

- [54] **SERVOACTUATOR WITH MECHANICAL FEEDBACK**
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Related U.S. Application Data

- [63] Continuation of Ser. No. 858,604, Sept. 17, 1969, abandoned.
[52] U.S. Cl. **91/3, 91/186, 91/387, 91/445, 91/506**
[51] Int. Cl. **F01b 1/00, F15b 13/16**
[58] Field of Search **91/3, 387, 504, 505, 91/506, 445, 186**

References Cited

UNITED STATES PATENTS

- 2,887,998 5/1959 Thorner 91/387
3,017,864 1/1962 Atchley 91/3

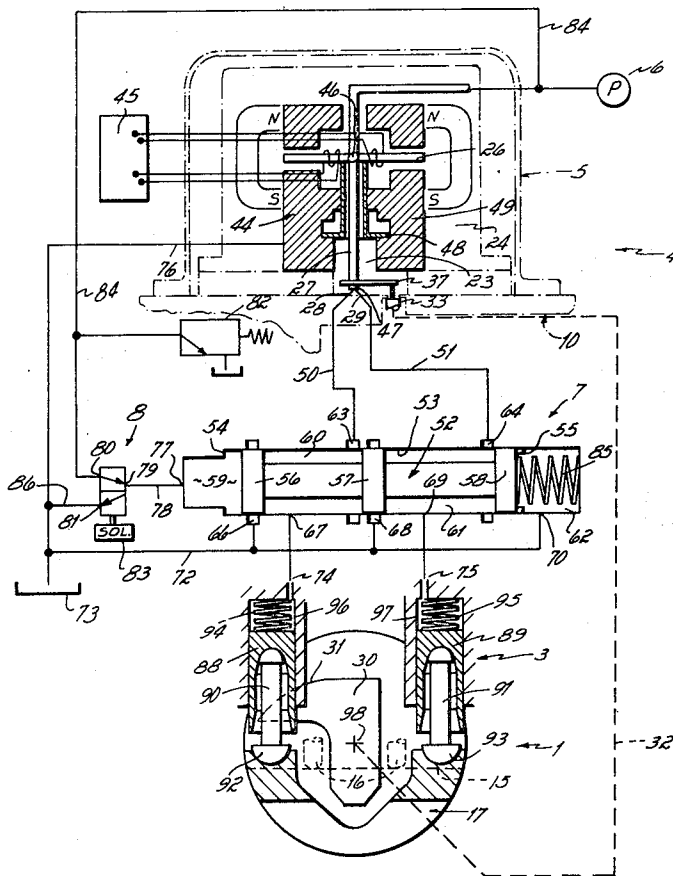
3,429,225 2/1969 Keyworth 91/506

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[57] **ABSTRACT**

The displacement of a servoactuator such as a variable volume pump or motor is controlled by a servovalve of the jet discharge type having a movable jet tube which is responsive to an electrical input to establish a pressure differential between a pair of fluid lines in accordance with the magnitude of an electrical signal. The pressure differential is applied to operate the opposed hydraulic motors which position the displacement changing means of the pump or motor. A resilient feedback spring is connected mechanically from the displacement changing means to the wet side of the jet tube, and as the displacement changing means is moved by the hydraulic motors, the spring increasingly urges the jet tube toward its null position.

18 Claims, 6 Drawing Figures



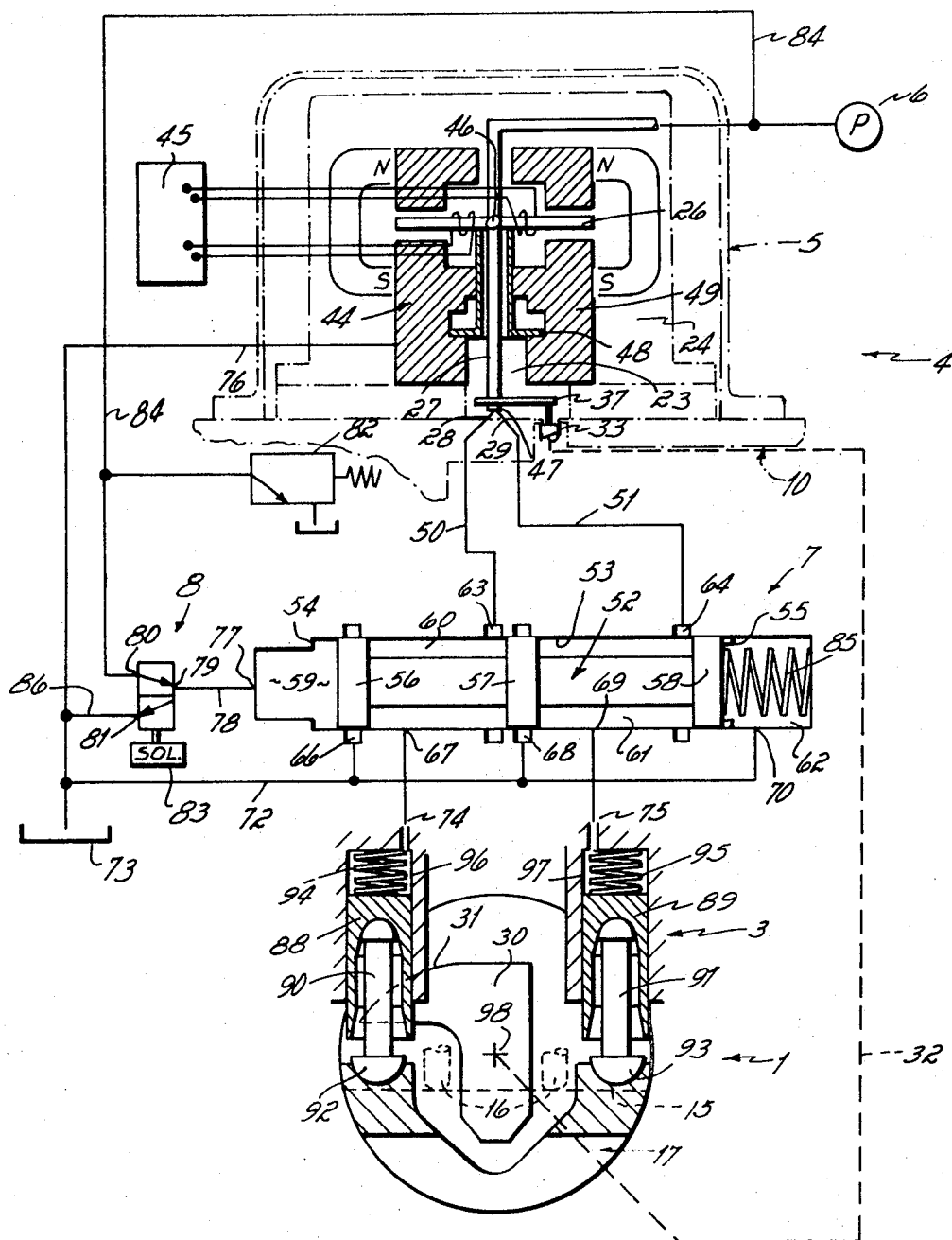


Fig. 1

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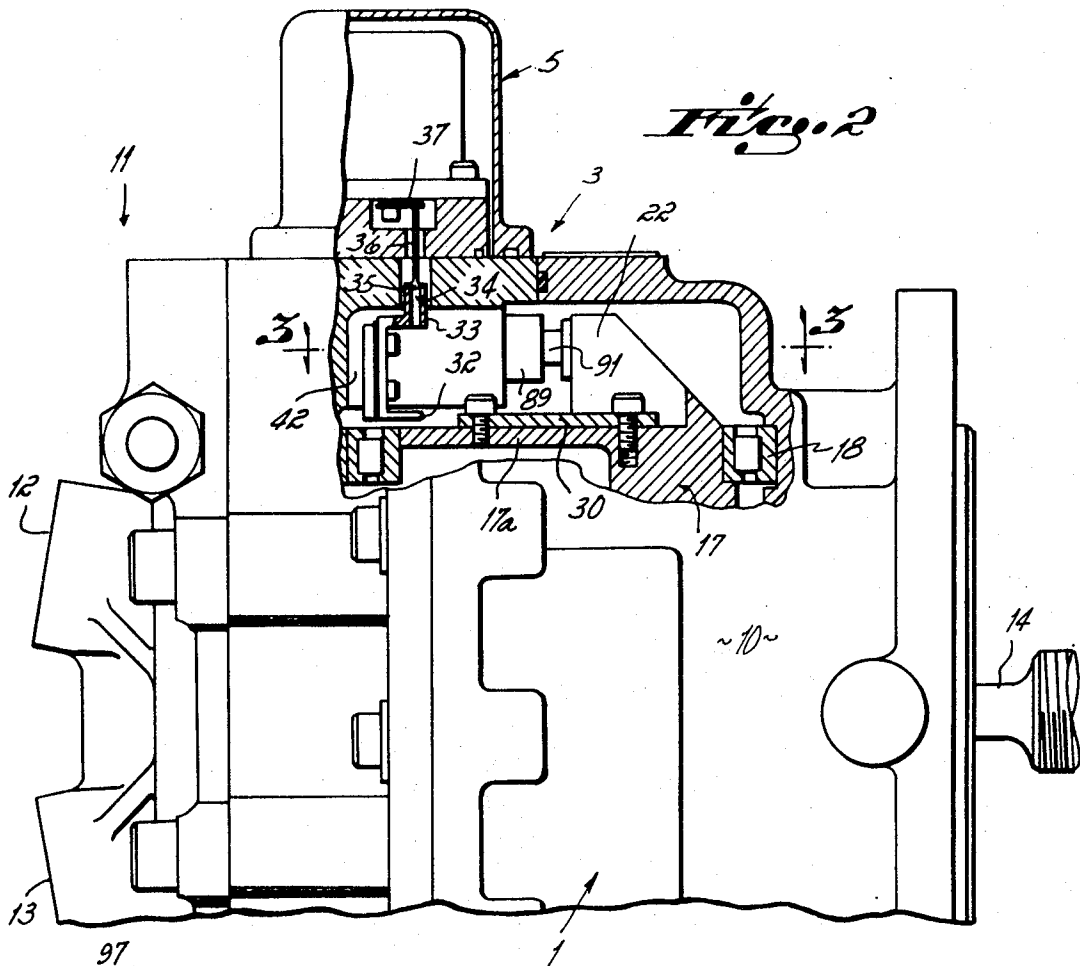
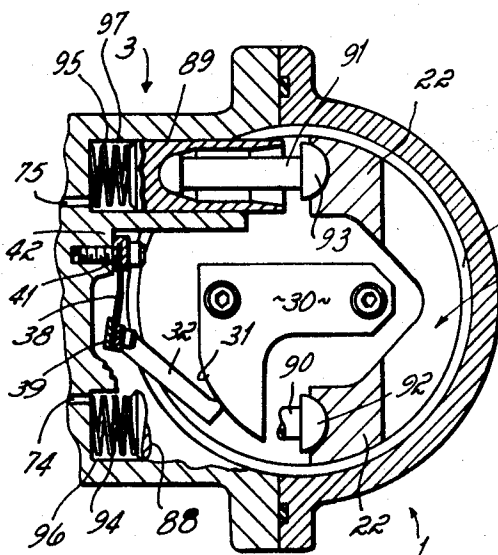
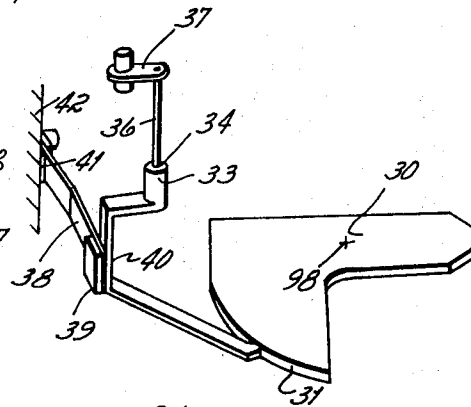
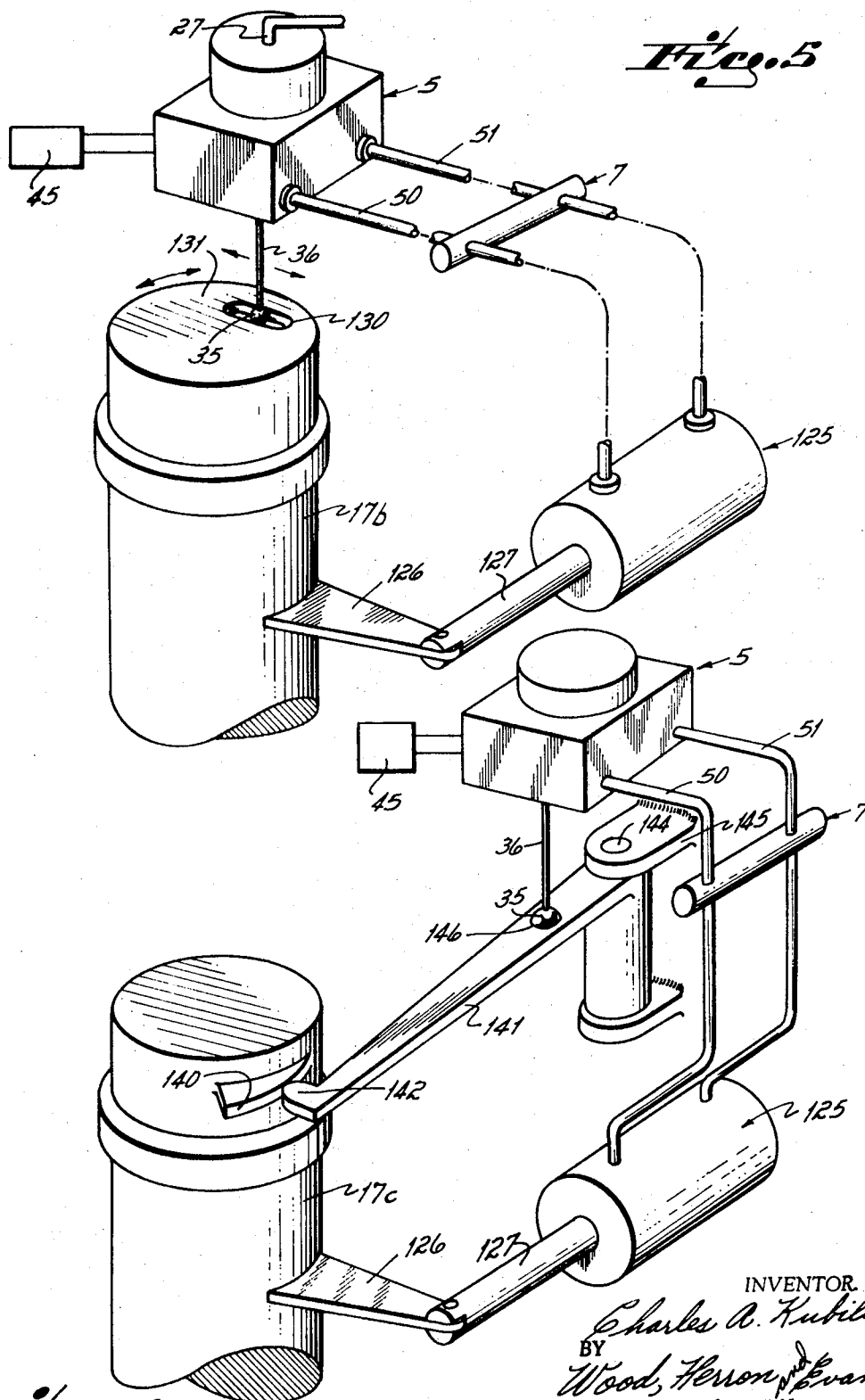


Fig. 3

Fig. 4

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SERVOACTUATOR WITH MECHANICAL FEEDBACK

This application is a Continuation of application Ser. No. 858,604, filed Sept. 17, 1969, now abandoned.

This invention relates to a mechanical feedback system for a servoactuator. More particularly, the invention relates to a mechanical feedback system of a servo controlled pump or motor which operates in accordance with the magnitude of an electrical command control signal to vary the volume of hydraulic fluid passed per unit time through the pump or motor.

The mechanical feedback system of this invention may be used in any hydraulic servoactuator system which utilizes a spring feedback to balance an angular or rotation command signal, whether the command is mechanical or electrical. As one preferred application, it may be utilized to operate the angularly adjustable displacement changing means of hydraulic pumps and motors wherein the displacement changing means is positionable by a fluid motor, piston, or ram. For example, the controlled device may comprise a variable volume pump or motor which is of the vane type or which is of the axial piston type. For purposes of illustrating a preferred embodiment, the invention is described hereinafter as used to control the displacement of a variable volume axial piston pump having a trunnion-mounted hanger or swash plate which is angularly adjustable with respect to the axis of the cylinder barrel.

The displacement control of this invention preferably includes a jet discharge electrohydraulic servovalve of the type wherein a fluid jet from a nozzle is divided into two fluid streams having a static pressure differential between them which is related to the magnitude and direction of an electrical control signal applied to the servovalve. Pressure fluid for operating the servovalve and the controlled device is supplied from a pressure source or pilot pump which may be incorporated as a part of the controlled device itself. The servovalve adjustably divides the jet of fluid issuing from the jet nozzle between two receptor ports which are connected, through a by-pass or shut-off valve, to a pair of opposed balanced area hydraulic rams by which the hanger or other movable displacement changing means of the pump or motor can be positioned. The application of an electrical signal of given magnitude to the servovalve directs pressure fluid from the jet nozzle toward one or the other of the hydraulic rams, and the resulting difference in static pressure develops a force which causes the displacement changing means to move at a rate proportional to the magnitude of the electrical signal. Movement of the displacement changing means continues, increasing or decreasing the volume of flow per unit time or changing the sense of the flow, so long as the jet impinges unequally between the two receptor ports.

The servoactuator of this invention is an improvement upon the servocontrolled pump disclosed in U. S. Pat. No. 3,429,225 of Albert Keyworth for "Electrohydraulic Displacement Control with Mechanical Feedback", issued Feb. 25, 1969, and assigned to the assignee of this application. That servocontrol system requires that the feedback motion from the displacement changing means to the jet tube pass through a dynamic seal. Specifically, the feedback spring is attached at one end to the trunnion of the pump hanger or displacement means and at the opposite end to the jet tube on the dry or torque motor side of the servovalve. To

maintain the electrical torque motor dry in that application, a dynamic seal is required around the trunnion. That system also requires a complex spring arrangement to effect the mechanical feedback.

It has been an objective of this invention to eliminate all dynamic seals from the servomotor control system and to minimize the complexity of the spring feedback arrangement. This objective has been accomplished by connecting the feedback spring at one end directly to the trunnion shaft and at the opposite end of the fluid or wet side of the torque motor. When thus connected there is no need for any dynamic seals around the trunnion or any portion of the servo-controlled pump so as to maintain the dry side of the torque motor isolated and sealed with respect to the remainder of the system. This arrangement also has the advantage of being much less complex from a mechanical standpoint.

Another objective of this invention has been to minimize feedback error due to bearing run out or deflection of the trunnion from which the feedback spring is actuated. By utilizing a relatively large throw cam on the trunnion to displace a lever and then utilizing the lever to effect displacement of the feedback spring, trunnion run out or deflection errors are minimized. The pivot point of the lever arm is then accurately fixed relative to the valve so that normal displacements of the trunnion axis have an insignificant effect on the feedback spring displacement. The cam shape can then be varied to generate any performance characteristic desired. In a preferred embodiment, the cam is so configured that it produces an increasing feedback slope at higher displacements.

These and other objects and advantages of this invention will be more readily apparent from the following description of the drawings in which:

FIG. 1 is a diagrammatic illustration of a hydraulic system including a variable displacement axial piston pump and control means in accordance with a preferred embodiment of this invention for operating the displacement changing means of the pump,

FIG. 2 is a side elevational view partially broken away through an aircraft axial piston pump which is fitted with a displacement control in accordance with this invention,

FIG. 3 is a cross-sectional view through the pump of FIG. 2 taken on Line 3—3 of FIG. 2,

FIG. 4 is a diagrammatic perspective view of the mechanical feedback portion of the control system of the pump of FIG. 2,

FIG. 5 is a diagrammatic perspective view of a second embodiment of a mechanical feedback system of a servoactuator system, and

FIG. 6 is a diagrammatic perspective view of a third embodiment of a mechanical feedback system of a servoactuator system.

Referring to the drawings and particularly to FIGS. 1 and 2, the numeral 1 designates a variable volume axial piston pump of known type with which the invention is suitable for use, the pump 1 being shown fragmentarily and diagrammatically in FIG. 1 and partially in section in FIG. 2. The pump 1 has an adjustable displacement changing means or hanger 17 which is operated by parallel aligned fluid motor means 3. The displacement control 4 includes a jet discharge type single stage servovalve 5 which directs pressure fluid from a source of pressure 6 to the fluid motor means 3, through a by-pass or shut-off valve 7 controlled by a so-

lenoid operated valve 8. One preferred embodiment of the invention includes the valves 7 and 8 but the system is operable without these valves so that they may be omitted without departing from the invention of this application.

More specifically, as shown in FIG. 2, pump 1 has a cylinder barrel located within a housing 10, a port surface 11, inlet and outlet ports 12 and 13 and an operating shaft 14. The barrel contains a plurality of parallel reciprocable pistons 16. These pistons 16 are constrained to run upon a conventional swash plate 15 carried on a hanger 17 which can be tilted or swung about trunnions 17a or hanger supporting means on tracks or trunnions bearings 18 journaled in the pump housing 10 to permit the angle or inclination of swash plate 15 with respect to pistons 16 to be varied.

The hanger 17 has an integral arm or extension 22 which is engaged by the fluid motor means or stroke control mechanism 3. The stroke control mechanism 3 operates to set the inclination angle of hanger 17, and hence of swash plate 15, with respect to pistons 16, thereby determining the stroke of these pistons 16 and the rate and direction of fluid flow through pump 1.

Pump 1 is of the cross-center type, in which hanger arm 22 can be swung from one side of the centered, or zero stroke, position shown in FIG. 1, to the other side thereof, causing the direction of fluid flow through the pump to be reversed for a given direction of shaft 14. However, it should also be understood that the invention can also be used with single side pumps and motors, which can be adjusted as to magnitude but not direction of flow.

The servovalve 5 is a jet discharge, electrohydraulic type valve which operates the fluid motor means 3 through the shut-off valve 7. The servo-valve 5 has a rotationally displaceable armature 26 to which a torque of adjustable magnitude can be applied. This armature 26 urges a jet tube 27 selectively toward one or the other of two receiver or receptor ports 28 and 29 from its normal centered or null position between the ports. Jet tube 27 at its lower or wet side end or wet chamber end is mechanically connected with the hanger 17 via the cam and cam follower assembly 2 (FIG. 4). This mechanical connection consists of a cam 30 fixedly secured to the outer or upper end of the hanger 17. This cam has a cam surface 31 engageable by one end of a cam follower arm 32, the opposite end 33 of which is provided with a socket 34 for the reception of a ball 35 secured to the lower end of a force transmitting spring rod 36. The upper end of this spring rod 36 is fixedly secured to the lower or wet end of the jet tube 27 by a bracket 37 located in the wet chamber 23 of the torque motor. A spring 38 is secured at one end 39 to an intermediate section 40 of the cam follower 32 and is fixedly connected at its opposite end 41 to a section 42 of the case or pump housing 10.

The jet discharge electrohydraulic servovalve 5 may suitably be of the type described in U.S. Pat. No. 3,017,864 to Atchley. As described in detail in U.S. Pat. No. 3,017,864, this type of valve conventionally has a wet side or wet chamber adjacent the fluid discharge end of the jet tube and a dry side or dry chamber within which the electrical torque motor is sealed from the fluid ejected from the jet tube. As shown in FIG. 1, the servovalve 5 includes a polarized torque motor (generally at 44) receptive to an electrical current of controlled magnitude from electrical source 45

which may be conventional. The torque motor armature 26 is rotatable about an axis 46 and is connected to jet tube 27 to displace the latter through small excursions relative to the two receiver ports 28 and 29.

The spring rod 36 applies a mechanical feedback source to the jet tube varying with the piston of the displacement changing means 2, for restoring the jet tube to a centered position between the two receiver ports 28 and 29 when the hanger has reached a position correlated to the electric current signal from electric source 45.

Jet tube 27 has an inlet to which pressure fluid is supplied from pressure source 6. At its other end, jet tube 27 terminates in a jet nozzle 47 which passes through an aperture in a plate 48 mounted on the servovalve body 49. The jet nozzle 47 is closely adjacent receptor ports 28 and 29 and, when armature 26 is displaced from the centered position between the receptor ports in response to an electric signal, the jet of fluid issuing from nozzle 47 is divided unequally between ports 28 and 29, thereby creating a difference in the fluid pressures established at those ports.

Receptor ports 28 and 29 are connected by passageways 50 and 51 to the fluid pressure operated by-pass or shut-off valve 7 which is of the spool type. Valve 7 controls the application of fluid from passageways 50 and 51 to the fluid motor means 3. The valve 7 includes a spool 52 slideable in a bore 53 between end stops 54 and 55. Spool 52 has circumferential lands 56, 57 and 58 spaced along it which cooperate with spool bore 53 to define chambers 59, 60, 61, and 62. Bore 53 is provided with axially spaced inlet grooves or ports 63 and 64 from passageways 50 and 51, respectively, and also with axially spaced outlet grooves or ports 66, 67, 68, 69, and 70. Outlet grooves 66, 68 and port 70 are connected through a passageway 72 to a fluid reservoir or tank 73, to which the body 49 of servovalve 5 is also connected via line 76. Ports 67 and 69 are connected via passageways 74 and 75, respectively, to two opposed equal area fluid rams which comprise the opposite stroke control mechanism of fluid motor means 3. Stop 54 is dimensioned so that grooves 63 and 64 are blocked when grooves 66 and 68 are open.

The lands 56, 57, and 58 of spool 52 are positioned to direct pressure fluid from the jet nozzle 47 through the spool chambers 60 and 61 to stroke control mechanism of fluid motor means 3 via passageways 74 and 75, or to close off ports 63 and 64 and dump the control pressure fluid to tank 73 via passage 72.

Valve 7 is also provided with an end port 77 in chamber 59, and this port 77 communicates through a passageway 78 with the solenoid operated valve 8. Valve 8 has three ports, indicated at 79, 80 and 81. When its solenoid 83 is energized, valve 8 applies pressure fluid from port 80, to which pressure source 6 is connected via line 84, to port 79 and into valve chamber 59. Application of pressure in chamber 59 on the end surface of spool land 56 holds the spool 52 against stop 55 in the position shown in FIG. 1, against the biasing action of a spring 85.

When solenoid 83 is de-energized, the spool of valve 8 is moved to connect port 79 to port 81 which leads to tank 73 via a line 86. In this condition port 80 is blocked against the application of pressure to port 79. This relieves the endwise pressure force on spool 52, permitting spring 85 to urge the spool against the other end stop 54. The pressure in line 84 from pressure

source 6 is held constant by a relief valve 82 which spills excess fluid to tank.

The stroke control mechanism of fluid motor means 3 includes a pair of parallel aligned fluid rams or left and right stroking pistons 88 and 89 for engaging opposite sides of hanger arm 22. A dumbbell shaped connector pin 90, 91 extends between and interconnects each piston 88, 89 to one side of the hanger arm 22. The hemispherical ends 92, 93 of each of the pins 90, 91 seat within semispherical recesses in the piston 88, 89 and the arm 22 respectively so as to allow some limited pivotal movement of the ends of the pins 90, 91 in the pistons 88, 89 and the arm 22, respectively.

A pair of compression springs 94, 95 are located between the ends of the piston cylinders 96, 97 and the ends of the pistons 88, 89. These springs 94, 95 are of equal strength and normally hold the arm 22 and thus the attached hanger 17 in a centered or null position.

In describing the operation of this control mechanism let it be assumed that at the start the hanger 17 of pump 1 is in the centered position shown in FIG. 1, corresponding to substantially zero displacement of the pump pistons 16, and that the pressure source 6 is supplying pressure fluid to line 84 and to the inlet of servovalve 5.

Pressure from source 6 is communicated through line 84 to port 80 of solenoid operated valve 8. If solenoid 83 is energized, the pressure at port 80 is applied through the valve 8 into chamber 59 of the valve 7, in which it acts on the end surface of spool land 56, holding the spool against end stop 55.

When no signal is applied from electrical source 45, servovalve 5 is at null and the jet of fluid issuing from nozzle 47 of jet tube 27 impinges equally on receptor ports 28 and 29, thereby establishing equal pressures at those ports.

The pressure at receptor ports 28 and 29 are communicated through passageways 50 and 51 and chambers 60 and 61 respectively of the valve 7 into passageways 74 and 75 through which they are applied to the annular end surface areas of the left and right stroking pistons 88 and 89 respectively. Since these annular areas are equal, the equal pressures establish equal forces on the pistons 88 and 89, thereby maintaining hanger 17 in the initial or centered position.

The control is actuated by applying to torquemotor 44 a differential current from electrical source 45 having a magnitude and polarity corresponding to the direction and magnitude of desired fluid flow through pump 1. This signal causes the torquemotor 44 to create an electromagnetic field about armature 26 which turns the armature about its axis 46. Assuming that the polarity of the field is such that the armature 26 is turned in a clockwise direction, a disproportionate portion of the jet of hydraulic fluid will thereby be directed toward the left receptor port 28, increasing the pressure of fluid at port 28 and in passageway 50 relative to that at port 29 and in passageway 51.

The differential pressures in passageways 50 and 51 is communicated across chambers 60 and 61 of valve 7 and into passages 74 and 75. A larger pressure acts on the left stroking piston 88 than on the right stroking piston 89, hence hanger arm 22 of hanger 17 is urged to the left or in the counterclockwise direction rotating the hanger 17 on its trunnion bearings 18. Fluid in cylinder 97 is displaced through the by-pass valve 7 to tank as the right stroking piston 89 is displaced into its

cylinder 97. Fluid pressure and/or the force of spring 95 maintains piston rod 91 in engagement with hanger arm 22, thus freeing the stroking mechanism of fluid motor means 3 of backlash.

As the hanger turns about the hanger supporting means or trunnions 17a, its motion is transmitted or fed back through the rotation of the cam about the trunnion axis 98 and the resilient spring member to the lower end of jet tube 27 directly through the cam follower 32. This force opposes and tends to counteract the electromagnetic torque acting in the clockwise direction on armature 26 and tends to move the jet tube in the opposite direction, that is, toward the position in which the jet tube is more nearly centered between receptor ports 28 and 29. As the hanger continues to be moved, the magnitude of this mechanical feedback force increases, until the mechanical feedback force applied to the jet tube through spring rod 36 is of sufficient magnitude that the jet tube is restored to centered position between the receptor ports.

At this time the difference between the pressure acting on the end areas of the stroking pistons 88, 89 is equalized and the movement of the displacement changing means ceases. The new position of the hanger will be maintained so long as the same signal from electrical source 45 continues to be applied to the torquemotor 44.

From the foregoing it will be seen that for an electric signal of given magnitude there corresponds a certain hanger position which is maintained by the control. The operation of the device is the same in response to an electrical signal of opposite polarity, but in this case armature 26 will be rotated in the counterclockwise direction, pressure in line 51 will exceed that in line 50, and the hanger will be moved in the counterclockwise direction.

In the event of electrical system failure, solenoid 83 of valve 8 is de-energized. This causes chamber 59 to be connected directly to tank through port 81, thereby relieving the pressure force on the end land 56 of the spool. Spring 85 moves the spool 52 to the left so that lines 50 and 51 are blocked. Spool leakage is directed to tank 73 via ports 66, 68 and 70. When fluid flow from jet nozzle 47 is blocked, spool 52 is in such a position as to release the pressures in cylinders 96 and 97 to tank via ports 66 and 68. With release of pressures in cylinders 96 and 97, the springs 94, 95 move the pistons 88, 89 to a position in which the hanger 17 is centered. In this manner the control responds to electrical system failure to restore the pump to center position in which its displacement is zero.

In the event of hydraulic system pressure failure, pressure in chamber 59 falls, spool valve element 52 moves to the left, and the operation of the elements is similar to that just described, the pistons 88 and 89 causing the hanger to be moved to center position.

Where an especially high pressure gain is required to operate the displacement changing means, a two-stage jet servovalve may be used to supply the necessary pressure fluid, with a first stage similar to that previously described herein.

As can be seen in FIG. 2 of the drawings, the hanger 17, attached cam 30 and the mechanical feedback system 32, 33 and 36 from the pump hanger to the jet tube 27 of the servovalve 5 are all located inside the case 10 of the pump on the wet chamber side or the nonelectrical side of the electrohydraulic servovalve 5. The elec-

trical or dry chamber 24 of servovalve 5 thus stays dry without the necessity of dynamic seals around the mechanical feedback system. Consequently, this feedback system eliminates the necessity for any dynamic seals between the trunnions and the mechanical feedback system. It also has the advantage of providing a relatively simple mechanical feedback system which has no undesirable mechanical spring windup characteristic.

Another advantage of the particular feedback system illustrated in FIG. 4 is that it minimizes errors which might otherwise result from trunnion run-out or eccentricity. Even though the cam 30 may as a result of wear, shift radially and run untrue on the axis 98 of the trunnions, the error is not reflected in jet tube displacement because of the use of the long lever arm to impart feedback movement to the jet tube and the face that the pivot point of the lever remains fixed and does not move with the trunnions.

Referring now to FIG. 5, there is illustrated another modification of the mechanical feedback system illustrated in FIGS. 1-4. In general, the overall control system of this modification is identical to that of FIGS. 1-4 and accordingly corresponding parts or components have been given identical numerical designations. Principally, this system differs in that it utilizes a single hydraulic motor or stroking piston to effect displacement of the hanger and it utilizes a different mechanical feedback from the trunnion to the servovalve 5. In this modification, the stroking piston 125 is connected directly to a radial arm 126 of the trunnion 17b.

The electrohydraulic servovalve 5 and the by-pass or shut-off valve 7 of this modification are identical to the corresponding numerical components of the modification of FIGS. 1-4. The mechanical feedback between the trunnion 17b and the spring arm 36 of this modification comprises an eccentric slot 130 machined in the radial end face 131 of the trunnion 17b and a feedback spring ball 35 located within the slot 130. Upon rotation of the trunnion, the slot 130 acts upon the ball and the attached feedback rod or spring 36 to transmit a mechanical feedback force back to the jet tube 27. This force opposes and is opposite to the magnetic force which actuates the hydraulic cylinder 125.

The advantage of this feedback system is that it, too, may be completely located on the wet chamber side of the hydroelectric servovalve 5. It also has the advantage of providing a very simple feedback spring interconnection between the trunnion shaft 18 and the jet tube 27 of the hydroelectric servovalve 5.

Referring now to FIG. 6, there is illustrated still another modification of the mechanical feedback interconnection between the trunnion 17c and the electrohydraulic servovalve 5. Specifically, in this modification the cam 140 of the feedback system is welded or otherwise fixedly secured to the peripheral face of the trunnion 17c. This cam is operable to cause movement of a lever arm 141, the outer end 142 of which bears against the cam 140. The opposite end of the lever arm is pivotally mounted upon a pivot post 144 journaled within lugs 145 of the pump housing or case.

In this modification, the ball 35 on the end of the feedback spring 36 is located within a circular recess 146 in the lever arm adjacent to the pivot post 144. Consequently, rotational movement of the trunnion results in radial movement of the cam follower end 142 of the lever arm 141. This results in transverse movement of the ball 35 and of the feedback spring 36. This

transverse movement of the feedback spring is in turn reflected in a feedback force being transmitted to the jet tube 27 of the electrohydraulic valve 5. The feedback force is in the direction opposite to the magnetic force which initially caused the stroking piston to effect movement of the hanger.

As in the case of the modification of FIG. 1, the mechanical feedback system of the modification of FIG. 6 is located on the wet chamber side of the hydroelectric servovalve 5 and within the casing of the pump. Thus there is no necessity for dynamic seals around the trunnion to protect against the loss of case pressure or fluid around the trunnion. This modification also has the advantage of utilizing a fixed or stationary pivot 144 for the lever arm so that run-out or eccentricity of the trunnion has only a minimal effect upon the feedback system.

While I have described only three modifications of my improved feedback for a servomotor in this application, those persons skilled in the arts to which this invention pertains will readily appreciate other modifications and changes which may be made without departing from the spirit of this invention. Specifically, the invention is applicable to any type of servomotor, single stage or two stage or to any type of system which incorporates a feedback system to a servovalve. Therefore, I do not intend to be limited except by the scope of the appended claims.

Having described my invention, I claim:

1. A variable displacement hydraulic pressure energy translating device having movable displacement changing means and including fluid motor means for moving and positioning said displacement changing means, means supporting said displacement changing means, and a case surrounding and enclosing said displacement changing means, said motor means, and said supporting means,

a jet discharge electrohydraulic servovalve, said servovalve having a wet chamber and a dry chamber, said servovalve including a pair of adjacent receptor ports located in the wet chamber, an armature operated by a torque motor, said torque motor being located in said dry chamber on one side of said armature, a jet tube having a nozzle at one end thereof located in said wet chamber, said jet tube being fixedly mounted at a point spaced from said one end, said tube being displaceable by said armature about said point for adjustably dividing a jet stream from said nozzle between said receptor ports, said wet chamber of said servovalve being open to the interior of said case,

means for supplying pressure fluid to said jet tube, passageways connecting said receptor ports with the fluid motor means for supplying pressure fluid to said fluid motor means from said receptor ports, feedback spring means separate from said armature and tube mechanically connected to said displacement changing means and to said jet tube for increasingly urging said tube toward a null position between said receptor ports as said displacement changing means is moved away from the no displacement position thereof, said spring means being connected to said tube on the other side of said armature which is remote from said torque motor, said spring means being wholly located within said wet chamber and the interior of said case.

2. The structure of claim 1 wherein said displacement changing means is rotatable about said supporting means and said spring means is connected between said supporting means and said jet tube.

3. The structure of claim 1 which further includes valve means operated by hydraulic pressure acting on a control surface thereof to permit pressure from said servovalve to be applied to operate said motor means, and said valve means being opposingly spring biased toward a position releasing pressure in said passageways.

4. The structure of claim 3 wherein the said hydraulic pressure is applied to said control surface of said valve means through an electrically operated cut-off valve which discharges said hydraulic pressure in response to electrical failure.

5. The structure of claim 1 wherein the fluid motor means includes opposed pistons having equal areas exposed to pressure from said passageways.

6. A variable displacement fluid pressure energy translating device having means supporting a rotatable displacement changing means, a case surrounding and enclosing said displacement changing means and said supporting means,

a jet discharge operated valve having a wet chamber and a dry chamber, said valve including a pair of receptor ports located in said wet chamber, a jet tube having an outlet nozzle located in said wet chamber and adjustably displaceable from a null position for dividing the jet discharge stream therefrom between said receptor ports,

said wet chamber of said valve being open to the interior of said case,

means for supplying pressure fluid into said jet tube, fluid motor means located within said case and operable to rotate said displacement changing means in response to pressure applied thereto,

spring centering means biasing said displacement changing means toward a centered position,

passageways connecting said receptor ports with the fluid motor means for supplying pressure fluid to the fluid motor means from said receptor ports,

and a resilient spring means connected between said displacement changing means and a point in said jet tube for urging said tube toward said null position as said displacement changing means is moved by said fluid motor means in response to unequal division of said jet discharge stream between said receptor ports, the point of connection of said resilient spring means to said jet tube being located in the wet chamber at the nozzle end of said jet tube, said spring means being wholly located within said wet chamber and the interior of said case.

7. The variable displacement fluid energy displacement device of claim 6 wherein said resilient spring means is actuated and controlled by a cam surface secured to said supporting means.

8. The variable displacement fluid energy displacement device of claim 7 wherein said resilient spring means is actuated by a cam secured to the radial end surface of said supporting means.

9. The variable displacement fluid energy displacement device of claim 7 wherein said resilient spring means is actuated by a cam secured to the peripheral end surface of said supporting means.

10. The structure of claim 8 wherein said spring

means is secured to the supporting means through a ball secured to one end of the spring means and movable within a cam slot in the end face of said supporting means.

11. The structure of claim 7 wherein said tube is fixed at one end and is angularly displaceable about said one end by a torque motor armature for dividing said stream between said receptor ports.

12. A rotatable variable displacement device having a rotatable trunnion secured thereto, said device being rotatable about the axis of said trunnion secured thereto, said trunnion being surrounded and enclosed by a case,

a jet discharge operated valve having a wet chamber and a dry chamber, said valve including a pair of receptor ports located in said wet chamber, a jet tube having an outlet nozzle located in said wet chamber and adjustably displaceable from a null position for dividing the jet discharge stream therefrom between said receptor ports,

said wet chamber of said valve being open to the interior of said case,

means for supplying pressure fluid into said jet tube, fluid motor means operable to rotate said device and the attached trunnion in response to pressure applied thereto,

resilient centering means biasing said device toward a centered position,

passageways connecting said receptor ports with the fluid motor means for supplying pressure fluid to the fluid motor means from said receptor ports,

and a resilient spring connected between the trunnion of said device and a point on said jet tube for urging said tube toward said null position as said device is moved by said fluid motor means in response to unequal division of said jet discharge stream between said receptor ports, the point of connection of said spring to said jet tube being located at the nozzle end of said jet tube, and said spring being actuated and controlled by a cam surface secured to and rotatable with said trunnion, said spring and said cam surface being wholly located within said wet chamber and the interior of said case.

13. The variable displacement device of claim 12 wherein said resilient spring is actuated by a cam secured to the radial end surface of said trunnion.

14. The variable displacement device of claim 12 wherein said resilient spring is actuated by a cam secured to the peripheral end surface of said trunnion.

15. The structure of claim 12 wherein said tube is fixed adjacent one end and is angularly displaceable about said one end by a torque motor armature for dividing said stream between said receptor ports.

16. The variable displacement device of claim 12 wherein said cam effects movement of a pivoted lever arm, said lever arm having a fixed pivot and being connected to one end of said resilient spring.

17. The variable displacement device of claim 16 wherein said cam is fixed to a radial end surface of said trunnion.

18. The structure of claim 13 wherein said spring is secured to the shaft through a ball on the end of the spring movable within a cam slot in the radial end surface of said trunnion.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,750,532

Dated August 7, 1973

Inventor(s) Charles A. Kubilos

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 64 "met" should be--jet--.

Column 3, line 28 before "shaft"--rotation of--has been omitted.

Column 4, line 6 "source" should be--force--; "piston" should be--position--; line 12 "tue" should be--tube--.

Column 7, line 16 "face" should be--fact--; line 64--17c--omitted after "trunnion--.

Signed and sealed this 20th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents