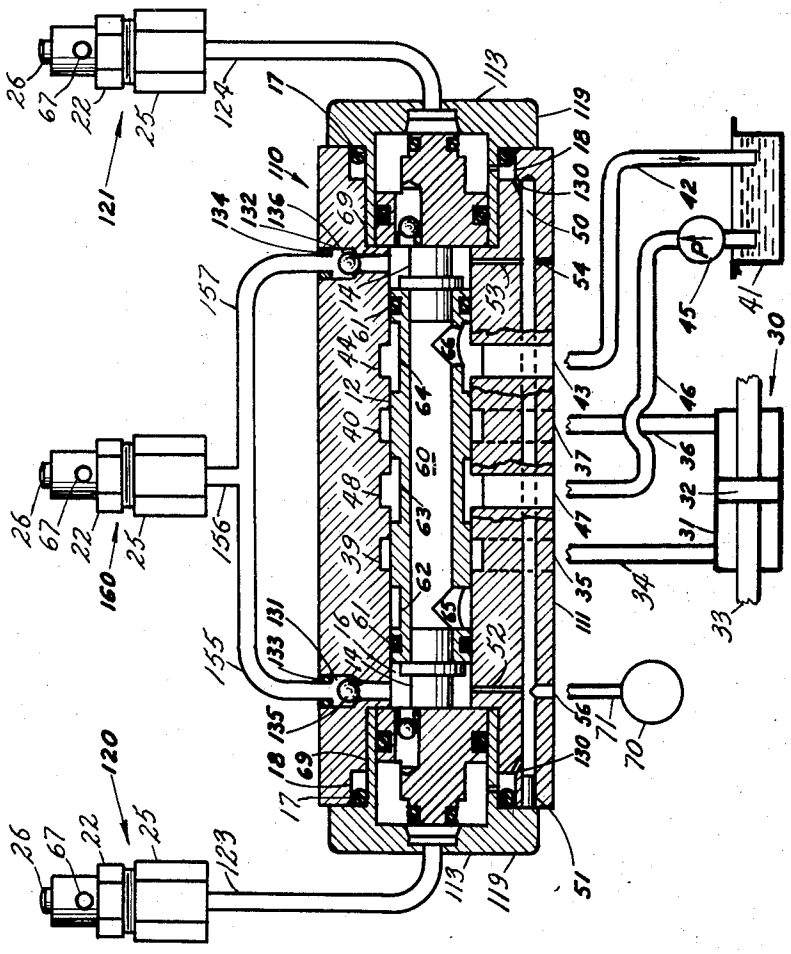


Fig. 3

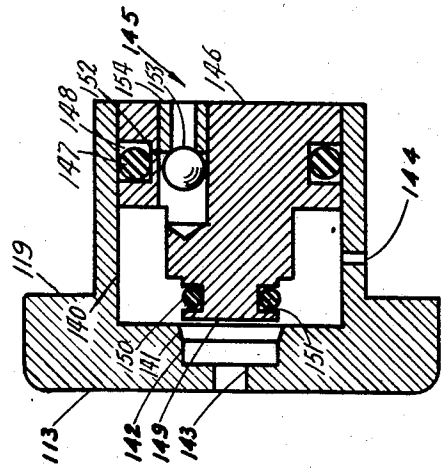


Fig. 4

VIKTORAS BILAISIS.
INVENTOR.

BY Paul J. Rose Jr.
HIS ATTORNEY

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PNEUMATICALLY OPERATED CONTROL VALVE FOR HYDRAULIC ACTUATORS

Viktoras Bilaisis, Chicago, Ill.

Application January 11, 1956, Serial No. 558,559

6 Claims. (Cl. 137—622)

This invention relates generally to methods and apparatus for operating directional control valves for hydraulic actuators.

Hydraulic actuators are widely used in the machine tool industry to reciprocate machine tool sliding heads. The direction of movement of the sliding head may be automatically controlled by an automatically operable directional control valve, which in a self-contained sliding head is generally mounted directly on the sliding head and reciprocates therewith. The directional control valve is usually operated by pilot valves, which in turn are operated by solenoids. The solenoids are electrically energized in response to the tripping or closing of limit switches mounted on the sliding head and operated by cams or other surfaces on a stationary part of the machine as the sliding head reaches the limits of its movement. Thus, as the sliding head reaches the end of a stroke, it trips a limit switch which energizes a solenoid to shift a pilot valve and thus shift the directional control valve, which reverses the sliding head by reversely interconnecting the power and exhaust lines leading from the valve to the respective ends of the hydraulic actuator. Sometimes the directional control valve is provided with a neutral position, enabling the sliding head to be stopped at the limits of its travel or in any position therebetween.

One such directional control valve is shown on page 235 of "Oil Hydraulic Power and Its Industrial Applications," by Walter Ernst, published in 1949 by McGraw-Hill Book Co., Inc. It will be noted that pilot valves and solenoids are provided, and in a conventional control system for a machine tool sliding head, limit switches are provided to operate the solenoids. These pilot valves, limit switches, and solenoids are relatively expensive.

It is therefore an object of my invention to provide a novel method and apparatus for controlling hydraulic actuators.

Another object of my invention is to provide a simple automatically operable directional control valve having fewer operating parts for initiating shifting of the valve spool than conventional automatically operable directional control valves for hydraulic actuators.

A further object of my invention is to provide a method and apparatus for controlling hydraulic actuating systems, including an automatically operable directional control valve, in which the means for initiating shifting of the valve spool of the directional control valve are simpler and less costly than the corresponding means in conventional controls for hydraulic actuators.

The movement of hydraulic actuators may also be manually controlled, as on a hydraulic press, for example, by a manually operable directional control valve in which the valve spool is provided with an operating handle or lever extending through the casing of the valve. Since all of the hydraulic actuating fluid must pass through the directional control valve, large actuators may require large directional control valves if desired speeds are to be obtained. In the past, when high pressures were used in actuating systems having large directional control

valves, it sometimes became difficult to manually shift the valve spool, even when long operating handles or levers were provided. In addition, the necessity of extending an operating handle through the valve casing of conventional manually operable directional control valves creates sealing problems and results in a complicated valve structure.

It is therefore another object of my invention to provide a manually operable directional control valve for hydraulic actuators which is easier to operate and is of simpler construction than conventional manually operable directional control valves.

A further object of my invention is to provide a simple manually or automatically operable directional control valve for hydraulic actuators which has fewer operating parts for initiating shifting of the valve spool than conventional automatically operable directional control valves and is easier to operate and of simpler construction than conventional manually operable directional control valves.

A more specific object of my invention is to provide a simple automatically operable directional control valve for hydraulic actuators in which the need of limit switches, solenoids, or pilot valves for initiating shifting of the valve spool is eliminated.

A still further object of my invention is to provide a simple manually operable directional control valve for hydraulic actuators in which there is no operating handle or lever connected to the valve spool and extending through the valve casing.

Another object of my invention is to provide a means of controlling a hydraulic actuating system having a hydraulic actuator and an automatically operable directional control valve, in which the medium for controlling the spool of the directional control valve is distinct from and is restrained from mixing with the hydraulic actuating fluid.

These and other objects of my invention will appear from time to time as the following specification proceeds with reference to the accompanying drawings wherein:

Figure 1 is a fragmentary longitudinal sectional view of a directional control valve and operating means therefor constructed in accordance with my invention, and includes a schematic representation of a pump, a hydraulic fluid reservoir, a hydraulic actuator, and connecting fluid conduits;

Figure 2 is an end view of the valve and actuating means shown in Figure 1;

Figure 3 is a fragmentary longitudinal sectional view of another form of directional control valve and operating means therefor constructed in accordance with my invention, and includes a schematic representation of a pump, a hydraulic fluid reservoir, a hydraulic actuator, and connecting fluid conduits; and

Figure 4 is an enlarged sectional view of an end cap and centering member of Figure 3.

With reference first to the embodiment of my invention illustrated in Figures 1 and 2, the directional control valve is generally indicated by the numeral **10**. The valve **10** includes a hollow valve body **11** having a bore **16** therein closed at its ends by end caps **13** inserted into larger diameter end bores **69** and fastened to the valve body by means such as screws **15**. The bore **16** of the valve body **11** contains a hollow valve spool **12** having a bore **60** therein closed at its ends by plugs **14** pressed thereinto. The end caps **13** are permanently magnetized and plugs **14** are of magnetizable material for reasons to be hereinafter set forth as the specification proceeds. In the alternative, plugs **14** may be permanently magnetized and end caps **13** may be of magnetizable material.

A hydraulic actuator which may be controlled by the valve **10** is schematically shown in Figure 1 and indicated

by the numeral 30. The actuator 30 includes a cylinder 31 and a piston 32 mounted on a piston rod 33. The cylinder 31 may be stationary and the piston rod 33 connected to a movable part of a machine to be actuated, or in the alternative the piston rod 33 may be stationary and the cylinder 31 fastened to a movable part of a machine to be actuated, as is well understood in the art.

A conduit 34 for hydraulic fluid may be suitably connected between one end of the cylinder 31 on one side of the piston 32 and a passageway 35 in the valve body 11 communicating with an annular groove 39 therein. A conduit 36 for hydraulic fluid may be suitably connected between the other end of the cylinder 31 on the other side of the piston 32 and a passageway 37 in the valve body 11 communicating with an annular groove 40 therein.

A reservoir for hydraulic fluid is schematically shown in Figure 1 and indicated by the numeral 41. A conduit 46 having a pump 45 mounted therein for supplying hydraulic fluid to one end of the actuator 30 may be suitably connected between the reservoir 41 and a passageway 47 in the valve body 11 communicating with an annular groove 48 therein. A conduit 42 for hydraulic fluid exhausted from the other end of the actuator 30 may be suitably connected between the reservoir 41 and a passageway 43 in the valve body 11 communicating with an annular groove 44 therein.

The valve body 11 is provided with a passageway 50 drilled lengthwise nearly therethrough and plugged at its open end by a plug 51. Cross-passageways 52 and 53 are provided to connect passageway 50 with opposite ends of the bore 16. Passageway 53 is plugged at its outer end by a plug 54. O-ring seals 17 are contained within annular grooves 18, provided in the valve body 11 at opposite ends thereof, by flanges 19 of end caps 13.

The valve spool 12 is provided at its opposite ends with suitable annular grooves containing O-ring seals 61 therein, and intermediate the ends annular grooves 62, 63, and 64 are provided for purposes to be hereinafter described. Passages 65 and 66 are provided to connect the bore 60 with grooves 62 and 64, respectively.

A source of compressed air 70 may be connected in any suitable manner to the passageway 50, as by a pipe 71 connected at 56, which may be a continuation of passageway 52.

A bleeder valve 20 communicates with the bore 16 of the valve body 11 on one side of the valve spool 12 by means of a conduit 23, which may be connected to the valve body 11 and to the bleeder valve 20 in any suitable manner. An identical bleeder valve 21 communicates with the bore 16 on the other side of the valve spool 12 by means of a conduit 24, which may be connected to the valve body 11 and to the bleeder valve 21 in a similar manner. The valves 20 and 21 include hollow body portions 22 having hexagonal wrench surfaces 55 and screw threads therebelow screwed into caps 25, and valve pistons 26 guided in bores 27 of body portions 22 and biased outwardly thereof against O-ring seals 28 by compression springs 29 bottomed on caps 25 at their inner ends and centered at their outer ends on bosses 57 protruding from flanges 58 on the inner ends of pistons 26. Bleed holes 67 communicate with the bores 27 in body portions 22 adjacent reduced diameter portions 68 of piston 26.

The valve spool 12 is shown in Figure 1 in a neutral position. That is, hydraulic fluid from the pump 45 cannot go anywhere after reaching the groove 48, which is blocked, and the pump merely builds up pressure until a relief valve (not shown) opens. Normally, however, the valve spool 12 is either at its extreme left position or its extreme right position. If a positive neutral position is desired, a construction such as is illustrated in Figure 3 may be used.

To shift piston 32 to the left in Figure 1 (or to shift cylinder 31 to the right, if the arrangement is such that the piston is stationary), valve piston 26 of bleeder valve 21 is depressed, manually in manual operation of a machine, or by a cam surface on the machine actuated by hydraulic actuator 30, in automatic operation. Air under pressure will then flow from the right end of bore 16 in Figure 1, through conduit 24, past flange 58 and reduced diameter portion 68, and out bleed holes 67 in bleeder valve 21. The passageway 53 is small in diameter and cannot supply air from passageway 50 and the source 70 as fast as it is being exhausted from bleeder valve 21. Thus the air pressure at the right end of bore 16 is reduced, while substantially the full air pressure of the source 70 is present at the left end of bore 16. This pressure differential causes valve spool 12 to move to the right in Figure 1, until the right plug 14 engages the right end cap 13. In this position of the valve spool 12, groove 63 will connect groove 48 with groove 40, groove 62 will be in registry with groove 39, and groove 64 will be in registry with groove 44. The valve piston 26 of bleeder valve 21 may then be released, whereupon the spring 29 will return flange 58 against seal 28 to close bleeder valve 21 and allow the air pressure to build up again in the right end of bore 16. The valve spool 12 will then remain in its rightward position, since the pressures in the ends of the bore 16 are the same and act on equal areas. In addition, the valve spool 12 will be maintained in its rightward position against any unintentional shifting by the magnetic force between the right end cap 13 and the right plug 14.

With the grooves of valve body 11 and valve spool 12 aligned as above in the rightward position of the valve spool 12, the pump 45 will pump hydraulic fluid from the reservoir 41 through conduit 46, passageway 47, groove 48, groove 63, groove 40, passageway 37, and conduit 36 to the right end of cylinder 31. At the same time, fluid from the left end of cylinder 31 will be exhausted through conduit 34, passageway 35, groove 39, groove 62, passage 65, bore 60, passage 66, groove 64, groove 44, passageway 43, and conduit 42 back to the reservoir 41. The piston 32 will thus be shifted to the left in Figure 1 (or the cylinder 31 will be shifted to the right, if the arrangement is such that the piston is stationary).

To shift piston 32 to the right in Figure 1 (or to shift cylinder 31 to the left, if the arrangement is such that the piston is stationary), valve piston 26 of bleeder valve 20 is depressed, manually in manual operation of a machine, or by a cam surface on the machine actuated by hydraulic actuator 30, in automatic operation. Air under pressure will then flow from the left end of bore 16 in Figure 1, through conduit 23, past flange 58 and reduced diameter portion 68, and out bleed holes 67 in bleeder valve 20. The passageway 52 is small in diameter and cannot supply air from passageway 50 and the source 70 as fast as it is being exhausted from bleeder valve 20. Thus the air pressure at the left end of bore 16 is reduced, while substantially the full air pressure of the source 70 is present at the right end of bore 16. This pressure differential causes valve spool 12 to move to the left in Figure 1, overcoming the magnetic force between the right end cap 13 and the right plug 14, until the left plug 14 engages the left end cap 13. In this position of the valve spool 12, grooves 63 will connect groove 48 with groove 39, and groove 64 will connect groove 40 with groove 44. The valve piston 26 of bleeder valve 20 may then be released, whereupon the spring 29 will return flange 58 against seal 28 to close bleeder valve 20 and allow the air pressure to build up again in the left end of bore 16. The valve spool 12 will then remain in its leftward position, since the pressures in the ends of bore 16 are the same and act on equal areas. In addition, the valve spool 12 will be maintained in its leftward position against any unintentional shifting by the

magnetic force between the left end cap 13 and the left plug 14.

With the grooves of the valve body 11 and the valve spool 12 aligned as above in the leftward position of the valve spool 12, the pump 45 will pump hydraulic fluid from the reservoir 41 through conduit 46, passageway 47, groove 48, groove 63, groove 39, passageway 35, and conduit 34 to the left end of cylinder 31. At the same time, fluid from the right end of cylinder 31 will be exhausted through conduit 36, passageway 37, groove 40, groove 64, groove 44, passageway 43, and conduit 42 back to the reservoir 41. The piston 32 will thus be shifted to the right in Figure 1 (or the cylinder 31 will be shifted to the left, if the arrangement is such that the piston is stationary).

In most cases it is desirable to be able to shift the spool of a directional control valve to a neutral position, in order that the associated hydraulic actuator may be stopped in any position at or between the limits of its travel without stopping the pump. While it is theoretically possible to shift valve spool 12 to the neutral position shown by bleeding off at one end only enough air to shift the spool half of its normal stroke, it would be difficult to tell just how much air to bleed off. Therefore I have illustrated in Figure 3 an embodiment of my invention in which a positive neutral position of the directional control valve spool is provided. Certain parts identical with those of Figure 1 have been identified by the same numerals, while certain other very similar parts have been identified by numerals 100 higher than those of Figure 1.

In Figure 3, the directional control valve is generally indicated by the numeral 110. The valve 110 includes a hollow valve body 111 substantially identical with valve body 11 of Figure 1. The valve body 111 is provided with grooves 39, 48, 40 and 44, passageways 50, 52, 53, 35, 47, 37, and 43, and bore 16, all identical with and serving the same purpose as the identically numbered grooves, passageways, and bore of Figure 1, and so not further described herein. The valve body 111 is also provided with annular grooves 18 at its opposite ends and passages 130 connecting grooves 18 with passageway 50 for a purpose to be hereinafter described. Passageways 131 and 132 having bushings 133 and 134 therein retaining ball check valves 135 and 136, respectively, are provided in valve body 111 adjacent its opposite ends. The passageways 131 and 132 include tapered portions providing valve seats for the valves 135 and 136, respectively, and smaller diameter inner portions communicating with bore 16 at opposite ends thereof. The bore 16 contains a hollow valve spool 12 having a bore 60, grooves 62, 63, and 64, passages 65 and 66, and grooves for O-ring seals 61 therein, all identical with and serving the same purpose as the identically numbered bore, grooves, and passages of the valve spool 12 of Figure 1, and so not further described herein. Plugs 14 pressed into the bore 60 also are identical with those of Figure 1.

A hydraulic actuator 30, including a cylinder 31 and a piston 32 mounted on a piston rod 33, a pump 45, a reservoir 41 for hydraulic fluid, and hydraulic fluid conduits 34, 46, 36, and 42 are provided, and are arranged and connected with respect to valve body 111 in the same manner as the identically numbered parts in Figure 1 are arranged and connected with respect to valve body 11, and so are not further described herein.

The valve body 111 is closed at its ends by end caps 113 inserted into larger diameter end bores 69 and fastened to the valve body by means (not shown) such as screws 15 in the embodiment of my invention illustrated in Figures 1 and 2. Flanges 119 of end caps 113 retain O-ring seals 17 within the annular grooves 18. The end caps 113 are exteriorly substantially the same as end caps 13 of Figures 1 and 2, but they are provided with large diameter bores 140 (see Figure 4) communicating with smaller tapered portions 141, which in turn terminate in smaller diameter bores 142 communicating with central apertures 143. Orifices 144 provide communication between annular grooves 18 and the outer portions of bores 140 for a purpose to be later described.

The end caps 113 contain centering members 145 guided for axial movement in bores 140 by larger diameter inner portions 146 sealed with respect to bores 140 by O-ring seals 147 provided in annular grooves 148. Smaller diameter outer portions 149 of centering members 145 are adapted to fit sufficiently within bores 142 to be sealed relative thereto by O-ring seals 150 provided in annular grooves 151. Passageways 152, containing ball check valves 153, seating on and retained therein by bushings 154, provide communication through larger diameter portions 146 of centering members 145, between the ends of bore 16 in valve body 111 and the outer portions of bores 140.

As in the embodiment of my invention illustrated in Figures 1 and 2, a source of compressed air 70 may be connected in any suitable manner to the passageway 50, as by a pipe 71 connected at 56, which may be a continuation of passageway 52.

A conduit 123 leading to a bleeder valve 120 is connected in any suitable manner to the left end cap 113 in Figure 3 through the central aperture 143 thereof. A conduit 124 leading to a bleeder valve 121 is connected in any suitable manner to the right end cap 113 in Figure 3 through the central aperture 143 thereof. A conduit 155 leading through a conduit 156 to a bleeder valve 160 is connected in any suitable manner to the passageway 131 in valve body 111 through the bushing 133 therein. A conduit 157 leading through the conduit 156 to the bleeder valve 160 is connected in any suitable manner to the passageway 132 in valve body 111 through the bushing 134 therein. The bleeder valves 120, 121, and 160 may be identical to each other and are identical to the bleeder valves 20 and 21 in the embodiment of my invention illustrated in Figures 1 and 2, and so are not further shown in the drawings or described herein.

To shift piston 32 to the left in Figure 3 (or to shift cylinder 31 to the right, if the arrangement is such that the piston is stationary), valve piston 26 of bleeder valve 121 is depressed, manually in manual operation of a machine, or by a cam surface on the machine actuated by hydraulic actuator 30, in automatic operation. Air under pressure will then flow from the right end of bore 16 in Figure 3, past check valve 153 and through passageway 152 in the right centering member 145, through the outer portion of bore 140, tapered portion 141 and bore 142 in the right end cap 113, through conduit 124, and out bleed holes 67 in bleeder valve 121. Air at the left end of bore 16 is prevented from flowing through conduits 155 and 157 to the right end of bore 16 and out bleeder valve 121 by the ball check valve 136. Passageway 53 in valve body 111 and orifice 144 in the right end cap 113 are small in diameter and cannot supply air from passageway 50 and the source 70 as fast as it is being exhausted from bleeder valve 121. Thus the air pressure at the right end of bore 16 in valve body 111 and at the outer portion of bore 140 in the right end cap 113 is reduced, while substantially the full air pressure of the source 70 is present at the left end of bore 16. This pressure differential causes valve spool 12 to move to the right in Figure 3, and the right plug 14 pushes the right centering member 145 to the right until the smaller portion 149 thereof is sufficiently within bore 142 of the right end cap 113 to cause sealing by O-ring seal 150 and prevent further bleeding of air through bleeder valve 121. The valve piston 26 of bleeder valve 121 may then be released to close bleed holes 67 thereof, as previously explained with respect to bleeder valve 21 of Figure 1.

Upon sealing of bore 142 in the right end cap 113 by O-ring 150, the air pressure at the right end of bore

16 in valve body 111 and at the outer portion of bore 140 in the right end cap 113 will increase to the full air pressure of the source 70, air being supplied to the right end of bore 16 through passageway 53 and to the outer portion of bore 140 through the right passageway 130, the right annular groove 18, and orifice 144 in the right end cap 113. The right centering member 145 will be held in its rightward position, since the pressure on its inner end acts on a larger area than is available to the pressure on its outer end after portion 149 is sealed within bore 142 by the O-ring 150. The valve spool 12 will remain in its rightward position, since the pressures in the ends of bore 16 are again the same and act on equal areas. However, to guard against any unintentional shifting for any reason, the centering members 145 may be made of permanently magnetized material and the plugs 14 may be made of magnetizable material. In the alternative, the plugs 14 may be made of permanently magnetized material and the centering members 145 may be made of magnetizable material. The valve spool 12 will thus be maintained in its rightward position by the magnetic force between the right centering member 145 and the right plug 14.

In the rightward position of the valve spool 12, groove 63 will connect groove 48 with groove 40, groove 62 will be in registry with groove 39, and groove 64 will be in registry with groove 44. The pump 45 will then pump hydraulic fluid from the reservoir 41 through conduit 46, passageway 47, groove 48, groove 63, groove 40, passageway 37, and conduit 36 to the right end of cylinder 31. At the same time, fluid from the left end of cylinder 31 will be exhausted through conduit 34, passageway 35, groove 39, groove 62, passage 65, bore 60, passage 66, groove 64, groove 44, passageway 43, and conduit 42 back to the reservoir 41. The piston 32 will thus be shifted to the left in Figure 3 (or the cylinder 31 will be shifted to the right, if the arrangement is such that the piston is stationary).

To shift piston 32 to the right in Figure 3 (or to shift cylinder 31 to the left, if the arrangement is such that the piston is stationary) valve piston 26 of bleeder valve 120 is depressed, manually in manual operation of a machine, or by a cam surface on the machine actuated by hydraulic actuator 30, in automatic operation. Air under pressure will then flow from the left end of bore 16 in Figure 3, past check valve 153 and through passageway 152 in the left centering member 145, through the outer portion of bore 140, tapered portion 141, and bore 142 in the left end cap 113, through conduit 123, and out bleed holes 67 in bleeder valve 120. Air at the right end of bore 16 is prevented from flowing through conduits 157 and 155 to the left end of bore 16 and out bleeder valve 120 by the ball check valve 135. Passageway 52 in the valve body 111 and orifice 144 in the left end cap 113 are small in diameter and cannot supply air from passageway 50 and the source 70 as fast as it is being exhausted from bleeder valve 120. Thus the air pressure at the left end of bore 16 in valve body 111 and at the outer portion of bore 140 in the left end cap 113 is reduced, while substantially the full air pressure of the source 70 is present at the right end of bore 16. This pressure differential causes valve spool 12 to move to the left in Figure 3, and the left plug 14 pushes the left centering member 145 to the left until the smaller portion 149 thereof is sufficiently within bore 142 of the left end cap 113 to cause sealing by O-ring seal 150 and prevent further bleeding of air through bleeder valve 120. The valve piston 26 of bleeder valve 120 may then be released to close bleed holes 67 thereof, as previously explained with respect to bleeder valve 20 of Figure 1.

Upon sealing of bore 142 in the left end cap 113 by O-ring 150, the air pressure at the left end of bore 16 in valve body 111 and at the outer portion of bore 140 in the left end cap 113 will increase to the full air pressure of the source 70, air being supplied to the left end of bore 16 through passageway 52 and to the outer portion of bore 140 through the left passageway 130, the left annular groove 18, and orifice 144 in the left end cap 113. The left centering member 145 will be held in its leftward position, since the pressure on its inner end acts on a larger area than is available to the pressure on its outer end after portion 149 is sealed within bore 142 by the O-ring 150. The valve spool 12 will remain in its leftward position, since the pressures in the ends of bore 16 are again the same and act on equal areas. In addition, the valve spool 12 will be maintained in its leftward position against any unintentional shifting by the magnetic force between the left centering member 145 and the left plug 14.

In the leftward position of the valve spool 12, groove 63 will connect groove 48 with groove 39, and groove 64 will connect groove 40 with groove 44. The pump 45 will then pump hydraulic fluid from the reservoir 41 through conduit 46, passageway 47, groove 48, groove 63, groove 39, passageway 35, and conduit 34 to the left end of cylinder 31. At the same time, fluid from the right end of cylinder 31 will be exhausted through conduit 36, passageway 37, groove 40, groove 64, groove 44, passageway 43, and conduit 42 back to the reservoir 41. The piston 32 will thus be shifted to the right in Figure 3 (or the cylinder 31 will be shifted to the left, if the arrangement is such that the piston is stationary).

To stop the movement of piston 32 (or to stop cylinder 31, if the arrangement is such that the piston is stationary) valve piston 26 of bleeder valve 160 is depressed, manually in manual operation of a machine, or by a cam surface on the machine actuated by hydraulic actuator 30, in automatic operation. Air under pressure will then flow from the left and right ends of bore 16 through passageways 131 and 132 respectively, past ball check valves 135 and 136, through conduits 155 and 157 respectively, through conduit 156, and out bleed holes 67 of bleeder valve 160. Air at the outer portions of bores 140 in end caps 113 is prevented from flowing through passageways 152 to the ends of bore 16 and out bleeder valve 160 by the ball check valves 153. Passageways 52 and 53 are small in diameter and cannot supply air from passageway 50 and the source 70 as fast as it is being exhausted from bleeder valve 160. Thus the air pressure at the inner ends of centering members 145 in the end caps 113 is reduced, while substantially the full air pressure of the source 70 is present at the outer ends of centering members 145. This pressure differential causes centering members 145 to shift inwardly in bores 140 of end caps 113 until they abut the valve body 111 and plugs 14 of the valve spool 12. The valve spool 12 is thus shifted by one of the centering members 145 to the neutral position shown in Figure 3. The valve piston 26 of bleeder valve 160 may then be released to close bleed holes 67 thereof and allow air pressure to build up again at the ends of bore 16 from the supply through passageways 52 and 53. The valve spool 12 will then remain in its neutral position, since the pressures in the ends of bore 16 are the same and act on equal areas. In addition, the valve spool 12 will be maintained in its neutral position against any unintentional shifting by the magnetic forces between the centering members 145 and the plugs 14.

In the neutral position of the valve spool 12, groove 63 does not connect groove 48 with either of grooves 39 and 40, groove 64 does not connect groove 40 with groove 44, and groove 62 is not in registry with groove 39. Thus the pump 45 cannot pump hydraulic fluid past groove 48 to either end of cylinder 31, and hydraulic fluid cannot be exhausted from the ends of cylinder 31 past grooves 39 and 40, respectively. Relative movement between piston 32 and cylinder 31 is prevented, and the pump 45 merely builds up hydraulic pressure until a relief valve (not shown) opens.

It will be seen that I have provided a novel method and

apparatus for controlling hydraulic actuators, in which the directional control valve may be operated either manually or automatically, manual operation thereof being easier than that of conventional manually operable directional control valves having operating handles, and automatic operation thereof not requiring the limit switches, solenoids, and pilot valves of conventional automatically operable directional control valves.

It will also be seen that variations and modifications in the embodiments of my invention illustrated herein may be made without departing from the scope of the novel concepts thereof.

I claim:

1. A control valve for controlling relative movement between a piston and cylinder of a hydraulic actuator, comprising a valve body having a chamber therein, a first passageway in said body adaptable to connect said chamber with one end of said cylinder on one side of said piston, a second passageway in said body adaptable to connect said chamber with the other end of said cylinder on the other side of said piston, an inlet passageway in said body adaptable to supply a first fluid medium under pressure to said chamber, an exhaust passageway in said body adaptable to exhaust said first fluid medium from said chamber to a reservoir for said first fluid medium, a valve spool in said chamber shiftable to one position to connect said inlet passageway with said first passageway and to connect said second passageway with said exhaust passageway and to another position to connect said inlet passageway with said second passageway and to connect said first passageway with said exhaust passageway, passageway means in said body adaptable to supply a second fluid medium under pressure to opposite ends of said chamber adjacent opposite ends of said spool, a first exhaust passageway means in said body adaptable to exhaust said second fluid medium from one end of said chamber, a first valve for controlling exhaust of said second fluid medium from said one end of said chamber through said first exhaust passageway means, a second exhaust passageway means in said body adaptable to exhaust said second fluid medium from the other end of said chamber, and a second valve for controlling exhaust of said second fluid medium from said other end of said chamber through said second exhaust passageway means, said first and second valves being selectively operable to bleed said second fluid medium under pressure from the respective ends of said chamber to shift said spool.

2. A control valve for controlling relative movement between a piston and cylinder of a hydraulic actuator, comprising an open ended valve body having a chamber therein, a first passageway in said body adaptable to connect said chamber with one end of said cylinder on one side of said piston, a second passageway in said body adaptable to connect said chamber with the other end of said cylinder on the other side of said piston, an inlet passageway in said body adaptable to supply a first fluid medium under pressure to said chamber, an exhaust passageway in said body adaptable to exhaust said first fluid medium from said chamber to a reservoir for said first fluid medium, a magnetic valve spool in said chamber shiftable to one position to connect said inlet passageway with said first passageway and to connect said second passageway with said exhaust passageway and to another position to connect said inlet passageway with said second passageway and to connect said first passageway with said exhaust passageway, passageway means in said body adaptable to supply a second fluid medium under pressure to opposite ends of said chamber adjacent opposite ends of said spool, a first exhaust passageway means in said body adaptable to exhaust said second fluid medium from one end of said chamber, a first valve for controlling exhaust of said second fluid medium from said one end of said chamber through said first exhaust passageway means, a second exhaust passageway means in said body adaptable to exhaust said second fluid medium from the other end of said chamber, a second valve for controlling exhaust of said second fluid medium from said other end of said chamber through said second exhaust passageway means, said first and second valves being selectively operable to bleed said second fluid medium under pressure from the respective ends of said chamber to shift said spool, and a pair of magnetic end caps respectively closing opposite ends of said valve body and chamber, each end cap and the respective adjacent end of said spool forming a combination in which at least one part is permanently magnetized, the magnetic attraction between an end of said spool and the adjacent end cap maintaining said spool in its shifted position until the other of said valves is operated to bleed said second fluid medium under pressure from the other end of said chamber to again shift said spool.

3. A control valve for controlling relative movement between a piston and cylinder of a hydraulic actuator, comprising a valve body having a chamber therein, a first passageway in said body adaptable to connect said chamber with one end of said cylinder on one side of said piston, a second passageway in said body adaptable to connect said chamber with the other end of said cylinder on the other side of said piston, an inlet passageway in said body adaptable to supply a first fluid medium under pressure to said chamber, an exhaust passageway in said body adaptable to exhaust said first fluid medium from said chamber to a reservoir for said first fluid medium, a valve spool in said chamber shiftable to one position to connect said inlet passageway with said first passageway and to connect said second passageway with said exhaust passageway and to another position to connect said inlet passageway with said second passageway and to connect said first passageway with said exhaust passageway, passageway means in said body adaptable to supply a second fluid medium under pressure to opposite ends of said chamber adjacent opposite ends of said spool, a first exhaust passageway means in said body adaptable to exhaust said second fluid medium from one end of said chamber, a first valve for controlling exhaust of said second fluid medium from said one end of said chamber through said first exhaust passageway means, a second exhaust passageway means in said body adaptable to exhaust said second fluid medium from the other end of said chamber, a second valve for controlling exhaust of said second fluid medium from said other end of said chamber through said second exhaust passageway means, and sealing means adjacent the ends of said spool preventing mixing of said first and second fluid media, said first and second valves being selectively operable to bleed said second fluid medium under pressure from the respective ends of said chamber to shift said spool.

4. A control valve for controlling relative movement between a piston and cylinder of a hydraulic actuator, comprising an open ended valve body having a chamber therein, a first passageway in said body adaptable to connect said chamber with one end of said cylinder on one side of said piston, a second passageway in said body adaptable to connect said chamber with the other end of said cylinder on the other side of said piston, an inlet passageway in said body adaptable to supply a first fluid medium under pressure to said chamber, an exhaust passageway in said body adaptable to exhaust said first fluid medium from said chamber to a reservoir for said first fluid medium, a magnetic valve spool in said chamber shiftable to one position to connect said inlet passageway with said first passageway and to connect said second passageway with said exhaust passageway and to another position to connect said inlet passageway with said second passageway and to connect said first passageway with said exhaust passageway, passageway means in said body adaptable to supply a second fluid medium under pressure to opposite ends of said chamber adjacent opposite ends of said spool, sealing means adjacent the ends of said spool preventing mixing of said first and second

fluid media, a first exhaust passageway means in said body adaptable to exhaust said second fluid medium from one end of said chamber, a first valve for controlling exhaust of said second fluid medium from said one end of said chamber through said first exhaust passageway means, a second exhaust passageway means in said body adaptable to exhaust said second fluid medium from the other end of said chamber, a second valve for controlling exhaust of said second fluid medium from said other end of said chamber through said second exhaust passageway means, said first and second valves being selectively operable to bleed said second fluid medium under pressure from the respective ends of said chamber to shift said spool, and a pair of magnetic end caps respectively closing opposite ends of said valve body and chamber, each end cap and the respective adjacent end of said spool forming a combination in which at least one part is permanently magnetized, the magnetic attraction between an end of said spool and the adjacent end cap maintaining said spool in its shifted position until the other of said valves is operated to bleed said second fluid medium under pressure from the other end of said chamber to again shift said spool.

5. A control valve for controlling relative movement between a piston and cylinder of a hydraulic actuator, comprising a valve body having a chamber therein, a first passageway in said body adaptable to connect said chamber with one end of said cylinder on one side of said piston, a second passageway in said body adaptable to connect said chamber with the other end of said cylinder on the other side of said piston, an inlet passageway in said body adaptable to supply a first fluid medium under pressure to said chamber, an exhaust passageway in said body adaptable to exhaust said first fluid medium from said chamber to a reservoir for said first fluid medium, a valve spool in said chamber shiftable to a first position to connect said inlet passageway with said first passageway and to connect said second passageway with said exhaust passageway and to a second position to connect said inlet passageway with said second passageway and to connect said first passageway with said exhaust passageway and to a neutral position to block flow of said first fluid medium from said inlet passageway to said first and second passageways and from said first and second passageways to said exhaust passageway, a pair of shiftable centering members respectively mounted in said chamber adjacent the opposite ends thereof on opposite sides of said spool, passageway means in said body adaptable to supply a second fluid medium under pressure to opposite ends of said chamber adjacent the inner and outer ends of said centering members, a first exhaust passageway means in said body and one of said centering members adaptable to exhaust said second fluid medium from one end of said chamber adjacent the inner and outer ends of said one centering member, a first vale for controlling exhaust of said second fluid medium from said one end of said chamber through said first exhaust passageway means, a second exhaust passageway means in said body and the other of said centering members adaptable to exhaust said second fluid medium from the other end of said chamber adjacent the inner and outer ends of said other centering member, a second valve for controlling exhaust of said second fluid medium from said other end of said chamber through said second exhaust passageway means, said first and second valves being selectively operable to bleed said second fluid medium under pressure from the respective ends of said chamber to shift said spool to said first and second positions, a third exhaust passageway means in said body adaptable to exhaust said second fluid medium simultaneously from both ends of said chamber adjacent the inner ends of said centering members, and a third valve for controlling exhaust of said second fluid medium from both ends of said chamber through said third exhaust passageway means, said third valve being operable to bleed said second fluid medium under pressure from both ends of said chamber adjacent the inner ends of said centering members to shift said centering members inwardly and shift said spool to said neutral position.

6. A control valve for controlling relative movement between a piston and cylinder of a hydraulic actuator, comprising an open ended valve body having a chamber therein, a first passageway in said body adaptable to connect said chamber with one end of said cylinder on one side of said piston, a second passageway in said body adaptable to connect said chamber with the other end of said cylinder on the other side of said piston, an inlet passageway in said body adaptable to supply a first fluid medium under pressure to said chamber, an exhaust passageway in said body adaptable to exhaust said first fluid medium from said chamber to a reservoir for said first fluid medium, a magnetic valve spool in said chamber shiftable to a first position to connect said inlet passageway with said first passageway and to connect said second passageway with said exhaust passageway and to a second position to connect said inlet passageway with said second passageway and to connect said first passageway with said exhaust passageway and to a neutral position to block flow of said first fluid medium from said inlet passageway to said first and second passageways and from said first and second passageways to said exhaust passageway, a pair of end caps respectively closing opposite ends of said valve body and chamber, each end cap having a large diameter bore adjacent said chamber and a small diameter bore outwardly of said large diameter bore, a pair of shiftable magnetic centering members respectively mounted in the large diameter bores of said end caps, said centering members having large diameter inner ends shiftably guiding said centering members in said large diameter bores and having small diameter outer ends adapted for sealing engagement with said small diameter bores, each centering member and the respective adjacent end of said spool forming a combination in which at least one part is permanently magnetized, passageway means in said body adaptable to supply a second fluid medium under pressure to opposite ends of said chamber adjacent the inner ends of said centering members, passageway means in said body and end caps adaptable to supply said second fluid medium under pressure to the large diameter bores in said end caps adjacent the outer ends of said centering members, a first exhaust passageway means in one of said end caps and centering members adaptable to exhaust said second fluid medium from one end of said chamber and from the bores in said one end cap adjacent the outer end of said one centering member, a first valve for controlling exhaust of said second fluid medium from said one end of said chamber and from the bores in said one end cap through said first exhaust passageway means, a second exhaust passageway means in the other of said end caps and centering members adaptable to exhaust said second fluid medium from the other end of said chamber and from the bores in said other end cap adjacent the outer end of said other centering member, a second valve for controlling exhaust of said second fluid medium from said other end of said chamber and from the bores in said other end cap through said second exhaust passageway means, said first and second valves being selectively operable to bleed said second fluid medium under pressure from the respective ends of said chamber and the bores in said end caps to respectively shift said spool to said first and second positions and respectively shift said centering members outwardly into sealing engagement with the small diameter bores of the respective end caps, said centering members being maintained in their outwardly shifted positions against unintentional shifting by the pressure of said second fluid medium after closing of the re-

spective first and second valves and said valve spool being respectively maintained in said first and second positions against unintentional shifting by magnetic attraction between said valve spool and the respective centering members, a third exhaust passageway means in said body adaptable to exhaust said second fluid medium simultaneously from both ends of said chamber, and a third valve for controlling exhaust of said second fluid medium from both ends of said chamber through said third exhaust passageway means, said third valve being operable to bleed said second fluid medium under pressure from both ends of said chamber adjacent the inner ends of said centering members to shift said centering members inwardly into engagement with said body and

shift said spool to said neutral position in which said spool is maintained against unintentional shifting by magnetic attraction between said spool and centering members after closing of said third valve.

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