Jan. 13, 1959 M. W. HUBER 2,867,976

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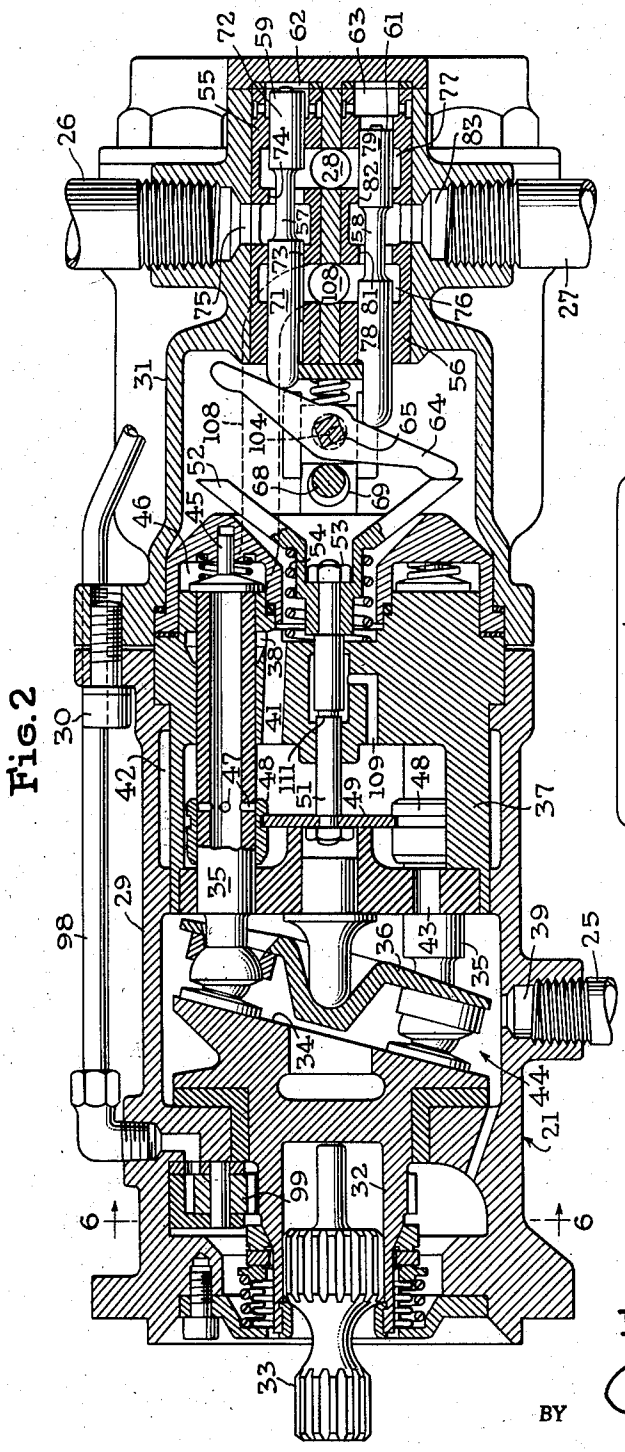


Fig. 2

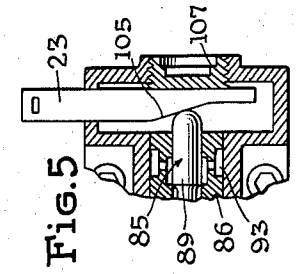


Fig. 5

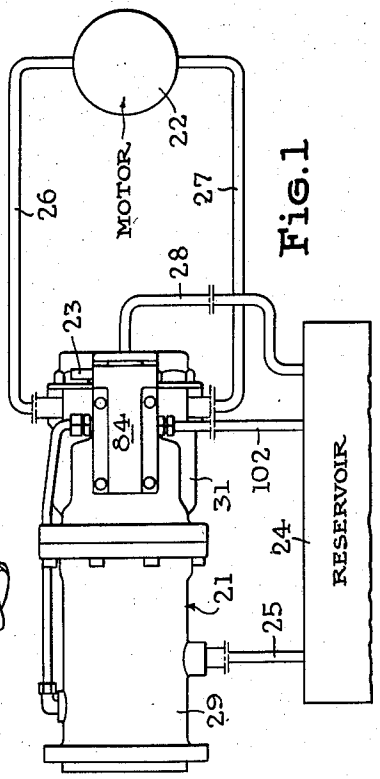



Fig. 1

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Fig. 3

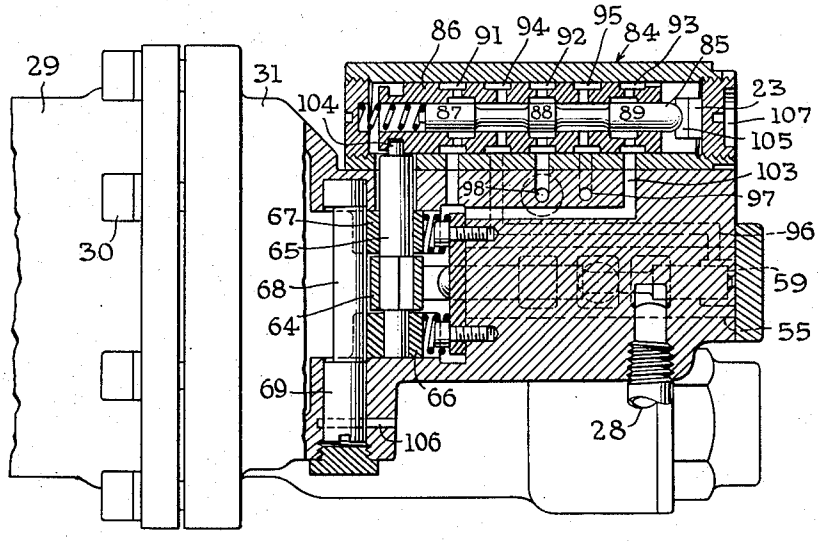



Fig. 4

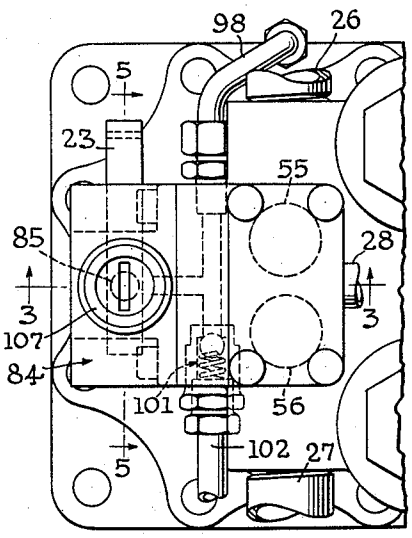
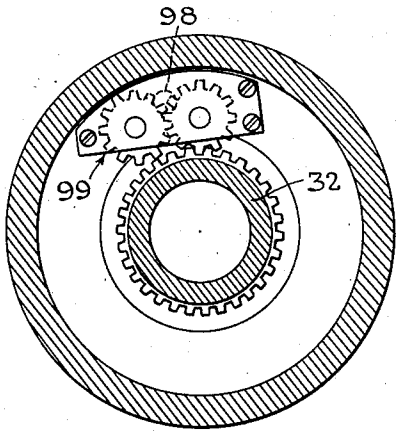



Fig. 6




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2,867,976

# PUMP

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Application October 11, 1956, Serial No. 615,368

7 Claims. (Cl. 60—52)

This invention relates to servo pumps and more particularly to the combination of a servo control and a unidirectional variable displacement pump.

A servo pump, as the term is used herein, is a device for producing a variable flow of hydraulic fluid in either of two delivery paths in response to an input signal. Up to this time the generally accepted device of this type included an overcenter pump, i. e., a pump having a pumping control element which when displaced from a null position in either of two directions progressively increased the rate of flow from the pump. Inasmuch as the element operated on both sides of a null position, it was capable of reversing the pressure relationship between the inlet and discharge ports. When these ports were connected to opposite sides of a reversible fluid motor and a servo control was provided for operating the displaceable element, it was possible to control the amount and direction of motor movement in response to an input applied to the servo control.

Servo pumps of the type just described contain certain inherent disadvantages which limit their usefulness. In the first place, the only active fluid in a system employing such a pump is that contained in the passages between the motor and the pump. Repeated operation of the system causes this small volume of fluid to be continuously forced through the pump thereby producing a considerable rise in fluid temperature. In order to minimize this temperature effect, a circuit must be provided to bypass the active fluid into a reservoir where it may be cooled. The provision of this auxiliary circuit frequently necessitates the use of a replenishing pump to keep the system fully charged with hydraulic fluid at all times.

A further disadvantage of the prior art servo pumps is their inherently low response characteristic which results from the high inertia of the overcenter element of the pump. While in certain industrial applications this disadvantage is of no great importance, it becomes a prime consideration in the control of high speed missiles and aircraft.

The object of this invention is to provide a servo pump free from the inherent disadvantages of the prior art devices. Briefly stated, the invention comprises a unidirectional variable displacement pump and a reversing valve arranged in combination with servo control mechanism which simultaneously varies the rate and direction of flow from the pump in response to an input signal. The reversing valve is arranged to control the discharge from the pump to the system and the return from the system to the reservoir. Since this return flow from the system is not transmitted directly to the pump inlet, the temperature effect encountered in the prior art systems is not present and thus no auxiliary cooling circuit and replenishing pump need be provided.

Another feature of the invention is the substitution of the relatively low inertia reversing valve for the relatively high inertia overcenter element of the prior art with the resulting increase in response characteristics.



A further advantage of this invention is the interaction between the displacement varying means and the reversing valve which insures that the opening of the reversing valve will always be proportional to the rate of flow from the pump. This feature establishes a substantially constant pressure drop across the reversing valve thereby eliminating one of the variables which prevent the proper operation of a servo system.

A preferred form of the invention will now be described in connection with the drawings, in which:

Fig. 1 is a schematic diagram of a control system incorporating the present servo pump.

Fig. 2 is a longitudinal section of the complete pump and reversing valve combination with the reversing valve shown in the actuated position.

Fig. 3 is a sectional view taken on line 3—3 of Fig. 4 wherein the servo valve is shown in the null position.

Fig. 4 is an end view of the servo pump taken at the reversing valve end thereof.

Fig. 5 is a sectional view taken on line 5—5 of Fig. 4 showing the arrangement of the input control rod.

Fig. 6 is a sectional view taken on line 6—6 of Fig. 2 showing the arrangement of the control pump.

Referring to Fig. 1, the servo pump 21 of this invention is shown in combination with an hydraulic system arranged to control a fluid motor 22 in response to a signal from input rod 23. The pump, which is supplied with hydraulic fluid from reservoir 24 via conduit 25, establishes a rate of flow proportional to the magnitude of the input signal in either conduit 26 or 27 depending on the direction of this signal. Concurrently with this operation, the unpressurized conduit is connected to the reservoir by way of return conduit 28. When the motor 22 has moved the desired amount, the operator returns input rod 23 to neutral position thereby reducing the pump output to a minimum and interrupting all flow to and from conduits 26 and 27.

As shown in Fig. 2, the preferred form of servo pump comprises a housing having two sections 29 and 31 connected by suitable attaching means 30. The section 29 contains a wobble plate pump driven through shaft 32 and splined coupling 33 by a suitable prime mover (not shown). The wobble plate 34, formed on the inner end of shaft 32 cooperates with a plurality of circumferentially arranged hollow pistons 35 which, under the action of the wobble plate and nutating plate 36, reciprocate in cylinders formed in block 37. These cylinders are provided with inlet chambers 38 which communicate with the pump inlet 39 via passages 41, chamber 42, port 43 and chamber 44. Fluid under pressure is discharged from the cylinders through check valves 45 to annular discharge chamber 46.

Each of the hollow pistons 35 contains a plurality of radial bleed passages 47 arranged for coaction with bleed valves 48 to control the displacement of the pump. These valves are carried by a spider 49 and rod 51 for reciprocation relative to the pistons as hereinafter described. The right-hand end of the rod 51 is formed with a shoulder against which saddle 52 is rigidly held by means of a nut 53. A spring 54, reacting between the cylinder block 37 and the saddle 52, biases the saddle and consequently the bleed valves 48, to an extreme right-hand position determined by the neutral position of the mechanism in housing section 31. As described below, this position establishes a minimum rate of discharge from the pump.

The right-hand section 31 of the servo pump contains the reversing valve and the mechanism for controlling this valve and the bleed valves previously described. The reversing valve comprises two cylinder blocks 55 and 56 which are axially bored to snugly but slidably receive

plungers 57 and 58. The right-hand ends of these plungers form pistons 59 and 61 which extend into chambers 62 and 63 where they are subjected to a control pressure as described below. The left-hand ends of the plungers coact with rocker arm 64 to axially displace the saddle 52 and bleed valves 48 against the bias of spring 54. The rocker arm is rigidly attached to a rotatable shaft 65 which, as shown in Fig. 3, is mounted in adjustable spring-biased bearings 66 and 67. These bearings abut the intermediate eccentric portion 68 of a shaft 69.

The plunger 57 carries valve lands 71 and 72 which cooperate with fixed lands 73 and 74, respectively, to control communication between delivery port 75 and the pressure chamber 76 and return chamber 77. The plunger 58 carries lands 78 and 79 which cooperate with the fixed lands 81 and 82 to control communication between these same two chambers and delivery port 83.

The plunger actuating pistons 59 and 61 are operated by control pressure supplied to chambers 62 and 63 from the servo valve 84. Referring to Fig. 3, this valve comprises a plunger 85 slidably received in a movable valve sleeve 86. The lands 87, 88 and 89 formed on the plunger cooperate with the ports 91, 92 and 93 in the sleeve 86 to reversely pressurize the ports 94 and 95 which are connected to piston chambers 62 and 63, respectively, by passages 96 and 97. Control fluid is supplied to the port 92 via external conduit 98 from a gear pump 99 (shown in Figs. 2 and 6) located in housing section 29 and driven by the shaft 32. Conventional relief valve 101 regulates the pressure in conduit 98 and by-passes the excess flow to return conduit 102. The ports 91 and 93 in the sleeve 86 are connected to the low pressure reservoir within the pump housing by common return passage 103.

The servo valve sleeve 86 is actuated by an eccentric pin 104, carried by the end of rocker shaft 65, which coacts with an annular groove formed in the sleeve. The valve plunger 85 is operated by an input rod 23 which has a beveled contacting surface 105 for converting the reciprocating motion of the rod into a corresponding reciprocation of the plunger.

*Adjustment for operation*

Prior to operation of the pump, the axial position of the rocker arm 64 must be adjusted so that when the arm is in its null position (vertical as viewed in Fig. 2) and the reversing plunger lands 71, 72, 78 and 79 lap the fixed lands 73, 74, 81 and 82, the left-hand ends of the plungers 57 and 58 will be in contact with the rocker arm. This adjustment is accomplished by rotating the shaft 69 which, through the interaction of its eccentric portion 68 and the spring-biased bearings 66 and 67, causes axial movement of the rocker shaft 65 and the rocker arm 64. When the rocker arm has been properly positioned, the shaft 69 is drilled and locked by the insertion of pin 106. After making this adjustment, shims are placed between the saddle 52 and either the shoulder of rod 51 or the nut 53 so that the ends of the saddle will contact the rocker arm when the bleed valves 48 are in the extreme right-hand position. This position may correspond to zero pump displacement, though preferably the minimum displacement of the pump has a small finite value. In this way the discharge port 46, conduit 108 and pressure chamber 76 are pressurized, thereby giving the pump an extremely sharp null point.

The adjustments just described required axial and rotational movements of the rocker shaft 65 with accompanying movements of the eccentric pin 104 carried thereby. Since this pin engages the servo valve sleeve 86, it now becomes necessary to re-balance this valve so that the plunger land 88 laps the pressure port 92. This adjustment is accomplished by means of a screw 107 which acts on plunger 85 through input rod 23 to reposition the plunger against its spring bias. Concurrently with this adjustment, it may be necessary to axially displace the input rod so that when the plunger 85 is in its null position, the right-hand end thereof, as viewed in Fig. 5, contacts the center of beveled surface 105.

*Operation of the pump*

With the pump adjusted in the manner described above, a slight amount of pressure fluid will flow to chamber 76 from the discharge port 46 but since the reversing plungers are centered, no fluid will flow to the motor conduits 26 and 27.

If the operator now desires to actuate the motor 22 at a given rate in one of its two directions, he depresses the input rod 23 the prescribed amount. Downward movement of the rod, as viewed in Fig. 5, causes the beveled surface 105 to force the servo valve plunger 85 to the left, thereby displacing land 88 so that the control fluid supplied from gear pump 99 via conduit 98 will flow from port 92 to the port 95. This fluid is then transmitted along conduit 97 to piston chamber 63. At the same time, piston chamber 62 is connected to the low pressure sump within the housing by conduit 96, ports 94 and 91 and conduit 103. The pressure differential between these two chambers causes pistons 59 and 61 and the rocker arm 64 to reversely actuate the plungers 57 and 58. The movement of these plungers unseats the lands 72 and 78 from the fixed lands 74 and 81, thereby connecting pressure chamber 76 to delivery port 83 and return chamber 77 to delivery port 75. One side of the fluid motor 22 now communicates with pump discharge port 46 via conduit 27, port 83, pressure chamber 76, and conduit 108, and the other side communicates with the reservoir via conduit 26, port 75, return chamber 77, and conduit 28.

As the rocker arm 64 rotates under the action of plunger 58, the lower end thereof, as shown in Fig. 2, displaces the saddle 52 against the bias of spring 54, thereby moving the rod 51 and the bleed valves 48 to the left. As is well known in the art, the position of the bleed valves relative to the bleed ports 47 determines the effective stroke of the pistons 35. In this pump the effective stroke of the pistons is a minimum when the bleed valves are in an extreme right-hand position; this stroke progressively increasing as the valves move to the left. Therefore, when the valves move to the left as a result of the rotation of rocker arm 64, the pump displacement increases an amount proportional to the distance the valves move.

Simultaneously with the operation of the reversing valve and the bleed valves, the rotation of rocker arm 64 and shaft 65 causes eccentric pin 104, carried by this shaft, to move the servo valve sleeve 86 to the left, as viewed in Fig. 3, to a point where the plunger land 88 again laps the pressure port 92. When this point is reached the plunger lands isolate the ports 94 and 95, thereby blocking all flow from piston chamber 62 and to chamber 63. Upon interruption of these communications, the plungers 57 and 58, the rocker arm 64, and the bleed valves 48 are locked in their current positions by the pressure fluid trapped in piston chamber 63.

It should now be clear that the servo valve 84 is unbalanced by the shift of plunger 85 an amount proportional to the magnitude of the input signal and is rebalanced by the sleeve 86 when the reversing valve and bleed valves have been operated in compliance with this signal. Because of this feedback between the rocker arm and the servo valve, it is possible to vary the pump displacement in accordance with the magnitude of the movement of input rod 23. It should be equally clear from a consideration of Fig. 2 that the interaction between the reversing valve and the bleed valves guarantees that the movement of the plungers 57 and 58 is proportional to the displacement of the pump. The effect of this feature is that the size of the adjustable orifice formed between the edges of lands 72 and 78 and fixed lands 74 and 81 varies with the rate of flow through these orifices, thereby giving a constant pressure drop across the reversing valve

regardless of flow rate. This feature is of great importance in high performance servo systems as it makes a constant of an otherwise variable quantity and thus eliminates the need for complex and inaccurate compensators.

When the motor has moved the desired amount, the operator withdraws the input rod **23** to its null position. This action permits the servo plunger **85** to move to the right under the influence of its biasing spring, thereby pressurizing port **94**, conduit **96** and piston chamber **62**, and venting chamber **63**, conduit **97**, and port **95** to the housing sump via port **93** and conduit **103**. This reverse pressurization of the chambers **62** and **63** causes the plungers **57** and **58** and the rocker arm **64** to return to their null positions thus reducing the pump displacement to its minimum value and interrupting flow to delivery port **83** and from delivery port **75**. As the reversing valve and the bleed valves return to their null positions, the feedback link provided by eccentric pin **104** moves the servo valve sleeve **86** to the right so as to rebalance this valve and cut-off the flow from port **92**. When the components of the servo pump again reach their null positions the motor **22** stops in its new position.

From a consideration of the preceding description and the accompanying drawings, it will be obvious that movement of the input rod **23** in an outward direction from its null position will cause the motor **22** to operate in the reverse direction. In this case, the plungers **57** and **58** and the rocker arm **64** would move to positions just the reverse of those shown in Fig. 2; but in all other respects the operation of the servo pump would be the same as previously described.

Throughout this description it has been assumed that the operator would manually move the input rod **23**. This expedient was adopted in order to simplify the presentation of the invention. However, it will be obvious to persons skilled in the art that this member would, in most applications, be operated by some form of remote control system. Further, such systems frequently would include a feedback link between the motor **22** and the input member **23** so that the motor could be stopped automatically upon reaching a predetermined position.

In actual tests of the preferred form of this invention, it has been found that the use of spring **54** to return the pump controls to the null position produced satisfactory response characteristics up to a frequency of about 30 cycles per second. This value represents the probable resonant frequency of a spring of this type and operation above this value would obviously be impossible. Where it is desirable to have response frequencies on the order of 80 to 100 cycles per second, it is only necessary to block the communication between passage **109** and low pressure chamber **42** and reconnect this passage to the external conduit **98**. In this way the control pressure from gear pump **99** reacts on differential motor **111** to increase the effective bias on saddle **52** and the bleed valves **48**, thereby increasing the rate of response of these devices. When the saddle moves to the left against this bias the hydraulic fluid in motor **111** and passage **109** is forced back into the conduit **98** and from there it is discharged through the relief valve **101**. This high frequency modification can be used without spring **54** though it is recommended that the spring be included as a safety measure in the event that the gear pump fails.

As stated above, the drawings and description relate only to a preferred embodiment of the invention and it will be readily apparent to one skilled in the art that there are many changes which can be made in this structure without departing from the inventive concept. The scope of the invention should not be limited in any respect, except in accordance with the following claims.

What is claimed is:

1. In combination, a pump; adjustable means for progressively varying the displacement of said pump; yielding means for biasing said adjustable means to a position establishing minimum pump displacement; a pump discharge passage and two delivery paths; a reversing valve normally closing said discharge passage but operable to vary progressively the communication between said passage and a selected delivery path; and means responsive to a selection of pump displacement and path of delivery for positioning said adjustable means against the bias of said yielding means and for simultaneously operating said reversing valve to establish a communication between said discharge passage and the selected delivery path proportional to the movement of said adjustable means.

2. In combination, a pump; adjustable means for progressively varying the displacement of said pump; yielding means for biasing said adjustable means to a position establishing minimum pump displacement; a pump discharge passage, and a return passage; first and second delivery paths; first and second valve means normally closing said first and second delivery paths, respectively, but operable to vary progressively the communication between the respective paths and either the discharge passage or the return passage; and means responsive to a selection of pump displacement and path of delivery for positioning said adjustable means against the bias of said yielding means and for simultaneously reversely operating said first and second valve means to establish a communication between the discharge passage and the selected delivery path proportional to the movement of said adjustable means and another similar communication between the other delivery path and the return passage.

3. In combination, a pump; adjustable means for progressively varying the displacement of the pump; yielding means for biasing said adjustable means to a position establishing minimum pump displacement; a pump discharge passage and a return passage; first and second delivery paths; first and second delivery valves movable from positions in which they close the first and second delivery paths respectively to positions in which the respective paths communicate with either the discharge passage or the return passage; actuating means including a fluid motor operatively connected with each delivery valve for reversely opening said valves in one direction or the other depending on which of the fluid motors is pressurized; means interconnecting the actuating means and the adjustable means for moving the latter against the bias of said yielding means an amount proportional to the opening of each delivery valve; and a control circuit operable from a null condition in response to a selection of pump displacement and path of delivery for selectively pressurizing one of said fluid motors, said circuit including feedback means for returning the circuit to the null condition when the desired movements of the delivery valves and the adjustable means have been effected.

4. A servo control system for operating a fluid motor in response to an input signal, comprising a reservoir; a pump for delivering pressure fluid from the reservoir to a discharge passage; adjustable means for progressively varying the displacement of said pump; yielding means biasing said adjustable means to the minimum displacement position; first and second delivery paths; a return passage connected to the reservoir; a reversible fluid motor connected to said delivery paths and having a member movable in one direction or the other according as the first or second path is pressurized; a flow-reversing mechanism comprising first and second valve means normally closing said first and second delivery paths, respectively, but operable to open the respective paths to either the discharge passage or the return passage; and actuating means responsive to one characteristic of said input signal for reversely opening said first and second valve means and responsive to another characteristic of said signal for positioning the adjustable means against the bias of said yielding means and simultaneously regulating the opening of each valve means in accordance with the movement of said adjustable means.

5. The combination defined in claim 2 in which the

yielding means comprises a mechanical spring and a fluid motor operable to provide a constant force in aid of the biasing force exerted by the mechanical spring.

6. In combination, a pump; adjustable means for progressively varying the displacement of said pump; yielding means for biasing said adjustable means to a position establishing minimum pump displacement; a pump discharge passage and two delivery paths; a reversing valve normally closing said discharge passage but operable to connect said passage with a selected delivery path; and common actuating means responsive to a selection of pump displacement and path of delivery for positioning said adjustable means against the bias of said yielding means and for simultaneously opening said reversing valve to establish a communication between said discharge passage and the selected delivery path, said actuating means being operable to coordinate the opening movement of the reversing valve with the movement of the adjustable means.

7. A servo control system for operating a fluid motor in response to an input signal, comprising a reservoir; a pump for delivering pressure fluid from the reservoir to a discharge passage; adjustable means for progressively varying the displacement of said pump; yielding means biasing said adjustable means to the minimum displacement position; first and second delivery paths; a return passage connected to the reservoir; a reversible fluid motor connected to said delivery paths and having a member movable in one direction or the other according as the first or second path is pressurized; a flow-reversing mechanism comprising first and second valve means normally closing said first and second delivery paths, respectively, but operable to open the respective paths to either the discharge passage or the return passage; and common actuating means responsive to one characteristic of said input signal for reversely opening said first and second valve means and responsive to another characteristic of said signal for positioning the adjustable means against the bias of said yielding means, said actuating means being operable to coordinate the opening movement of the first and second valve means with the movement of the adjustable means.



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