

[54] **APPARATUS FOR REGULATING THE OPERATION OF HYDRAULIC MACHINES**

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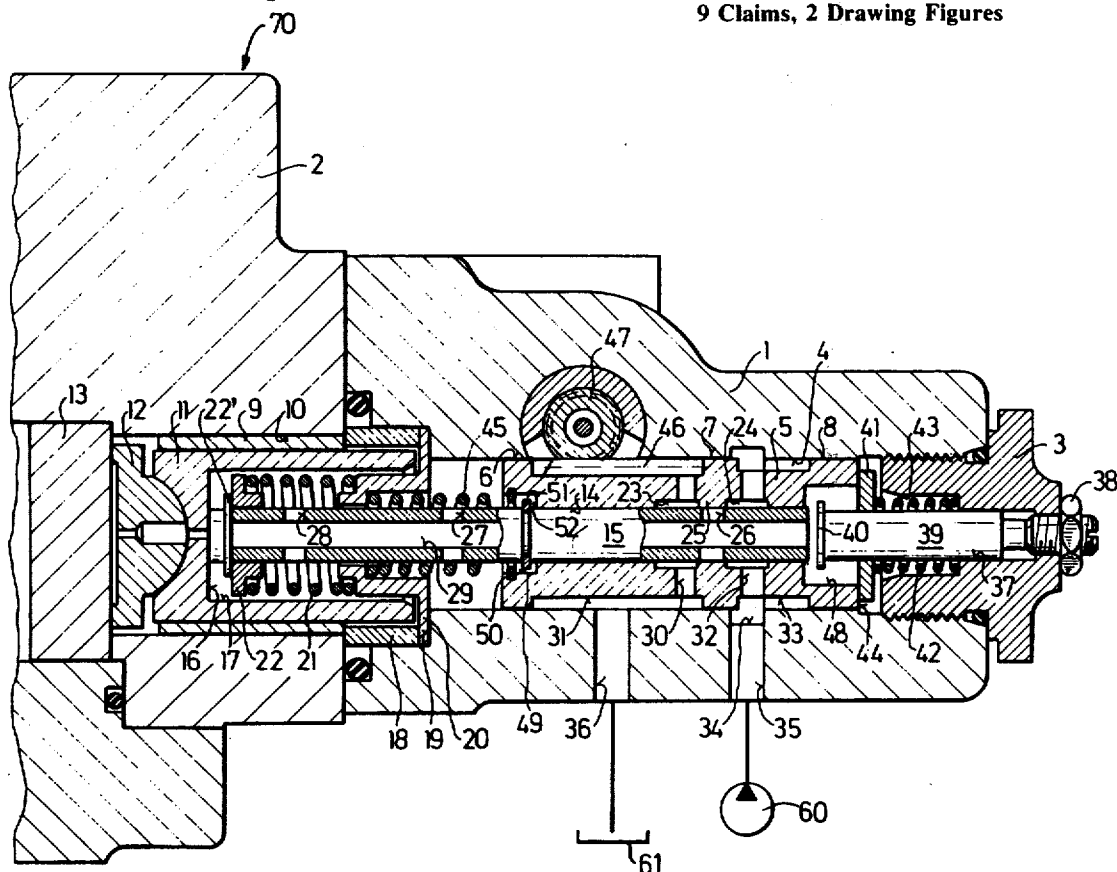
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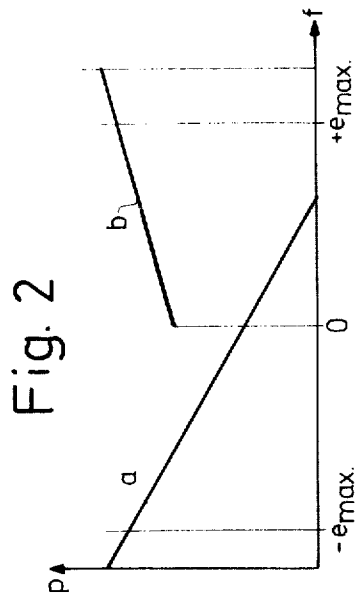
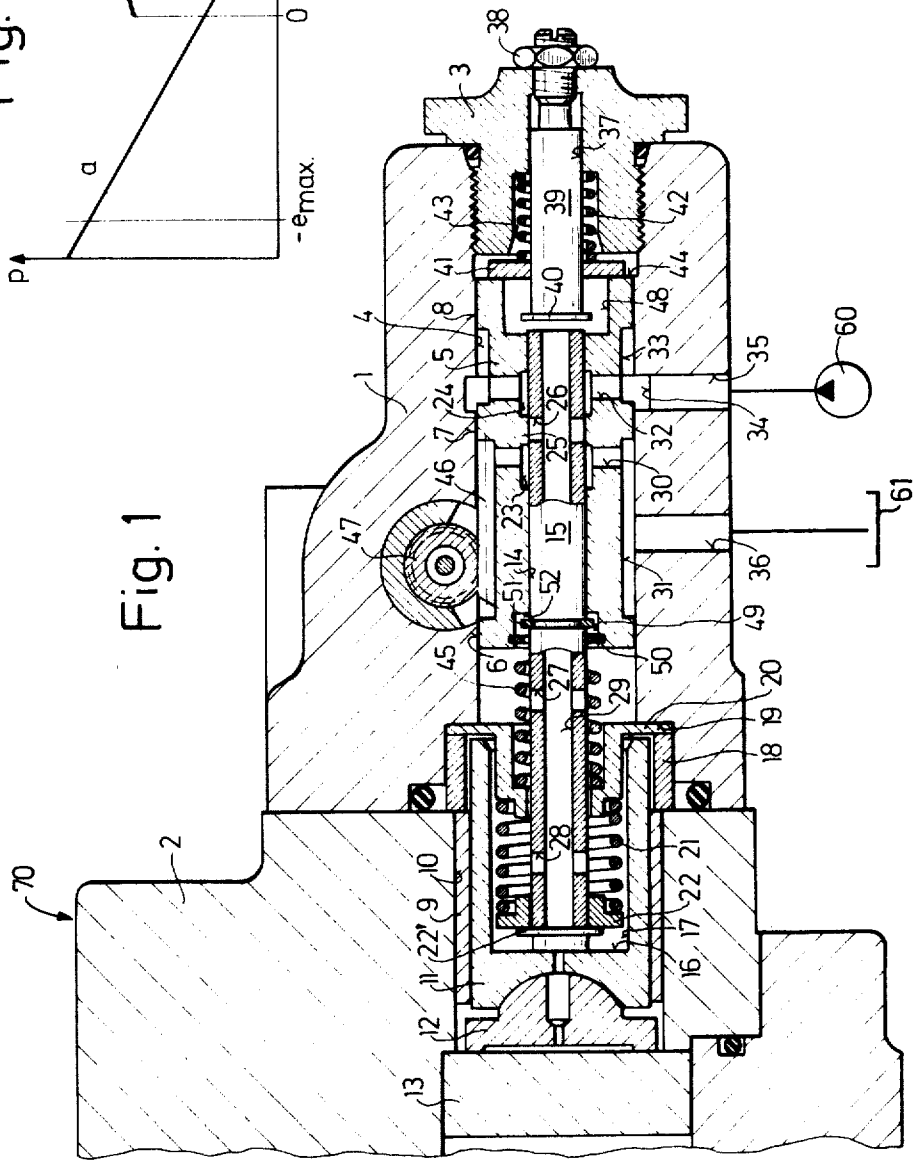
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[57] **ABSTRACT**

A servo mechanism for the slide block of a variable delivery radial piston pump, for the tilting plate of an axial piston pump or for analogous regulating members of hydraulic motors has a housing which is bolted to the body of a hydraulic machine and receives a reciprocable piston which is movable in a cylinder of the housing to thereby displace the regulating member of the hydraulic machine when the cylinder receives pressurized fluid. The flow of fluid into and from the cylinder is regulated by a spool-like control member surrounding an axially movable follower plunger which is biased against the piston by a spring. The control member can be moved axially by a pinion and is biased in opposite directions by two helical springs one of which surrounds the follower plunger and the other of which surrounds an axially adjustable stop supporting a retainer which can be biased against the adjacent end face of the control member. The control member is automatically moved to a neutral position corresponding to the neutral position of the regulating member in the hydraulic machine when it is not held against such movement by the pinion. The bias of one of the two helical springs is half the bias of the other helical spring when the control member assumes its neutral position. The control member cannot move back and forth beyond the neutral position except when shifted by the pinion.

9 Claims, 2 Drawing Figures





APPARATUS FOR REGULATING THE OPERATION OF HYDRAULIC MACHINES

BACKGROUND OF THE INVENTION

The present invention relates to apparatus for regulating the operation of hydraulic machines, and more particularly to improvements in servo mechanisms which can be used to change the position of fluid flow regulating members in hydraulic pumps or motors, for example, to change the position of the slide block in a variable-displacement radial piston pump or the angle of the tilting plate in a variable-displacement axial piston pump.

German Auslegeschrift No. 1,150,852 discloses a servo mechanism whose control member is a piston which is reciprocable in the axial bore of a tubular follower and can be shifted by way of a plunger. A first spring is provided to bias the follower against a sleeve whose threads mate with the threads of an adjusting device for the angle of the tilting plate in an axial piston pump. The sleeve receives a second spring which urges the control member against the plunger. The tilting plate of the axial piston pump is engaged by a piston which tends to change the angle of the tilting plate against the action of the adjusting device and is acted upon by pressurized fluid furnished by an auxiliary pump. The adjusting device controls two pistons which are shiftable by the servo mechanism. Thus, when the plunger of the servo mechanism moves axially, the control member connects the two pistons with the auxiliary pump or with a tank whereby the angle of the tilting plate is changed and the tilting plate causes the adjusting device to change the position of the follower which thereby seals the path for the flow of pressurized fluid.

A drawback of the just described servo mechanism is that, though the output of the axial piston pump is variable between a maximum and a minimum value, the minimum value can be reached under operation but cannot be selected at will. Therefore, such servo mechanism cannot be used in or with pumps whose output should be variable in such a way that an operator can set the pump for zero delivery. Moreover, the conventional servo system is extremely bulky, complex, prone to malfunction and expensive.

SUMMARY OF THE INVENTION

An object of the invention is to provide an apparatus, such as a hydraulic servo mechanism, which can be used to change and select the position of regulating members in hydraulic machines with a high degree of accuracy and which can adjust the regulating member of a hydraulic pump or motor in such a way that the delivery of the pump or the fluid consumption of the motor is zero.

Another object of the invention is to provide a servo mechanism which can be combined with or installed in existing pumps (such as variable-displacement radial or axial piston pumps) or hydraulic motors.

A further object of the invention is to provide a servo mechanism which can change the position of the slide block in a radial piston pump, the angle of the tilting plate in an axial piston pump or the position of the corresponding regulating member in a hydraulic motor with a high degree of accuracy and reproducibility, which is of simple and compact design, and which is less expensive and more reliable than heretofore known servo mechanisms.

The invention resides in the combination of a hydraulic machine (such as a radial piston pump) having a regulating member (such as the slide block of the radial piston pump) which is biased in a predetermined direction with a novel and improved servo mechanism which is actuatable to move the regulating member counter to the aforementioned direction. The servo mechanism comprises a housing which includes a cylinder and has an inlet for pressurized fluid (e.g., a hydraulic fluid supplied by an auxiliary pump) and an outlet for spent fluid, a piston which is displaceable in the cylinder by pressurized fluid to thereby move the regulating member of the hydraulic machine counter to the predetermined direction, fluid flow controlling means including a follower plunger and a preferably spool-shaped control member which is movable in the housing between two end positions and a plurality of intermediate positions including a neutral or zero position to thereby control the flow of fluid between the cylinder and the inlet and outlet, first and second resilient means mounted in the housing to act upon the control member in opposite directions and to bias the control member in the neutral position with forces of first and second magnitude (whereby the magnitude of one of the forces may but need not equal exactly half the magnitude of the other force) as well as to bias the control member in at least some of the other positions including the two end positions, shifting means which is operable to move the control member relative to the housing, and preferably adjustable stop means which is provided in the housing and is directly or indirectly engaged by the control member in the neutral position of the control member when the latter is not held by the shifting means against movement to the neutral position.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved servo mechanism itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a fragmentary sectional view of a radial piston pump and an axial sectional view of the improved servo mechanism which is used to displace the slide block in the radial piston pump; and

FIG. 2 is a diagram of forces furnished by the two resilient elements in different axial positions of the control member of the servo mechanism.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a servo mechanism which is used to regulate the operation of a hydraulic machine 70. The hydraulic machine 70 is a radial piston pump having a body 2 and a slide block 13 which is permanently biased in a direction to the right, as viewed in FIG. 1, by a conventional structure not shown in the drawing.

The servo mechanism comprises a housing 1 which is bolted or otherwise secured to the body 2 of the radial piston pump 70 and is formed with an axially extending bore 4 having portions of different diameters

and receiving at its right-hand end an externally threaded sealing member or plug 3. The bore 4 receives an axially movable control member in the form of a spool 5 having peripheral surfaces 6, 7 and 8 which are received in the adjacent portions of the bore 4 with minimal clearance. The left-hand end of the bore 4 in the housing 1 communicates with a coaxial bore 10 which is machined into the body 2 and receives a sleeve-like liner 9 for an axially reciprocable adjusting member or piston 11. The piston 11 is movable in the liner 9 with minimal clearance and can displace the slide block 13 of the radial piston pump 70 by way of an articulately mounted shoe 12. The leftmost portion of the housing 1 can be said to constitute a cylinder for the piston 11.

The control member 5 is formed with an axial bore 14 which receives with minimal clearance a hollow follower plunger 15. The latter constitutes with the control member 5 a fluid flow controlling device which controls the flow of fluid into and from the aforementioned cylinder for the piston 11. The plunger 15 abuts against the bottom surface 16 in an axial blind bore 17 of the piston 11. The left-hand end of the bore 4 in the housing 1 is enlarged to receive a ring 18 serving to urge the radially outwardly extending flange of a sleeve 20 against an internal shoulder 19 of the housing 1. The left-hand end face of the ring 18 bears against the pump body 2. The sleeve 20 acts as a retainer for the rightmost convolution of a helical spring 21 which is received in the bore 17 of the piston 11 and bears against a retainer 22 on the plunger 15. The latter is provided with a split ring 22' against which the retainer 22 abuts under the action of the spring 21. The spring 21 insures that the left-hand end face of the plunger 15 abuts against the internal surface 16 in the bore 17 of the piston 11. At the same time, the spring 21 causes the plunger 15 to urge the shoe 12 against the slide block 13 by way of the piston 11.

The axial bore 14 of the control member 5 has two enlarged portions 23, 24 formed by annular grooves machined into the internal surface of the control member. The enlarged portions of grooves 23, 24 are separated from each other by an annular internal projection or rib 25 of the control member 5. The width of the rib 25, as considered in the axial direction of the control member 5, slightly exceeds the diameter of a radial port or bore 26 which is machined into the plunger 15. The latter is provided with two additional radial ports or bores 27 and 28. Each of the ports 26-28 communicates with an axial bore or passage 29 of the plunger 15.

The control member 5 is further provided with a radially extending bore or channel 30 which connects the groove 23 with an annular chamber 31 extending between the peripheral surfaces 6 and 7 of the control member. A second radially extending bore or channel 32 connects the groove 24 with a second annular chamber 33 which extends between the peripheral surfaces 7 and 8 of the control member 5 and whose outer side is surrounded by the internal surface of the housing 1, the same as the outer side of the chamber 31.

The surface surrounding the bore 4 in the housing 1 is formed with an annular groove 34 which communicates with the chamber 33 of the control member 5 and with a radial inlet 35 machined into the housing 1 and connected to a source 60 of pressurized hydraulic fluid, e.g., an auxiliary pump. The chamber 31 communicates

with a radial outlet 36 which is machined into the housing 1 and is connected with a tank or reservoir 61 wherein the fluid is maintained at atmospheric pressure.

The externally threaded sealing member or plug 3 has an axial bore 37 which includes several portions of different diameter and receives a pin-shaped carrier 39 whose external threads mesh with the internal threads in the right-most portion of the sealing member 3 and which is held in a selected axial position by a lock nut 38. The bore 37 of the sealing member 3 is coaxial with the passage 29 of the plunger 15. The leftmost portion of the carrier 39 is provided with a collar 40 serving as an abutment for a ring-shaped motion transmitting retainer 41. The latter surrounds and is movable axially of the carrier 39 under or against the bias of a resilient element here shown as a helical spring 42 received in an enlarged portion 43 of the bore 37. In the illustrated axial position of the control member 5, the latter's right-hand end face 44 abuts against the retainer 41 and stresses the spring 42 by maintaining the retainer 41 out of contact with the collar 40 on the carrier 39. The spring 42 reacts against an internal shoulder of the sealing member 3 and permanently urges the retainer 41 toward or against the collar 40. The parts 39, 40, 41 constitute an axially adjustable stop for the control member 5.

The aforementioned sleeve 20 acts as a retainer for a further helical spring or an analogous resilient element 45. The rightmost convolution of the spring 45 bears against the left-hand end face of the control member 5 when the latter is moved axially in a direction to the left, as viewed in FIG. 1, i.e., toward the body 2 of the radial piston pump 70.

A portion 46 of the control member 5 constitutes a toothed rack which is parallel to the axis of the bore 4 in the housing 1 and meshes with a pinion 47 constituting a shifting device which can be rotated from without the housing 1 to change the axial position of the control member 5 and to thus control the flow of fluid into or from the cylinder for the piston 11. The rack 46 extends between the peripheral surfaces 6 and 7 of the control member 5.

The manner in which the springs 42 and 45 cooperate is shown in the diagram of FIG. 2. The changes (f) in axial length of the springs 42, 45 are measured along the abscissa, and the bias (P) of the springs 42, 45 is measured along the ordinate. The force of the spring 45 is indicated by the straight-line curve a , and the force of the spring 42 is indicated by the straight-line curve b .

The spring 42 acts upon the right-hand end face 44 of the control member 5 by way of the motion transmitting retainer 41 to shift the control member toward the body 2 of the radial piston pump 70. The spring 42 can shift the control member 5 axially when the latter is not subjected to any external shifting forces, i.e., when it is not held by pinion 47 against axial movement under the action of the spring 42. The right-hand and left-hand end positions of the control member 5 are respectively indicated at $+e_{max.}$ and $-e_{max.}$ and the zero or neutral position of the control member 5 is indicated at 0. The neutral position 0 constitutes one of an infinite number of intermediate positions of the control member 5. The spring 45 begins to bias the control member 5 when the latter reaches a position substantially midway between the zero position 0 and the right-hand end position

$+e_{max.}$ (note the point where the curve a intersects the abscissa in FIG. 2). It will be seen that the bias of the spring 45 upon the control member 5 opposes the bias of the spring 42, i.e., that these resilient elements tend to move the control member 5 in opposite directions. The control member 5 assumes the zero position 0 when the retainer 41 abuts against the collar 40, i.e., when the control member indirectly engages the carrier 39. In the zero position 0 of the control member 5, the bias of the spring 45 is approximately half the bias of the spring 42 (see the diagram of FIG. 2). The spring 42 acts upon the control member 5 only between the right-hand end position $+e_{max.}$ and the neutral or zero position 0. If the shifting pinion 47 is rotated in a direction and to the extent to move the control member 5 beyond the zero position 0 and toward the left-hand end position $-e_{max.}$, the control member 5 is biased only by the helical spring 45 whose bias in the position $-e_{max.}$ equals or approximates the bias of the spring 42 in the position $+e_{max.}$ of the control member 5.

The axial bore 14 of the control member 5 includes an enlarged portion 48 which is adjacent to the end face 44 and receives with clearance the inner end portion of the carrier 39. The other end portion of the bore 14 in the control member 5 is also enlarged, as at 49, and the surface surrounding the end portion 49 is provided with a groove for a split ring 50. The peripheral surface of the plunger 15 is formed with a circumferential groove for a split ring 51 which is movable between the split ring 50 and an internal shoulder 52 of the control member 5. The parts 50, 51 and 52 limit the extent of axial movement of the control member 5 relative to the plunger 15.

If the shifting pinion 47 is rotated in a clockwise direction, as viewed in FIG. 1, the control member 5 moves in a direction to the left so that the groove 24 in the internal surface of the control member begins to communicate with the radial port 26 of the plunger 15. Pressurized fluid is then free to flow from the source 60, through the inlet 35 and groove 34 of the housing 1, annular chamber 33, radial channel 32 and groove 24 of the control member 5, port 26 and axial passage 29 of the plunger 15. Such fluid leaves the axial passage 29 by way of the ports 27, 28 in the plunger 15 and flows into the bore 4 of the housing 1 as well as into the bore 17 of the piston 11. The fluid in the bore 17 exerts pressure against the surface 16 of the piston 11 and causes the latter to displace the slide block 13 in a direction to the left, as viewed in FIG. 1 (through the intermediary of the shoe 12). As mentioned before, the radial piston pump 70 comprises a structure (not shown) which biases the slide block 13 in a direction to the right, i.e., against the shoe 12.

The spring 21 biases the plunger 15 against the surface 16 of the piston 11 so that the plunger 15 shares the leftward movement of the piston 11 under the action of fluid pressure against the surface 16 whereby the port 26 of the plunger 15 returns into register with and is sealed by the internal rib 25 of the control member 5. This terminates the admission of pressurized fluid into the bores 4 and 17, i.e., the piston 11 ceases to move in a direction to the left, as viewed in FIG. 1.

The extent to which the control member 5 can move axially relative to the plunger 15 in a direction to the left, as viewed in FIG. 1, is determined by the internal shoulder 52 which then abuts against the split ring 51 on the plunger 15. If the extent to which the control

member 5 is to be displaced toward the slide block 13 exceeds the distance between the shoulder 52 and split ring 51, further leftward movement of the control member 5 is determined by leftward axial movement of the plunger 15. In other words, the leftward movement of control member 5 is terminated when the shoulder 52 moves into abutment with the split ring 51; from there on, the control member 5 can move further toward the slide block 13 only if the plunger 15 moves deeper into the body 2 of the radial piston pump. The piston 11 comes to a standstill in the aforescribed manner when the movement of the control member 5 is interrupted.

If the shifting pinion 47 is rotated in a counterclockwise direction, as viewed in FIG. 1, the control member 5 is caused to move away from the body 2 of the radial piston pump. This moves the internal groove 23 of the control member 5 into register with the radial port 26 of the plunger 15 so that fluid is free to escape from the bore 17 of the piston 11 into the reservoir 61 by way of the bore 4, ports 27, 28, passage 29, port 26, groove 23, channel 30, annular chamber 31 and outlet 36. The aforesaid structure in the radial piston pump 70 is then free to move the slide block 13 in a direction to the right, as viewed in FIG. 1, so that the slide block 13 depresses the piston 11 by way of the shoe 12 and causes the fluid to flow from the bores 17 and 4 into the reservoir 61. The plunger 15 continues to abut against the internal surface 16 in the bore 17 of the piston 11 and is pushed in a direction to the right so that the port 26 returns into register with and is sealed by the rib 25 to thus interrupt the flow of fluid from the bore 17 into the reservoir 61. The piston 11 is then arrested and the slide block 13 is held against further movement toward the control member 5.

When the control member 5 is caused by the pinion 47 to move in a direction to the right, its movement relative to the plunger 15 is terminated when the split ring 50 reaches and engages the split ring 51. From there on, the control member 5 moves with the plunger 15 and is arrested in an axial position which is determined by the plunger.

The control member 5 assumes the zero position 0 (together with the slide block 13) when the retainer 41 abuts against the end face 44 of the control member as well as against the collar 40 of the carrier 39. Such zero position of the control member 5 can be changed while the radial piston pump 70 is in use by the simple expedient of loosening the lock nut 38 and thereupon changing the axial position of the carrier 39 and its collar 40.

If the control member 5 is located to the left of its zero position 0, it is biased by the spring 45 (see the curve a between 0 and $-e_{max.}$ in FIG. 2). If the shifting pinion 47 does not exert a force upon the control member 5, the spring 45 is free to expand and moves the control member in a direction to the right, as viewed in FIG. 1, so that the groove 23 moves into register with the port 26 and allows fluid to flow from the bores 4 and 17 into the reservoir 61 in the aforescribed manner. The piston 11 follows the rightward movement of the control member 5 until the end face 44 of the control member returns into abutment with the retainer 41 which is biased against the collar 40 by the spring 42. The bias of the spring 42 is greater than that of the spring 45 (see FIG. 2) so that the spring prevents further rightward movement of the control member 5. It

will be noted that, when the control member 5 assumes its zero position 0, it is biased in opposite directions by the springs 42 and 45 so that it remains in such zero position without any play in either direction. This insures that the slide block 13, too, is held in accurately determined neutral position.

If the control member 5 is located to the right of its zero position 0, it is acted upon by the spring 42 (through the intermediary of the retainer 41) and, in certain positions, also by the spring 45 (see the distance between the zero position 0 of FIG. 2 and the points where the curve *a* intersects the abscissa). If the control member 5 is not acted upon by the shifting pinion 47, it moves in a direction to the left under the action of the spring 42 and comes to a halt when the retainer 41 reaches the collar 40 of the carrier 39. The groove 24 then registers with the port 26 so that the bores 4 and 17 receive pressurized fluid from the source 60 and the piston 11 moves in a direction to the left until the control member 5 returns to the zero position 0. The control member 5 is then acted upon by the spring 42 (stronger bias) as well as by the spring 45 (weaker bias) and thus remains in the zero position without any play.

The improved servo mechanism exhibits the following advantages: The control member 5 can dwell in the neutral position 0 without appreciable play or without any play. The neutral position of the control member 5 can be changed while the hydraulic machine 70 is in use and such neutral position can be moved to either side of the previously selected neutral position. Also, the position of the control member 5 can be changed at will to any of an infinite number of positions including the two end positions.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of our contribution to the art and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

1. The combination of a hydraulic machine having a movable regulating member with a servo mechanism which is actuatable to move said regulating member in a predetermined direction, said mechanism comprising a housing having an inlet for pressurized fluid and an outlet including a cylinder; a piston displaceable in said cylinder by pressurized fluid to move said regulating member in said direction; fluid flow controlling means including a control member movable in said housing between two end positions and a plurality of intermediate positions including a neutral position to thereby control the flow of fluid between said cylinder and said inlet and outlet; first and second resilient means mounted in said housing and acting upon said control member in opposite directions so as to bias said control member in said neutral position with forces of first and second magnitude and to bias said control member in at least some of the other positions thereof; shifting means operable to move said control member; and stop means provided in said housing and being engaged by said control member in said neutral position when said control member is not held against movement to said neutral position by said shifting means, said stop means

being adjustable relative to said housing to thereby change said neutral position of said control member.

2. The combination of claim 1, wherein said first resilient means biases said control member from one of said end positions with a first predetermined force and said second resilient means biases said control member from the other of said end positions with a second predetermined force which equals or approximates said first force.

3. The combination of a hydraulic machine having a movable regulating member with a servo mechanism which is actuatable to move said regulating member in a predetermined direction, said mechanism comprising a housing having an inlet for pressurized fluid and an outlet and including a cylinder; a piston displaceable in said cylinder by pressurized fluid to move said regulating member in said direction; fluid flow controlling means including a control member movable in said housing between two end positions and a plurality of intermediate positions including a neutral position to thereby control the flow of fluid between said cylinder and said inlet and outlet; first and second resilient means mounted in said housing and acting upon said control member in opposite directions so as to bias said control member in said neutral position with forces of first and second magnitude and to bias said control member in at least some of the other positions thereof; shifting means operable to move said control member and comprising a toothed rack provided on said control member and a gear meshing with said rack and rotatably mounted in said housing; and stop means provided in said housing and being engaged by said control member in said neutral position when said control member is not held against movement to said neutral position by said shifting means.

4. The combination of a hydraulic machine having a movable regulating member with a servo mechanism which is actuatable to move said regulating member in a predetermined direction, said mechanism comprising a housing having a bore and an inlet for pressurized fluid and an outlet, both communicating with said bore, and said housing including a cylinder; a piston displaceable in said cylinder by pressurized fluid to move said regulating member in said direction; fluid flow controlling means including a control member having an axial bore and being reciprocable in said bore of said housing between two end positions and a plurality of intermediate positions including a neutral position, and a follower plunger in said axial bore of said control member to thereby control the flow of fluid between said cylinder and said inlet and outlet; first and second resilient means mounted in said housing and acting upon said control member in opposite directions so as to bias said control member in said neutral position with forces of first and second magnitude and to bias said control member in at least some of the other positions thereof; shifting means operable to move said control member; and stop means provided in said housing and being engaged by said control member in said neutral position when said control member is not held against movement to said neutral position by said shifting means.

5. The combination of claim 4 further comprising spring means arranged to urge said follower plunger against said piston.

6. The combination of claim 4, wherein one of said resilient means is guided by said follower plunger.

7. The combination of claim 4, wherein said stop means includes a carrier which extends into the bore of said housing and includes an abutment, and a motion transmitting member movable along said carrier toward and from engagement with said abutment and bearing against one end of said control member in said neutral position as well as when said control member moves beyond said neutral position toward one of said end positions thereof, one of said resilient means being arranged to bias said motion transmitting member toward said abutment, said motion transmitting member engaging said abutment in said neutral position of said control member.

8. The combination of claim 7, further comprising a sealing member for one end of the bore in said housing, said sealing member having threads mating with complementary threads of said carrier.

9. The combination of a hydraulic machine having a movable regulating member with a servo mechanism which is actuatable to move said regulating member in a predetermined direction, said mechanism comprising a housing having an inlet for pressurized fluid and an

outlet and including a cylinder; a piston displaceable in said cylinder pressurized fluid to move said regulating member in said direction; fluid flow control means including a control member movable in said housing between two end positions and a plurality of intermediate positions including a neutral position to thereby control the flow of fluid between said cylinder and said inlet and outlet; first and second resilient means mounted in said housing and acting upon said control member in opposite directions so as to bias said control member in said neutral position with forces of first and second magnitude and to bias said control member in at least some of the other positions thereof, the magnitude of one of said forces in said neutral position of said control member being about twice the magnitude of the other force; shifting means operable to move said control member; and stop means provided in said housing and being engaged by said control member in said neutral position when said control member is not held against movement to said neutral position by said shifting means.

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