

June 25, 1963

D. V. HEALY

3,095,002

DRY TYPE HYDRAULIC SERVO VALVE

Filed June 20, 1961

2 Sheets-Sheet 1

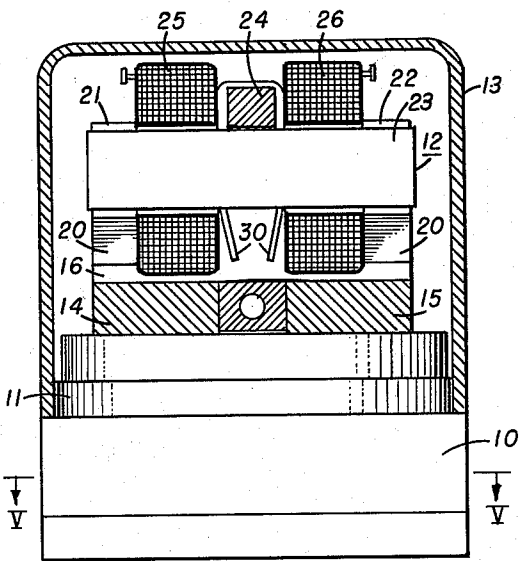


FIG. 1

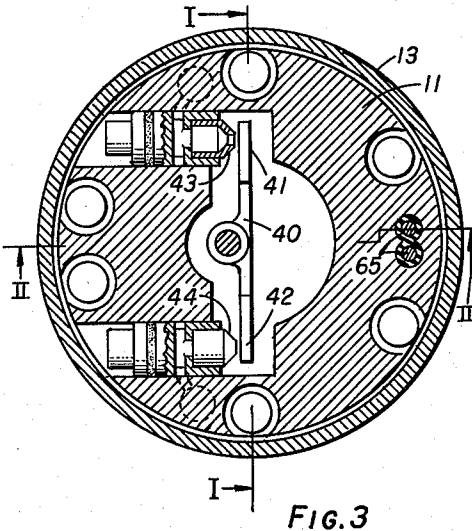


FIG. 3

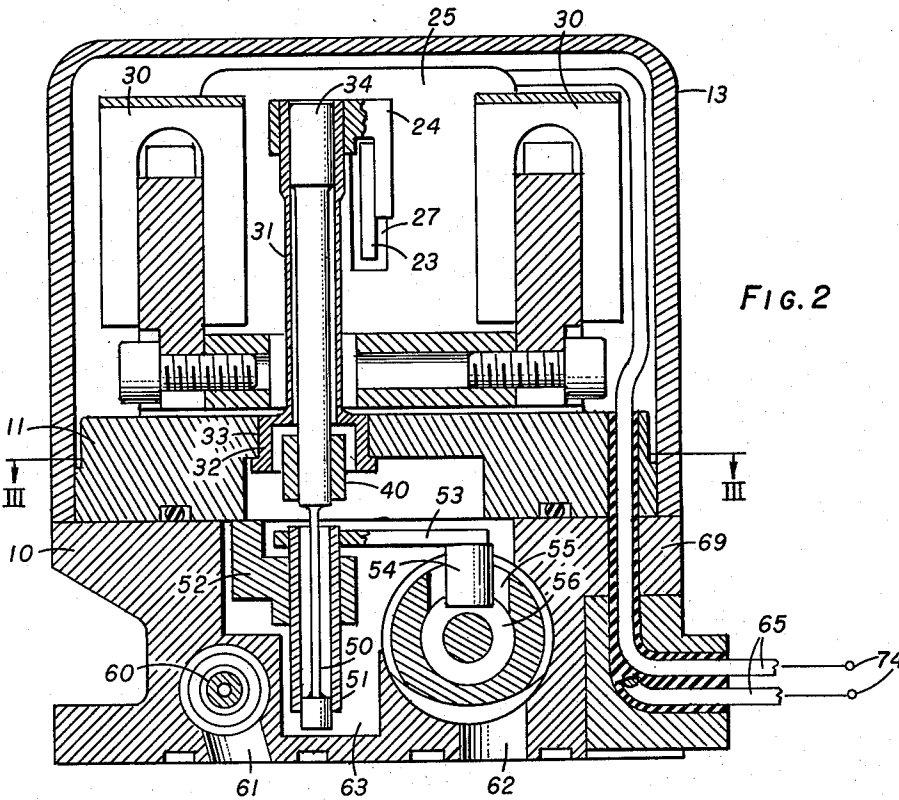


FIG. 2

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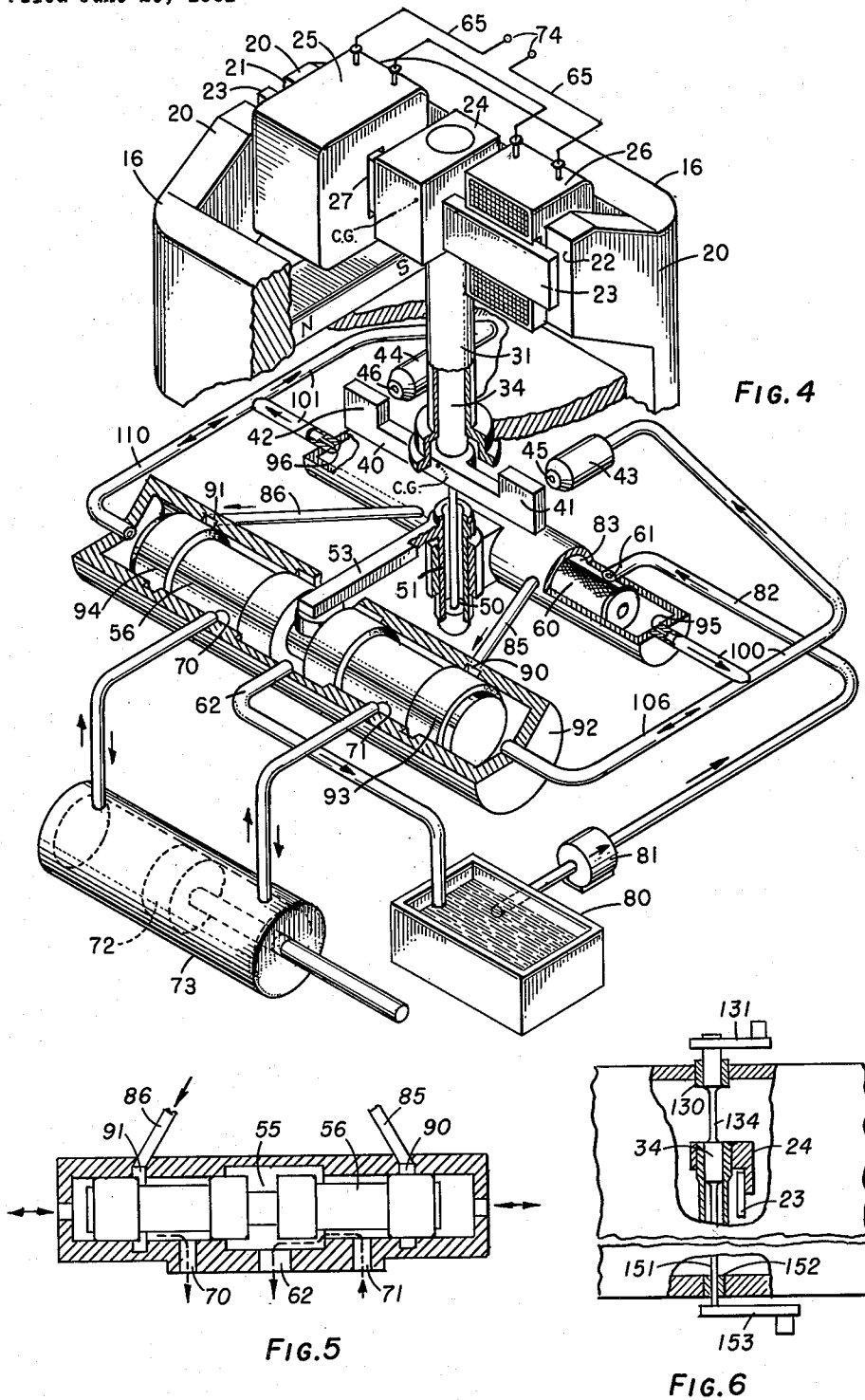
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DRY TYPE HYDRAULIC SERVO VALVE

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5 Claims. (Cl. 137—85)

This invention relates to hydraulic servo valves and, more particularly, to "dry" type valves employing a hydraulic housing containing all of the fluid-conducting passages and chambers and an external motive assembly including a coil and armature sealed from the hydraulic housing but operatively connected to control the flow of fluid through the valve in response to electrical signals applied to the coil.

My patent 2,823,689, issued February 18, 1958, teaches how the accurate control of fluid flow through a servo valve may be accomplished employing an electro-magnetically movable armature resiliently supported, including a pair of end portions positioned as flow-intercepting baffles in front of a pair of parallel nozzles. With the two nozzles communicating through restrictors to a common supply of hydraulic fluid, the pressure at the nozzles is a function of the relative positioning of the armature with respect to the two nozzles. Passages communicate between the nozzle regions and the opposite ends of a valve cylinder containing a spool or piston which controls the main output flow of the valve. Where the armature is normally positioned in the order of 0.001" from the nozzle tips, slight movement of the armature under the control of an electrical signal applied to the armature's coil creates a pressure differential between the two nozzles resulting in an amplified force differential applied to the ends of the valve spool or piston. By careful design of the assembly, a servo valve is produced in which the main flow through the valve, determined by the position of the spool, is a linear function of the current flow through the energizing coils associating with the armature.

In my patent, above identified, one particular problem common to servo valves is recognized, and the resilient mounting of the armature offers a solution. The problem is that regardless of the filtering of the hydraulic fluid used, often particles of dust or dirt are carried in the fluid and lodge between the nozzle tip and the armature. The novel suspension system for the armature allows the armature, in the presence of dirt particles, to move outward from the nozzle, allowing the particles to be dislodged with only momentary disturbing of the existing pressure differential between the two nozzles and thereby not significantly affecting the position of the spool. This self-clearing feature provides reliable operation.

Recently the desirability of eliminating all contact between the motor portions of servo valves and the hydraulic fluid has been recognized. This has given impetus to the design of so-called "dry coil" servo valves in which all fluid flow, in particular, the discharge from the nozzles, takes place in a housing which is sealed from the armature pole pieces and coil. With this arrangement the armature of course cannot be located in proximity to the discharge nozzles so that an auxiliary member (having the same general shape as the armature) and variously called a flapper or baffle plate, hereinafter referred to as a baffle plate, is positioned adjacent the nozzles and is coupled to the armature through a sealed connection in the wall of the housing.

One particularly desirable sealing arrangement for dry type servo valves is disclosed in Patent No. 2,905,871 to L. Martin, issued September 22, 1959, and assigned to the assignee of this invention. That sealing arrangement involves the use of a torque tube extending out of the sealed housing and secured thereto at one end. The outer or

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free end of the torque tube carries the armature and is mechanically joined to the end of a shaft closing the end of the tube. The opposite end of the shaft extends through the torque tube into the housing and carries a baffle plate. The torque tube seal furnishes an efficient fluid seal and motion-transmitting member.

However, the art has serious need for a dry coil type servo valve employing self-clearing operation of the type accomplished by the invention of my Patent No. 2,823,689.

It is a general object of this invention to provide a self-clearing dry coil type servo valve.

Another object is to provide a self-clearing servo valve in which the self-clearing operation takes place with minimum movement of the armature or disturbance of its normal dynamic equilibrium condition.

Another object is to provide a servo valve having improved stability when subject to acceleration force.

One further object is to provide a simple, effective, feedback connection from the valve spool to the baffle plate.

Still another object is to provide a servo valve including internal feedback from the valve spool and, additionally, provision for external feedback or external overriding controls.

These objects are accomplished in accordance with this invention, one embodiment of which comprises:

A fluid housing including a pair of parallel disposed nozzles in the arrangement disclosed in my above-identified patent with, however, a dual-arm baffle plate positioned opposite the outlets of the two nozzles. The baffle plate is mounted on a central shaft which extends out of the housing through a torque tube. The outermost end of the torque tube and shaft are sealed together and secured to the armature of the driving motor. Operatively associated with the armature are a pair of coils and a magnetic structure. The nozzles within the fluid housing are connected to a common fluid pressure supply and to a branch circuit to the ends of the operating sleeve contained in the spool or piston.

The shaft carrying the baffle bar extends below the baffle plate in reduced section, the end of which is coupled to the spool of the operating cylinder to provide mechanical feedback between the spool and the baffle plate and thereby provide a restoring force opposing that of the input signal.

In another embodiment, the support structure for the armature and baffle plate extend out of the motor space to allow for external feedback or overriding control of the electrical input.

One feature of this invention resides in a dry coil servo valve in which a composite structure made up of a torque tube and a rigid shaft mount a dual-arm baffle plate for rotational and translational movement.

Another feature resides in mounting the armature and baffle plate offset from their axis of rotation at a right angle with respect to the direction of travel of the valve spool so that acceleration forces tending to move the spool also affect the baffle plate and armature in a manner which compensates the acceleration forces on the spool.

Still another feature involves a second torsion spring for the baffle plate for introducing feedback from the valve spool.

One further feature resides in the extension of the baffle support through the motor housing to provide a point for external torque input to the system.

These and other features of this invention may be clearly understood from the following detailed description with reference to the drawing in which:

FIG. 1 is a vertical sectional view through the motor of a servo valve incorporating this invention;

FIG. 2 is a vertical section through the entire servo valve of FIG. 1 taken in the plane at right angles with respect to the plane of the section of FIG. 1;

FIG. 3 is a horizontal section through the nozzle block portion of the valve of FIG. 1;

FIG. 4 is an isometric projection of the valve of FIG. 1;

FIG. 5 is a longitudinal section to the valve sleeve and spool along lines 5—5 of FIG. 1; and

FIG. 6 is a fragmentary sectional view of another embodiment of the invention.

Now referring to FIG. 1, the servo valve incorporating this invention consists basically of a hydraulic housing 10 closed by a nozzle block 11 to which is secured the motor assembly 12, the last within a cap 13. Motor assembly 12 comprises a pair of bar magnets 14 and 15 mounted to introduce flux into a pair of ferromagnetic frame members 16, one of which is shown in the drawing. The frame members 16 include arms 20 terminating in faces 21 and 22 opposite the ends of an armature 23 mounted for rotation on a supporting arm 24, as best seen in FIG. 2. The armature 23 passes through central openings 27 in a pair of coils 25 and 26. Coils 25 and 26 are held in place within the enclosure made by the frame member 16 by a pair of spring clips 30, one of which appears in FIG. 1.

The armature 23 is lightly held midway between the opposing faces 21 and 22 of the magnetic frame members 16, for movement from the mid position under the control of changes in flux in the magnetic system resulting from passage of current through the coils 25 and 26, as well as from the reaction or feedback forces from the hydraulic spool as hereinafter described.

The interaction between the motor assembly 12 and the hydraulic assembly within housing 10 is more clearly seen in FIGS. 2 and 3. In FIG. 2 the arm 24 supporting armature 23 in the opening 27 of coil 25 is carried itself by an upstanding tubular support, hereinafter designated the torque tube 31, including enlarged collar portion 32 sealed in an opening 33 in the nozzle block 11 of the hydraulic assembly. The upper or free end of torque tube 31 is closed by a central shaft member 34 sealed therein as by brazing. The seal between the shaft 34 and tube 31 must be adequate to resist at least the drain or return hydraulic pressure and prevent the ingress of hydraulic fluid from the housing 10 into the motor space of the valve. The tube 31 is preferably of a spring material, such as beryllium copper, having a thin wall in the order of 0.006" to allow the rotational movement of the armature 23 about the axis of the tube 31 by twisting of the tube 31. The rotation of armature 23 is transmitted through shaft 34 into the housing 10. The shaft 34 carries a baffle plate 40, best seen in FIG. 3, including a pair of end baffle portions 41 and 42 directly opposite the orifices in nozzles 43 and 44 respectively. A nominal spacing between the baffle portion of plate 40 and the respective nozzles is in the order of 0.001", and movement from the nominal position varies under maximum signal conditions from 0 to 0.001" in either direction.

Referring again to FIG. 2, the lower end of shaft 34 includes a reduced diameter portion 50 constituting a torsion spring extending into and secured at its lower end to a rigid hollow shaft 51 for transmitting torque from a feedback arm 53 to the baffle plate 40. The shaft 51 is journaled in a bearing 52 secured to the nozzle block 11 and has at its upper or free end an arm 53 secured thereto and extending to one side and terminating in a depending finger 54 which rests in annular slot 55 in the spool or piston 56 of the valve. The arm 53, hollow shaft 51 and torsion spring 50 provide a mechanical feedback between the spool 56 and the baffle plate 40.

The hydraulic components of the valve in addition to the spool 56 include: a filter 60 at the main inlet port 61, a main return or drain port 62, and several communicating passages in the housing 10 and illustrated in schematic form in FIG. 4. The main internal cavity 63 in which

the shaft 34, shaft 51, feedback arm 53 and, most important, baffle plate 40, are all located, is exposed to the drain pressure of the system, and it is in this chamber where the nozzles 43 and 44 discharge fluid. The motor elements, of course, are all outside of the housing 10 and are sealed therefrom by the torque tube 31.

The electrical input to the motor is through a pair of leads 65 which enter a side opening in the housing 10 and pass through a flange portion 70 of the housing 10, through the nozzle block 11 and into the motor cavity without entering the hydraulic housing proper.

Operation, Generally

The operation of the servo valve is best understood from the simplified isometric showing of FIG. 4. The purpose of the valve is to apply a controlled flow in and out of two cylinder ports 70 and 71, which flow is a linear function of the magnitude of the current passing through a pair of terminals 74. The output ports 70 and 71 are normally connected to opposite ends of a double-acting piston 72 within an actuator cylinder 73. Movement of the piston 73 is accomplished upon longitudinal movement of the valve spool 56 from the intermediate neutral position toward one end whereby one of the cylinder ports 70 or 71 is connected to the pressure source, and the other cylinder port is connected to the drain port 62. Controlled movement of the valve spool 56 is accomplished by applying hydraulic pressure to a pair of pressure ports 90 and 91 from a fluid source 80 by means of a pump 81 and a main pressure line 82. The fluid is introduced through line 82 into an inlet chamber 83 containing a filter 84. The main hydraulic fluid path bypasses the filter 84 flowing through the enlarged central section of chamber 83 and a pair of passages 85 and 86 to the annular pressure ports 90 and 91 of the valve sleeve or cylinder 92. The pressure ports 90 and 91 are closed by respective lands 93 and 94 when the spool 56 is in its position. The ends of the filter chamber 83 are sealed from the inlet port 82 by the filter 84 so that hydraulic fluid reaching the end portions passes through the filter 84, and contaminants, in particular, particles of sufficient size to plug restrictors 95 and 96 or interfere with the operation of the differential nozzle mechanism hereinafter described, are retained. The ends of filter chamber 83 communicate through the flow restrictors 95 and 96 and passages 100 and 101 with the pair of nozzles 43 and 44 respectively positioned in substantially parallel relationship and each including an outlet orifice 45 or 46 directed toward opposite ends of the baffle plate 40. The passage 100 includes a branch passage 106 communicating with one end of the valve sleeve 92. A branch passage 110 from the passage 101 communicates with the opposite end of sleeve 92.

No Signal Operating Condition

In normal operation with the valve connected to a source of hydraulic pressure and no signal applied to the terminals 74, hydraulic fluid flows from the pump 81 through passage 82 to the filter chamber 83 from which it passes directly to the pressure ports 90 and 91 of the valve sleeve. The lands 93 and 94 cover the pressure ports 90 and 91 so that the outlet ports 70 and 71 both are exposed to equal pressure, to wit, a value approximately half-way between the system inlet and drain pressure due to leakage past the lands. Hydraulic fluid passing through the filter 84 in the filter chamber 83 flows through passages 100 and 101 to respective orifices 45 and 46. In the no signal condition, the baffle plate 40 is precisely located at equal distances from the orifices 45 and 46. Since both orifices are fed by a common supply pressure, and the pressure drops in the restrictors 95 and 96 are equal, the pressure applied to branch lines 106 and 110 is the same, and opposite ends of the valve spool 56 are exposed to the same forces. The spool 56 therefore remains in its centered position. Fluid emerging from

the orifices 45 and 46 striking the baffle plate 40 falls into the chamber 63, shown in FIG. 2, down to the drain port 62 and returns to the fluid supply 80.

Signal Condition Operation

When a current flows through terminals 74 and the coils 25 and 26, the magnetic equilibrium condition between the faces 21 and 22 of the pole pieces 16 is changed so that one end of the armature 23 is drawn toward one pole piece, and the opposite end of the armature 23 is drawn toward the opposite pole piece. This movement is about the axis of torque tube 31. Rotation of the armature 23 is accomplished by torsion-induced twisting of the tube 31 which is readily accomplished, since thin wall spring material tubing is used. Twisting of the torque tube 31 permits rotation of the shaft 34 within tube 31 and rotational displacement of the baffle plate 40. The movement of baffle plate 40 in rotation duplicates that of the armature 23. For example, in the drawing (FIG. 4) with command current of one polarity applied to the coil through terminals 74 such that the armature rotates in a clockwise direction as viewed from the top, the baffle plate 40 also rotates in a clockwise direction, moving the baffle 42 in close proximity to orifice 46 while the baffle 41 moves away from orifice 45. The pressure in the line 101 increases because of the baffle restriction at the orifice 46, while the pressure in line 100 falls off because of the opening up of orifice 45. The pressure changes in the lines 100 and 101 are communicated through lines 106 and 110 to the ends of the cylinder 92, causing movement of the spool 56 toward the lower right in FIG. 4. This condition is illustrated as well in FIG. 5.

Movement of the spool 56 introduces torque through the hollow shaft 51 which opposes the armature torque and tends to restore the baffle plate 40 to its previous position. An equilibrium condition in the moving elements of the valve is thereby established. As the spool 56 moves to the right, the pressure port 90 is uncovered as land 93 moves off the inner edge of port 90. The pressure port 90 then communicates with the cylinder port 71 while the cylinder port 70 is connected to the drain port 62. The pressure differential on the opposite ends of the piston 72 results in its movement to the left. The velocity of the piston 72 depends upon the rate of flow, which is determined by the extent of movement of the spool 56 from its neutral position. Spool 56 moves responsive to pressure differentials on its ends produced by displacement of the baffle plate 40 from center position. The position of baffle plate 40 in turn is determined by the summation of armature and feedback torques. Armature torque is a function of command signals applied to terminals 74.

Automatic Pressure-Compensation

Servo valves incorporating my invention automatically compensate for changes in pressure similar to my valve of Patent No. 2,823,689. The novel baffle plate mounting arrangement is symmetrical with respect to the axis of movement so that an increase in supply pressure produces an increase in pressure at both nozzles, resulting in equal forces applied to both ends of baffle plate 40, and no rotational movement of baffle plate 40 results. Lower shaft 50 is actually suspended in the intermediate region of a flexural support, so that upon an increase of inlet pressure the upper and lower supports are bent outward while no rotation is imparted to either shaft because the turning movement applied to both ends of the baffle plate 40 is equal. With the reduction in inlet pressure, the baffle plate 40 moves bodily toward both nozzles 45 and 46 without rotational motion.

Acceleration Force Stability

Improved stability under acceleration conditions is achieved employing this invention. It is apparent that when the valve structure as shown in FIG. 4 is subjected to acceleration forces, those forces will act upon the spool

56 as well as the valve body and may tend to move the spool 56 with respect to its cylinder or sleeve. Any force components acting transverse to the axis of the sleeve 92 are ineffective to change the position of the spool 56. However, forces acting along the line of the sleeve or valve cylinder 92 axis will tend to move the spool, resulting in unwanted and uncontrolled movement of the operating piston 72.

For example, if the valve body is subject to acceleration of several "G's" in the direction of the upper left-hand corner of FIG. 4, the spool 56, owing to its relatively large mass, will tend to move toward the lower right-hand corner of the drawing with respect to the valve body. Such movement can be sufficient to vary the flow of fluid through ports 70 and 71 and be interpreted by the operating piston as a command signal. However, it should be noted that both the armature 23 and the baffle bar 40 are mounted eccentrically on the shaft 34. Both have centers of gravity, marked C. G. in FIG. 4, displaced from the axis of rotation. Displacement is toward the spool 56. Whenever the valve is subject to acceleration causing the spool to move, as indicated before, toward the lower right-hand corner of the drawing (FIG. 4), the same force acting upon the bar 40 and particularly the armature 23 tends to cause these members to rotate bodily in the counterclockwise direction, causing an increase in pressure at the nozzle 43 similar to that encountered by a command signal which produces a pressure unbalance between the lines 106 and 110 with a force differential acting upon the spool 56 in the opposite direction from the acceleration force, to wit, toward the upper left in FIG. 4 in the example given. As a net result, the spool 56 does not move. Acceleration in the opposite direction results in similar compensating movement by the armature 23 and plate 40.

Therefore, valves incorporating the eccentric armature and baffle plate automatically eliminate movement of the spool 56 under the influence of acceleration forces.

Multiple Torque Inputs

The servo valve of FIGS. 1 through 5 is designed for a single electrical input through the terminal 74 and has internal feedback from the valve spool. In certain applications, it is desirable to have provision for external feedback, for example, from the operated piston 72 itself or from related apparatus. Additionally, it is sometimes desirable to have provision for an overriding manual control for the valve in case of malfunction of the valve or other parts of the system. In the past, complicated mechanisms have been required to provide either of these additional inputs to servo valves. However, employing the embodiment of FIG. 6, which is a modification of the same basic structure of FIGS. 1 through 5, the summation of one or more inputs from manual, mechanical, hydraulic or electrical sources is possible. This is achieved by the presence of an upper extension of the shaft 34 passing out through a bearing 130 and secured to an input torque arm 131. The upper extension of shaft 34 includes a reduced section 134 constituting a torsion spring. The torque arm 131 may be quite short, because only a small torque input to the upper end of shaft 34 is necessary in order to produce significant movement of the armature 23 and the baffle plate 40, unshown in the drawing. The arm 131 may be connected as a manual override control or as an additional torque input to the valve.

In the embodiment of FIG. 6, a lower torsion spring portion 151 of shaft 34 extends through a bearing 152 out of the housing 10. A torque arm 153 may be suitably attached to the extension 150 to provide an additional torque input to the system. The lower input through the spring section 151 is particularly adapted for the introduction of feedback from the operating cylinder or other parts of the hydraulic system, since it extends out of the hydraulic side of the valve. Where torque over 153 is

connected to the controlled mechanisms to provide feedback, the feedback path from spool 56 may be unnecessary or undesirable and may be eliminated.

It should be noted that any number of additive input forces in the system are possible by extending either the upper or lower end of the shaft 34 and attaching additional torque arms. This is all possible because the fundamental motion of the baffles within the valve is obtained by torque input to its support member, the shaft 34.

Although for the purpose of explaining the invention a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the exact details shown and described.

I claim:

1. A servo valve comprising:
 - a hydraulic housing;
 - a flow-control system within said housing including a pair of substantially parallel directed nozzles and an elongated baffle having spaced portions positioned to vary the flow of fluid from respective nozzles;
 - a motor compartment;
 - motor means within said compartment;
 - means sealing said hydraulic housing from said motor compartment;
 - said sealing means comprising a nonrigid tube with one end sealed to said hydraulic housing and a shaft sealing the free end of said tube and extending through said tube;
 - said shaft coupled to a point midway between the spaced portions to transmit torque from said motor means to said baffle to vary the relative spacing of said baffle spaced portions with respect to said nozzles simultaneously in opposite sense;
 - said tube and shaft supporting said baffle for simultaneous translation movement in the same sense toward and away from said nozzles in response to fluid pressure changes thereat.
2. A servo valve comprising:
 - a pair of generally parallel-positioned nozzles;
 - a source of hydraulic fluid pressure for said nozzles;
 - baffles positioned for restricting the flow of hydraulic fluid from said nozzles;
 - a motor including an armature for controlling the flow of fluid through said valve;
 - and means positioning said baffle for rotational motion toward one nozzle and away from the other nozzle upon the energizing of said motor, and for simultaneous translational movement in a same sense toward or away from said nozzles responsive to pressure changes of said hydraulic fluid pressure source;
 - said positioning means comprising a torque tube mounting said armature and baffle for rotational motion under the influence of said coil by twisting of said torque tube;
 - and a rigid member secured to the armature end of said torque tube and mounting said baffle for translational motion by flexural distortion of said torque tube.
3. An electrohydraulic servo valve comprising:
 - a housing;
 - a pair of nozzles within said housing positioned in relatively parallel relationship;
 - a common hydraulic fluid pressure source for said nozzles;

- an elongated baffle including portions for restricting flow from said nozzles to vary the pressure of hydraulic fluid at said nozzles;
 - a cylinder;
 - a spool positioned within said cylinder;
 - means communicating the fluid pressure at said nozzles to opposite ends of said spool to vary the position of said spool dependent upon the pressure differential of said nozzles;
 - a coil external to said housing including terminals for applying an electrical signal thereto to energize said coil;
 - an armature for said coil;
 - a torque tube sealing said housing from said coil and mounting said armature for rotational motion upon the energizing of said coil;
 - a shaft within said torque tube extending into said housing and mounting said baffle in position opposite said nozzles and symmetrically therewith whereby rotation of said armature and shaft rotates said baffle to restrict one and relieve the other of said nozzles; said baffle being resiliently mounted by said torque tube to move bodily toward or away from said nozzles responsive to fluid pressure changes thereat;
 - and torsion spring means coupled between said shaft and said spool constituting a mechanical feedback connection between said spool and said baffle.
4. An electrohydraulic servo valve employing mechanical feedback comprising:
 - a hydraulic housing;
 - a pair of nozzles within said housing positioned in relatively parallel relationship;
 - a common hydraulic fluid pressure source for said nozzles;
 - an elongated baffle including portions for restricting the flow from said nozzles and to vary the pressure of hydraulic fluid at said nozzles;
 - a valve cylinder;
 - a spool positioned within said cylinder;
 - means communicating the fluid pressure at said nozzles to the opposite ends of said spool to vary the position of said spool, dependent upon the pressure differential at said nozzles;
 - means supporting said baffle including a torsion member;
 - and a second torsion member coupled between said spool and said baffle for introducing torque into said baffle-supporting means upon relative displacement of said baffle and said spool.
 5. The combination in accordance with claim 4 wherein said support for said baffle extends out of the valve, thereby constituting an input connection for application of control torque to said valve.

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