

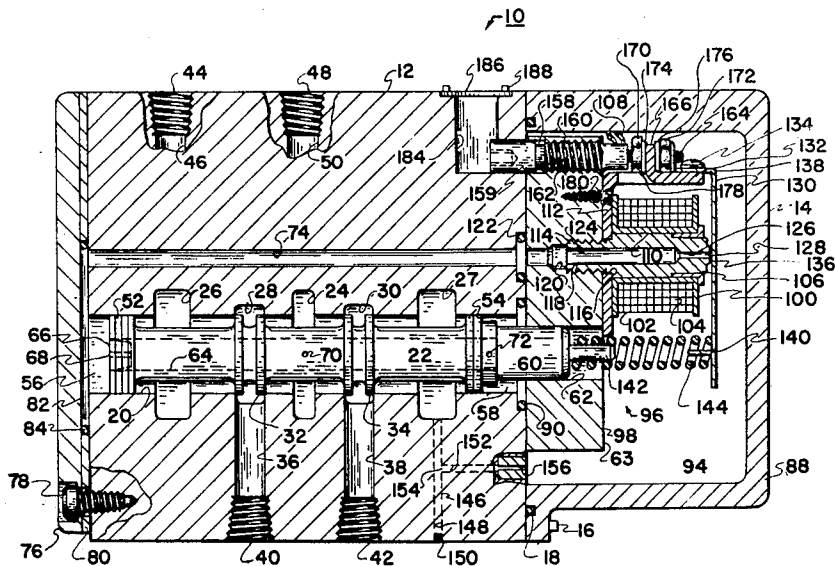
[72] Inventor **John Marshall**
Rochester, Michigan
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 [73] Assignee **Sperry Rand Corporation**
Troy, Michigan
a corporation of Delaware

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Primary Examiner—Henry T. Klinksiek
Attorney—Van Meter and George

[54] **FLAPPER SERVO VALVE WITH FEEDBACK**
9 Claims, 2 Drawing Figs.
 [52] U.S. Cl. 137/83,
 137/86, 625.61, 625.64
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 F16k 11/24
 [50] Field of Search 137/83, 85,
 86, 625.61, 625.62, 625.63, 625.64

ABSTRACT: A four-way, two stage, closed loop servomechanism having a spool for controlling the main fluid flow to and from the servomechanism; an electromagnetically operated flapper cooperating with a restriction for controlling the pressure differential on opposite sides of the spool to cause movement of the same; and a feedback means disposed between the flapper and the spool, the position of the spool being a function of the electromagnetic current.



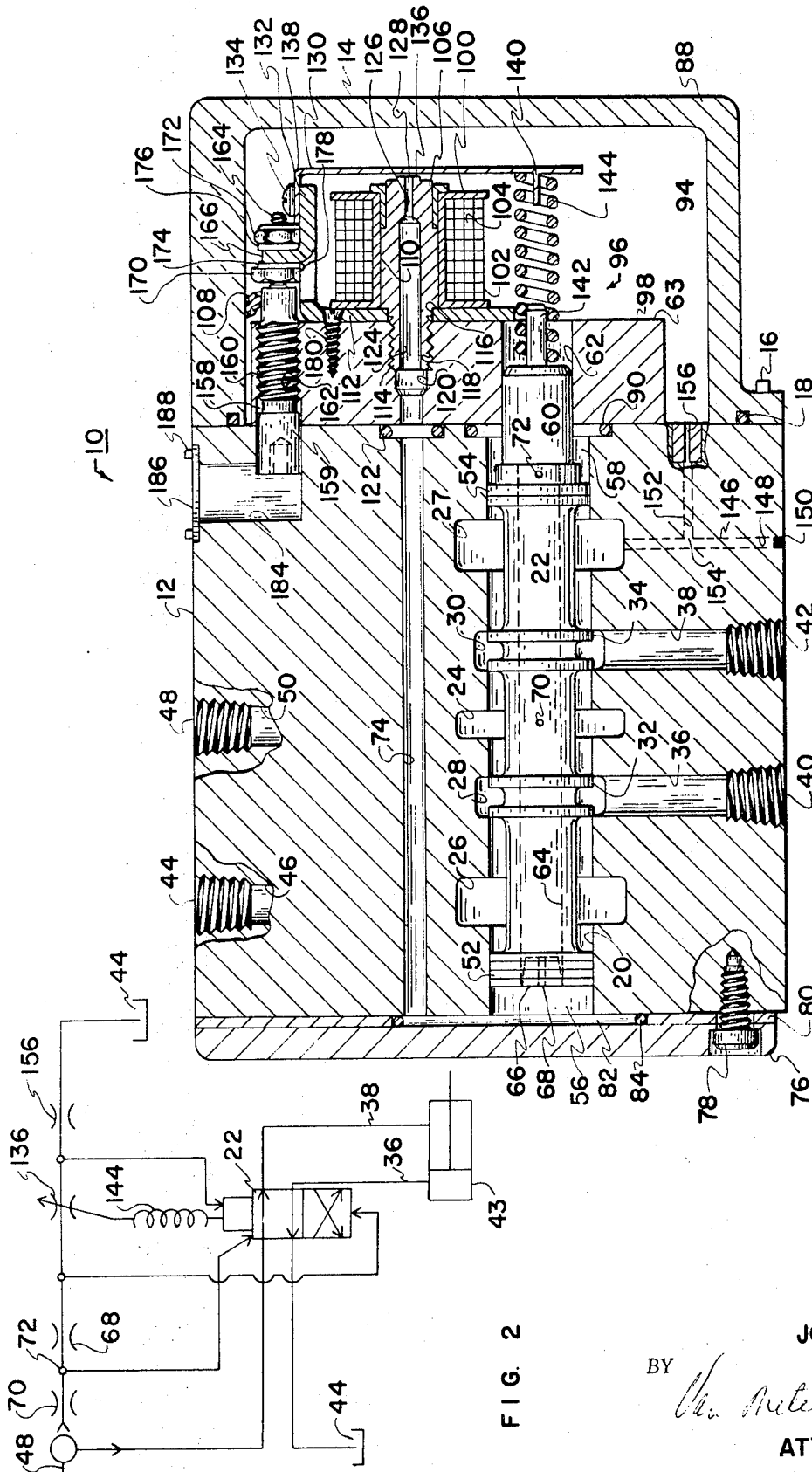


FIG. 1

FIG. 2

INVENTOR.
JOHN MARSHALL

BY

Wm. Miller & George

ATTORNEYS

FLAPPER SERVO VALVE WITH FEEDBACK

BACKGROUND OF THE INVENTION

This invention relates to power transmissions and is particularly applicable to those of the type comprising two or more fluid pressure energy translating devices, one of which may function as a pump and another as a fluid motor.

More particularly, this invention relates to a servocontrol system, and, more specifically, to an electrohydraulic servovalve for variably controlling a hydraulic output in direct proportion to an electrical input signal.

The prior art electrohydraulic servovalve is currently characterized by a relatively high-frequency response and stability of control obtained by virtue of an internal feedback. Because of their stability and accuracy, such valves have become a necessary element of automatic control equipment. Such valves, however, are exceedingly intricate and require complicated and expensive manufacturing techniques, and are difficult to maintain with any degree of reliability.

In order to achieve optimum response characteristics and sensitivity, such prior art devices utilize a pilot valve having a torque motor operated flapper which cooperates with an orifice of a predetermined size in a manner well known in the art. Such an orifice is designed to a very fine tolerance and is expensive to manufacture, and, further, may be the cause of malfunction of the valve due to the corrosive effects of contamination present in the control fluid. In prior art devices, the problem of malfunction due to contamination is treated by introducing filtering in series with the orifice.

Such prior art devices are generally limited in the range of pressures at which they operate. This is due to the corrosive effect that a wide range of pressure changes has on the sensitive orifice. Thus, such prior art devices are designed to function within a relatively narrow range of pressure operation so as to minimize this adverse effect on the orifice. In order to provide for this wide range of pressure operation necessary for automatic control equipment, servovalves with varying sized orifices must be designed, further adding to the expense of such valves, due to the duplication of design effort and manufacturing techniques required for each valve.

As heretofore mentioned, such servovalves have within their pilot stages a torque motor. Such torque motors are characterized by a relatively high frequency response and stability, however, they contribute substantially to the expense of such valves.

SUMMARY OF THE INVENTION

This invention provides a two stage, closed loop electrohydraulic servovalve having an electromagnetically operated flapper, cooperating with an orifice for regulating the pressure of the fluid flowing therethrough for creating a pressure differential on opposite sides of a flow control spool to cause movement of the same in such a manner that the output flow of the servovalve is a function of the electromagnetic current.

It is therefore an object of this invention to provide an improved and inexpensive two stage, closed loop electrohydraulic servovalve.

It is also an object of this invention to provide an improved, two stage closed loop electrohydraulic servovalve which is characterized by a relatively high frequency response and stability of control over a wide range of operating pressures.

It is also an object of this invention to provide an improved two stage, closed loop electrohydraulic servovalve of the character described which is capable of achieving maximum reliability, performance, and repeatability, and which requires a minimum number of moving components, and without the disadvantages of prior art devices.

Further objects and advantages of the present invention will become apparent from the following description, reference being made therein to the accompanying drawing wherein a preferred form of the present invention is clearly shown.

IN THE DRAWING

FIG. 1 is a longitudinal transverse section of a two stage closed loop electrohydraulic servovalve incorporating a preferred form of the present invention; and

FIG. 2 is a circuit diagram of the two stage closed loop electrohydraulic servovalve illustrated in FIG. 1.

Referring now to FIG. 1 wherein there is shown a presently preferred, but merely illustrative embodiment of the inventive principles, an electrohydraulic servovalve 10 having a body 12 and a pilot stage 14 attached thereto by any suitable means such as bolts, one of which is indicated by the numeral 16. An O-ring 18 is provided at the juncture of body 12 and pilot stage 14 to ensure a fluid tight seal. The body 12 has a longitudinal bore 20 with a pressure responsive operating spool 22 reciprocally mounted therein. The bore 20 is provided with spaced apart grooves forming a pressure port 24, two tank ports 26 and 27, and a pair of operating ports indicated by the numerals 28 and 30. The spool 22 is provided with lands 32 and 34 which are adapted to alternately connect and prevent communication between the pressure port 24 and either operating port 28 or 30. The operating ports 28 and 30 respectively communicate with passages 36 and 38 which open to the surface of body 12 respectively at external operating ports 40 and 42. The ports 40 and 42 are adapted to be connected to a pressure energy translating device such as a hydraulic motor 43, FIG. 2, for the purpose of conducting pressurized fluid to and from the motor. The spool lands 32 and 34 are also adapted to alternately connect and prevent communication between the tank ports 26 and 27 and either operating port 28 or 30. For example, if the spool 22 is shifted rightwardly, the spool land 32 will connect the tank port 26 with the operating port 28, but will prevent communication between the operating port 28 and the pressure port 24; while the spool land 34 will connect the pressure port 24 with the operating port 30 but will prevent communication between the operating port 30 and the tank port 27. The tank ports 26 and 27 are connected to the external tank port 44 by means of a passageway, a part of which is indicated within the partial sectional view at 46. External tank port 44 may be connected to any suitable reservoir, not shown, for the purpose of returning fluid from the servovalve.

The pressure port 24 is connected to an external pressure port 48 by means of a passageway, a part of which is indicated within the partial sectional view at 50. The external pressure port 48 is adapted to be connected to a pressure energy translating device such as a pump, not shown, for the purpose of pumping pressurized fluid to the pressure port 24 and to the operating ports 28 and 30, as hereinbefore explained.

Referring again to the operating spool 22 there is provided on opposite ends thereof lands 52 and 54. The lands 52 and 54 form, respectively a movable wall of the pressure chambers 56 and 58, the chamber 56 being to the left of land 52 and the chamber 58 being to the right of land 54. In addition to another function to be described hereinafter, the lands 52 and 54 respectively prevent fluid communication between the tank ports 26 and 27 and the pressure chambers 56 and 58. It should be noted that the land 54 has an extension 60 thereon which extends beyond the pressure chamber 58 into a bore 62 within a mounting block 63 within the pilot stage 14. The outer end of the extension 60 is not exposed to the pressure chamber 58 and is sized in such a manner that the effective area of land 54 which is exposed to pressure chamber 58 is one-half that of the effective area of land 52 which is exposed to pressure chamber 56, for a reason to be explained hereinafter.

Within the spool 22 there is provided an axial bore 64 which extends from the left end of spool 22 to beyond the spool land 54 and into the extension 60. Within the bore 64 at the left end, there is provided a plug 66 having a restriction 68 formed therethrough for the purpose of establishing communication between the bore 64 and the pressure chamber 56. The bore 64 is continuously in communication with the pressure port 24 by means of a radial bore extending through the spool 22 and

indicated by the numeral 70. The radial bore is of such a nature that it is considered a restriction. There is further provided a radial bore 72 on the extension 60 which extends therethrough to the bore 64 for the purpose of establishing fluid communication between the bore 64 and the pressure chamber 58.

Within the body 12, there is provided a second longitudinal bore 74 which extends from the left side to the right side of body 12. There is also provided a cover plate 76 which is attached to the left side of body 12 by any suitable fastening means, such as bolts, one of which is indicated at 78. A plate 80 has a bore 82 therethrough and is sandwiched between the cover plate 76 and the housing 12 while an O-ring 84 provides a fluid tight seal between the juncture of the cover, plate, and body. The plate bore 82 communicates with both the pressure chamber 56 and the body bore 74, thus establishing a fluid conduit between the two.

To the right end of the body 12, there is attached by means of bolts 16, the pilot stage housing 88. The pilot stage mounting block 63 is also attached to the body 12 by any suitable means such as a bolt, not shown. O-ring 90 is provided to ensure a fluid tight seal between the juncture of the mounting block 63 and housing 12 at the spool bore 20.

Within the pilot stage housing 88 there is formed a fluid tight cavity 94 in which a control assembly 96 is contained. The control assembly 96 is mounted on a top surface 98 of the mounting block 63 by means to be described hereinafter.

The control assembly 96 comprises an electrical relay 100 having an electromagnet 102 with a cylindrical electrical coil 104 and a core 106. The coil 104 has a pair of electrical leads 108 which extend from the pilot stage through any suitable nonconductor plug type seal, not shown, and are adapted to be connected to a variable electrical current or input signal applied by a rheostat, not shown, or the life from an electrical power source. Coil 104 has a longitudinal cylindrical opening 110 therethrough in which the cylindrically shaped magnetic material core 106 is contained. The core 106 becomes magnetized only when an electrical current or input signal is applied to the electrical coil 104 and thus is demagnetized when there is no input signal. The coil 104 and the core 106 are mounted on one leg of an L-shaped member 112 made of a magnetic material which, in turn, is mounted on surface 98 of the mounting block 63. A threaded section 114 at one end of core 106 extends through an opening 116 in the member 112 and engages threads 118 formed within a bore 120. The bore 120 extends through the mounting block 63 and opens into the longitudinal bore 74 while the O-ring 122 provides a fluid seal between the junction of the two parts. The threaded connection between the core and mounting block firmly secures the control assembly 96 to the mounting block.

The core 106 has a longitudinal passage 124 in communication with bore 74 and thus with the pressure chamber 56 via bore 82. The passage 124 extends from the threaded section 114 of core 106 to a substantially smaller cylindrical passage or throat 126, thereby connecting pressure chamber 58 with the cavity 94. The throat 126 forms a fluid nozzle 128 having a fluid discharge, or jet stream, axis coinciding with the longitudinal axis of core 106.

A generally rectangular shaped flapper member 130 made of a flexible magnetic material forms the armature for the electromagnet 102 and is rigidly supported by the upper end of the upright leg 132 of the L-shaped member 112 by any suitable means such as bolts, one of which is indicated at 134. The flexible flapper extends from the leg 132 across the nozzle 128 and is substantially perpendicular to the discharge axis of the nozzle. The space between the flapper and the end of nozzle constitutes a magnetic gap and forms a variable control orifice 136. The effective area of orifice 136 is equal to the circumferential area of the throat 126 projected between the nozzle and the flapper. This effective area is a function of the diameter of the throat and the distance between the end of the nozzle and the flapper. Since the diameter of the throat is fixed, the effective area of the variable orifice is varied by

moving the flexible flapper relative to the end of the nozzle. The restrictive effect of the variable orifice on the fluid discharge through nozzle 128 is inversely proportional to the effective area of the variable orifice 136. That is, the restrictive effect of the variable orifice 136 is increased as its effective area is decreased, and, conversely, the restrictive effect of the variable orifice 136 is decreased as its effective area is increased. Thus, the restrictive effect of the variable orifice 136 is varied by moving the flexible flapper to and from the nozzle 128 so as to vary the distance between the flapper and the end of the nozzle. When an electrical current or input signal is applied to the leads 108, a magnetic field is established by the electromagnet, which flows through the core, the L-shaped member, the flapper, and across the magnetic gap back to the core, producing a magnetic force on the flexible flapper which urges the flapper to pivot about a fulcrum point 138 toward the end of nozzle 128. The flexible flapper 130 thereby provides a control member for variably restricting the discharge of fluid through the nozzle 128.

There is provided on the lower end of flapper 130 and on the spool extension 60 respectively, spring guides 140 and 142 which are adapted to receive and maintain in position between the same a compression-type spring 144 having a relatively low spring rate, the purpose of which will be described hereinafter.

In order to drain fluid from the pilot stage cavity 94, there is provided within the body 12 a passageway 146 which connects the cavity to the tank port 27 and thus to the reservoir, not shown. The passageway 146 comprises a vertical bore 148 which extends from the outer periphery of body 12 and which is sealed by means of plug 150 and by a horizontal bore 152 which extends from the cavity to the bore 148 and intersects the same at 154 thus completing the passageway 146. Disposed within the passageway 146 is a restriction 156 which is sized in such a manner so as to limit the drain flow from cavity 94 to a predetermined amount.

As hereinbefore mentioned, the flapper 130 provides a means for variably restricting the discharge of fluid through the nozzle 128. The initial size of the variable restriction can be predetermined by positioning the flapper at a predetermined distance from the nozzle 128. This is accomplished by means of what will hereinafter be referred to as a null screw and which is indicated by the numeral 158. The null screw comprises an adjusting screw 159 having a threaded portion 160 which is received into a threaded bore 162 within the mounting block 63. The adjusting screw is in a plane which is generally parallel to the upright leg 132 of the member 112. A threaded extension 164 of the adjusting screw is adapted to receive a perpendicularly extending portion 166 of the upright leg through a bore within the extending portion 166. The extending portion 166 is firmly attached to the threaded portion 164 by means of nuts 170 and 172 and washers 174 and 176 which are located on opposite sides of the extended portion 166. The nut 172 is of the elastomeric self-locking type. The threading of the null screw into the mounting block will cause the upright leg to be rotated in a clockwise direction which will carry the flapper with it; that is, positioning the flapper closer to the nozzle with a corresponding increase in the variable restriction. By threading the null screw away from the mounting block, the upright leg will be rotated in a counterclockwise direction, carrying the flapper further away from the nozzle with a corresponding decrease in the variable restriction. To ensure that the upright leg rotates or bends about the proper fulcrum point to achieve the desired amount of flapper displacement, a longitudinal half round groove is provided for along the width of the upright leg and is indicated by the numeral 178. A screw 180 is threaded through the lower leg and into the mounting block surface 98 in order to prevent separation of the lower leg from the mounting block surface, thus, further aiding the proper pivotal action of the upright leg during the initial positioning of the flapper by means of the null screw 158. Access to the null screw may be had by means of a bore 184 which extends from the outer

periphery of the body 12 to the adjusting screw 159. A cover plate 186 is attached to the body 12 by any suitable means such as bolts 188 to close bore 184 when access to the null screw is not required.

Referring now to both FIGS. for a description of the operation of the servovalve 10, a supply pressure enters the servovalve through the pressure port 24 and via the restriction 70 enters the spool bore 64. The object of restriction 70 is to reduce the supply pressure to a value which will facilitate the movement of spool 22 but will be of a sufficiently low value to avoid cavitation at the nozzle-flapper interface. In a typical application with a pressure operating range of 500 to 3,000 p.s.i., an orifice of approximately .020 inches should be appropriate for the size of restriction 70. This reduced pressure simultaneously communicates with the pressure chamber 58 via the radial bore 72 and with the pressure chamber 56 via the axially located pressure reducing restriction 68. The restriction 68 reduces the pressure entering chamber 56 to a value which is somewhat less than approximately half that of the value of the pressure in chamber 58 and again in a typical application with a pressure operating range from 500 to 3,000 p.s.i., an orifice of approximately .030 inches should suffice.

The fluid in chamber 56 will flow into the pilot stage cavity via the cover plate bore 82, body bore 74, nozzle 128, and the variable restriction 136. From the pilot stage cavity, fluid will flow into the tank port 27 via the flow passage 146 and restriction 156.

The pressure in chamber 58 acts against the sealing land 54 and tends to shift the spool 22 leftwardly toward the chamber 56. This movement is resisted by the pressure in chamber 56 which is acting against sealing land 52 tending to shift the spool 22 rightwardly. When the flapper is positioned away from nozzle 128, the resistance to the flow of fluid therethrough will decrease with a resultant decrease in the pressure of the fluid in chamber 56. Such a pressure decrease will create a force unbalance which will tend to shift the spool 22 leftwardly.

In a typical application, the electromagnet may have a current input rating of 0 to 400 ma. with the valve being centered to a neutral position such as is illustrated in FIG. 1 when the input signal is approximately 200 ma. This is accomplished by supplying an input signal of 200 ma. and by initially making use of the null screw in the manner hereinbefore described to raise or lower the pressure in chamber 56 so as to center spool 22 wherein neither of the operating ports are in fluid communication with the pressure port 24.

To obtain fluid communication between the pressure port and the operating port 28, the current input to the electromagnet is increased over 200 ma. until the pressure in chamber 56 increases to an amount which is sufficient to create a force unbalance acting on spool 22 so as to shift the same rightwardly. To obtain fluid communication between the pressure port and the operating port 30, the current input to the electromagnet is decreased under 200 ma. until the pressure in chamber 56 decreases to an amount which is sufficient to create a force unbalance acting on spool 22 so as to shift the same leftwardly.

The compression spring 144 connecting the spool and the flapper forms the feedback link between the main spool and the pilot stage. For example, as the current input to the electromagnet is increased, the resultant increase in chamber 56 will cause the spool to shift rightwardly toward the pilot stage, compressing the feedback spring. As the spring is compressed, it acts against the flapper tending to reopen the flapper against the electromagnetic force. This gives the spool a new stable position due to a new force balance between the fluid acting on the flapper, the electromagnetic force and the feedback spring. By either increasing or decreasing the input signal to the electromagnet, any desired amount of flow may be selectively directed to either of the operating ports.

It should also be noted that the control of the pressure in chamber 56 is dependent upon the interaction of the flapper and nozzle; specifically, the variable restriction 136. This

being the case, the throat of the nozzle need not be designed to the fine tolerance level as the prior art devices; thus, relative to the prior art devices it is contaminate resistant and will not require the use of a filter connected in series therewith.

It can thus be seen that the present invention has provided an improved and inexpensive two stage closed loop electrohydraulic servovalve which is capable of achieving the reliability, performance and repeatability of the prior art devices and which accomplishes this without the need of an expensive torque motor and other disadvantages of the prior art devices.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow:

I claim:

1. In combination with a flow control device of the type comprising:

a valve body;

a spool element disposed for reciprocal movement in said valve body and adapted to selectively control the passage of fluid under pressure therethrough;

a variable pressure chamber coupled to one end of said spool element for controlling the reciprocal motion of said spool element by variations in pressure therein and adapted for connection to a source of fluid under pressure;

a constant pressure bias chamber adapted to couple said fluid under pressure to the other end of said spool element, wherein the improvement comprises: an electromagnetic relay having a bore means extending therethrough, one end of which is connected to said variable pressure chamber, the other end forming an orifice to enable fluid flow therethrough along a jet stream axis; a flexible flapper member, one portion of which is rigidly carried within said valve body, said flapper member being disposed in a plane which is generally perpendicular to said jet stream axis and is adapted to control the effective opening of said orifice by transverse motion relative to a direction which is perpendicular to said jet stream axis, whereby relatively small displacements of said flapper member relative to said orifice cause the pressure in said variable chamber to vary and effect larger displacements of said spool element, said electromagnetic relay being the motive force for positioning said flapper member relative to said orifice; and, resilient feedback means coupling said flapper member to said spool element.

2. A combination as in claim 1 wherein said electromagnetic relay comprises: a core wherein said bore means are disposed; an electrical coil encircling said core which is adapted to be connected to a source of an electrical input signal for magnetically actuating said flapper member in response to said electrical input signal for varying the effective opening of said orifice and thus the restrictive effect thereof.

3. A combination as in claim 1 wherein said resilient feedback means comprises a mechanical resilient means.

4. A combination as in claim 1 wherein said flapper means is rigidly carried by a support member within said housing, said support member being laterally spaced from said core of said electromagnetic relay; means for mechanically bending said support member about a predetermined axis for adjusting the initial position of said flapper relative to said nozzle and thus, the pressure in said variable chamber for initially positioning said spool element.

5. A combination as in claim 4 including means forming a groove on said support member forming a fulcrum point about which said support member bends in response to said mechanically bending means.

6. In combination with a flow control device of the type comprising a valve body having a main body portion; a spool element disposed for reciprocal movement in said main body portion and adapted to selectively control the passage of fluid under pressure therethrough; a variable pressure chamber coupled to one end of said spool element for controlling the

reciprocal motion of said spool element by variations in pressure therein and adapted for connection to a source of fluid under pressure; a constant pressure bias chamber adapted to couple said fluid under pressure to the other end of said spool element, wherein the improvement comprises: a pilot body portion carried by said main body portion and having a fluid tight cavity formed therein; an L-shaped support member formed in said pilot body cavity; an electromagnetic relay within said cavity having a core and an electrical coil encircling said core to which an electrical input signal is applied, said core having a passage therethrough, one end of which is in fluid communication with said variable pressure chamber, the other end forming a fluid nozzle through which fluid is discharged from said chamber along a jet stream axis, said relay being mounted on one leg of said support member; a flexible flapper member spaced proximate the end of said nozzle in a plane which is generally perpendicular to said jet stream axis and which is adapted to control the effective opening of said orifice and thus, the pressure in said variable pressure chamber, one portion of said flapper member being rigidly mounted on the other leg of said L-shaped support member, said flapper member forming an armature for said electromagnetic relay such that said flapper member is magnetically actuated in response to said electrical input signal towards and away from said nozzle to control the effective opening of said orifice whereby relatively small displacements of said flapper member relative to said orifice cause the pressure in said variable chamber to vary and effect larger displacements of said spool elements; means for mechanically bending said other leg of said support member about a predetermined axis for adjusting the initial position of said flapper member relative to said nozzle and thus the pressure in said variable chamber for initially positioning said spool element; a resilient feedback means coupling said flapper member to said spool element; and means forming a restrictive passageway for venting said fluid tight cavity.

7. A combination as in claim 6 wherein said resilient feedback means comprises a light compression spring disposed between said spool element at the constant speed pressure bias chamber end thereof and a portion of said flapper member.

8. A combination as in claim 6 wherein said other leg of said support member is fastened to said bending means.

9. An electrohydraulic servovalve comprising: means forming a pressure chamber; a body portion having a fluid tight cavity formed therein; an L-shaped support member formed in said body cavity; an electromagnetic relay with said cavity having a core and an electrical coil encircling said core to which an electrical input signal is applied, said core having a passage therethrough, one end of which is adapted to be connected to said pressure chamber, the other end forming a fluid nozzle through which fluid is discharged along a predetermined jet stream axis, said relay being mounted on one leg of said support member; a flexible flapper member spaced proximate the end of said nozzle in a plane which is generally perpendicular to said jet stream axis and which is adapted to control the effective opening of said orifice and thus the pressure in said pressure chamber, one portion of said flapper member being rigidly mounted on the other leg of said L-shaped support member, said flapper member forming an armature for said electromagnetic relay such that said flapper member is magnetically actuated in response to said electrical input signal toward and away from said nozzle to control the effective opening of said orifice; means for mechanically bending said other leg of said support member about a predetermined axis for adjusting the initial position of said flapper member relative to said fluid nozzle; means forming a restrictive passageway for venting said fluid tight cavity; and resilient means for creating a force to oppose the movement of said flapper member toward said nozzle, said created force being dependent upon the pressure within said pressure chamber.

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