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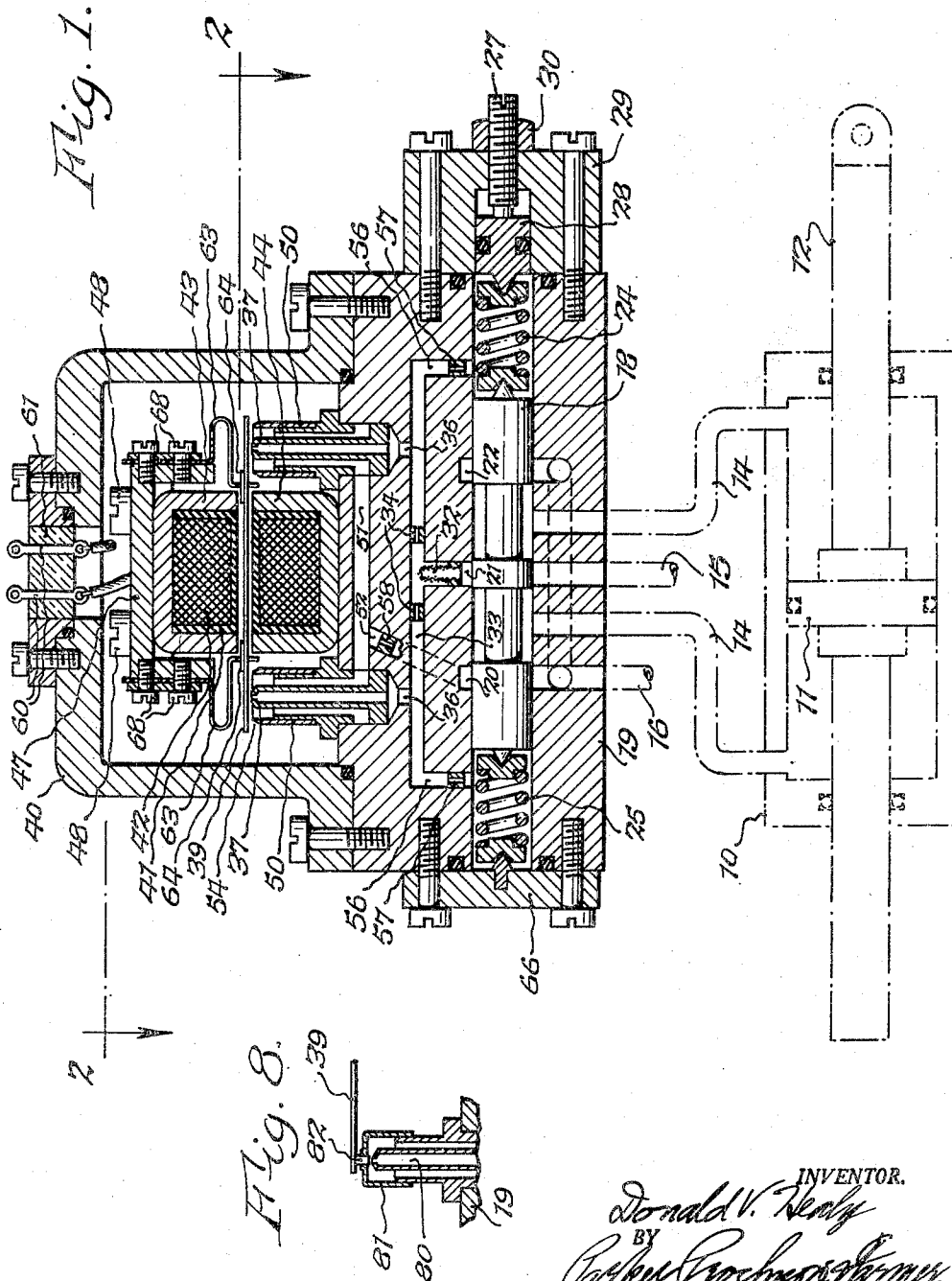
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2,823,689

ELECTRO-HYDRAULIC SERVO VALVE

Filed June 18, 1954

3 Sheets-Sheet 1



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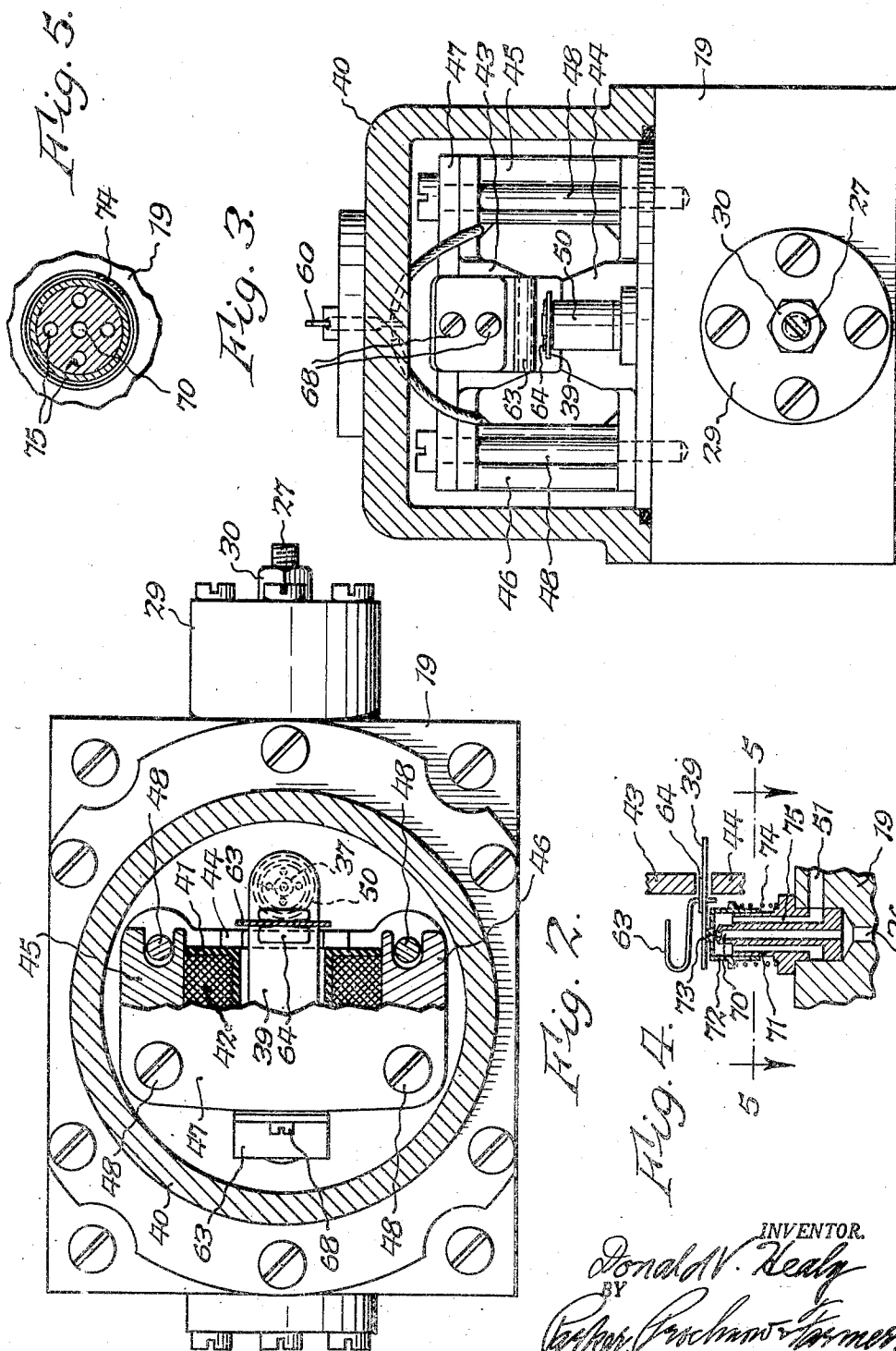
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Fig. 7.

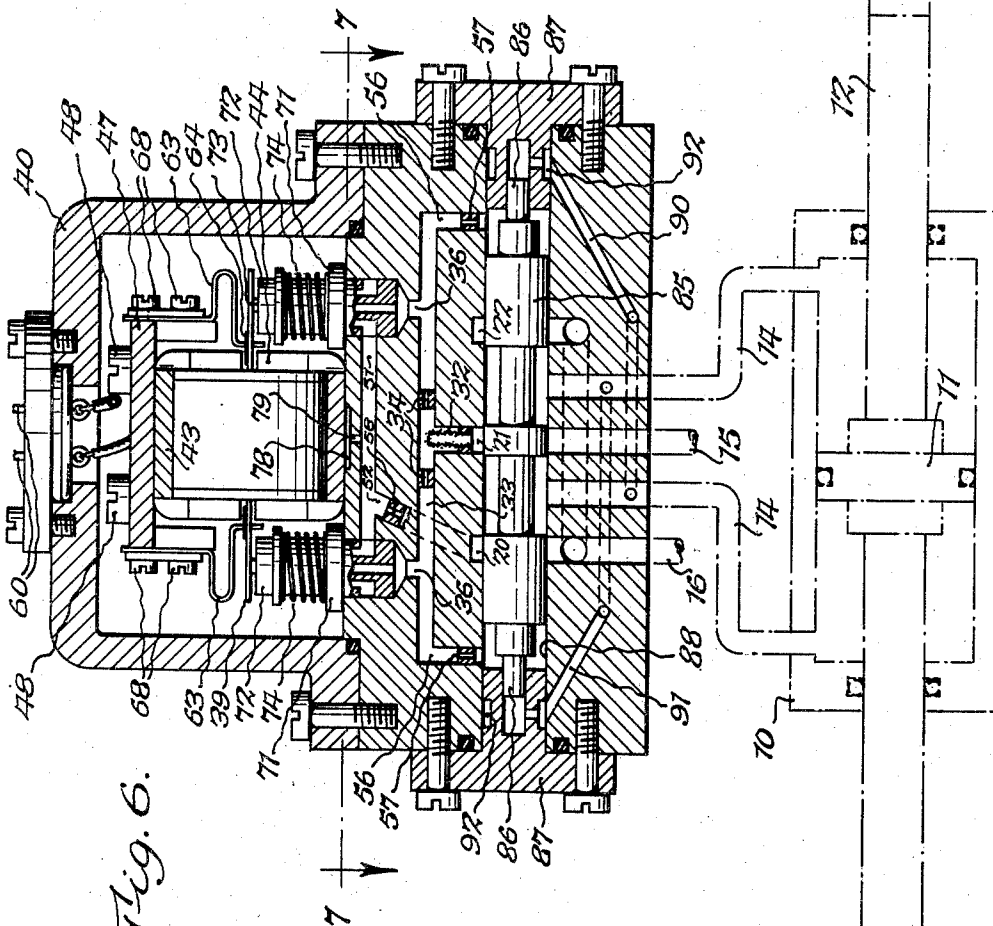
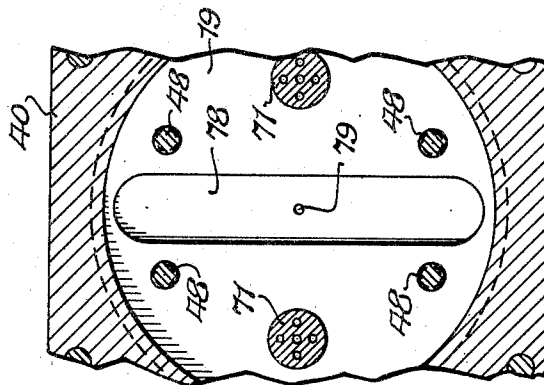


Fig. 6.

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ELECTRO-HYDRAULIC SERVO VALVE

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7 Claims. (Cl. 137—82)

This invention relates to electro-hydraulic amplifiers which include fluid discharge nozzles controlled by an armature actuated by means of an electrical signal.

In devices of this type one of the main causes of failure has been that, since the hydraulic fluid can never be entirely free from particles of dirt or other foreign matter, such particles clog the fluid discharge nozzles so that the amplifier fails to operate properly. The hydraulic fluid frequently contains magnetic particles of dirt or foreign materials which are too small to be removed by any filter, and consequently, such particles sometimes collect between the pole pieces or on the armature and nozzles where they interfere with the correct operation of the amplifier.

There have been devised electro-hydraulic amplifiers in which only a single nozzle is provided which acts on one side of an armature. Experience has, however, shown that this type of amplifier when used to operate a servo valve, cannot be compensated adequately for inlet pressure changes to make it practical for use in connection with most servo systems. This type of amplifier has also been easily effected by magnetic dirt particles between the pole pieces and the armature causing malfunction.

There have also been produced various types of double nozzle amplifiers which have utilized two coaxial opposed nozzles with a flat plate armature movable between them. These amplifiers compensate quite well for inlet pressure fluctuations but are very dirt-sensitive because of the fact that there must be a very small clearance between each fixed nozzle and the face of the armature. When the armature is in center position the nozzle gap is generally not more than .001 inch on each side. This gap cannot be increased without spoiling the linearity and symmetry of the out-put flow of valves controlled by said amplifier. These amplifiers are also troubled by magnetic dirt which cannot be removed from the hydraulic fluid by filters or screens because of the minute particle sizes. Whenever a nozzle type valve is in operation, hydraulic oil or other fluid is continually flowing from the nozzle against the armature and then near the pole pieces, giving the magnetic dirt plenty of vital magnetic areas to which it may adhere.

It is, consequently, an object of this invention to provide an electro-hydraulic amplifier of improved construction which results in more accurate and reliable operation of the same. A further object is to provide an electro-hydraulic amplifier in which the armature is acted on by fluid discharged from two nozzles both located near opposite ends of the armature and on the same face thereof.

Another object of this invention is to provide a double nozzle electro-hydraulic amplifier which is so constructed that dirt particles of much larger sizes can pass through the same than could heretofore be passed through devices of this kind. It is also an object of this invention to provide a device of this kind in which the accumulation of magnetic dirt particles is greatly reduced and takes place in parts of the amplifier in which they will not interfere with the proper operation of the same.

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A further object is to provide an amplifier of this type with means for guiding hydraulic fluid in paths which avoid exposure of this fluid to magnetic attraction.

Other objects and advantages will be apparent from the following description of one embodiment of the invention and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

In the accompanying drawings:

Fig. 1 is a central sectional elevation of an electro-hydraulic amplifier embodying this invention.

Fig. 2 is a sectional plan view thereof, on line 2—2, Fig. 1.

Fig. 3 is an elevation thereof, with the cover shown in section.

Fig. 4 is a fragmentary sectional elevation of a nozzle of modified construction.

Fig. 5 is a sectional plan view thereof, on an enlarged scale, on line 5—5, Fig. 4.

Fig. 6 is a central sectional elevation of my improved electro-hydraulic amplifier showing the same used with a servo valve of different construction.

Fig. 7 is a fragmentary sectional plan view thereof, on line 7—7, Fig. 6.

Fig. 8 is a fragmentary sectional elevation showing a nozzle of still another modified form.

In Figs. 1 and 6 I have shown in broken lines some hydraulic control devices which are of themselves old in the art, but in connection with which my improved electro-hydraulic amplifier operates. These devices in both cases include a hydraulic cylinder 10 in which a piston 11 is arranged to reciprocate, the piston being mounted on an elongated piston rod 12 extending through both ends or heads of the hydraulic cylinder. Passages or ducts 14 extend toward opposite ends of the cylinder. Fluid under pressure is admitted to the valve and to the amplifier through a tube or duct 15 and return fluid from the valve and amplifier passes to the system drain line through a duct or passage 16.

The valve for controlling the operation, in Fig. 1, of the piston 11 in the cylinder 10 includes a valve spindle or spool 18, that shown being of cylindrical form and having a close running fit in a bore formed in the base or body 19 of the valve. The base or body 19 has three annular grooves 20, 21 and 22, formed therein in such manner that they are slightly overlapped by each of the enlarged portions or lands of the spool. In the construction shown in Fig. 1, the valve spool 18 is normally held in a zero position as shown by two opposed compression springs 24 and 25 which can be adjusted for zero position by means of a set screw 27 acting on a centering plug 28 guided in an aperture in a head 29. A lock nut 30 may be provided for holding the adjusting screw 27 in its desired position.

The body portion 18 of the valve is provided with suitable passages, one of which connects with the annular groove 21 and contains a filter or strainer 32 of any suitable or desired type. It will be noted that the tube 15 connects with the groove 21 in the body portion 19, and consequently, fluid under the system pressure is admitted continuously to the electro-hydraulic amplifier section of the valve through the strainer 32. The inlet passage containing the strainer connects with a longitudinal passage 33 in the block 19 and this passage contains two equal flow restrictors 34 arranged at opposite sides of the inlet passage containing the strainer.

At opposite sides of the restrictors 34 the passage 33 connects with upwardly extending passages 36, each leading to a nozzle 37 which terminates adjacent to opposite ends of an armature 39. These nozzles may be of any usual type such as employed in connection with instruments of this type and the armature is so supported that it normally floats within a .001 of an inch of nozzle tip.

The nozzles and the electrical parts of the amplifier are arranged in a motor chamber formed within a cover or lid 40 suitably bolted or otherwise secured to the body portion 19.

The armature is in the form of a flat plate or strip of iron and extends through a slot formed in a spool 41 of suitable non-metallic material upon which a coil 42 is wound. This coil is electrically connected to receive signal currents as is common in amplifiers of this type. The coil, consequently, will magnetize the armature 39 to form south or north seeking poles at either end thereof, depending upon the direction of the signal current flowing in the coil 42. The coil is partly enclosed by means of pole pieces 43 and 44 which are in contact with permanent magnets 45 and 46, and the pole pieces and magnets are securely fastened together, for example, by means of a bracket member 47 of non-magnetic material, such for example as brass, secured in place by means of screws 48, the lower ends of which have a threaded engagement with the valve block or body portion 19. It will be noted that the pole pieces are of U-shape with their legs spaced apart to form two air gaps within which the armature 39 is arranged. Consequently, if the armature is magnetized by current in the coil 42, one end of the armature will be attracted by one end of one pole piece, and the other end of the armature will be attracted by the opposite end of the other pole piece, so that the armature is tilted by what might be called a "push-and-pull" action. This results in the movement of the armature away from one nozzle and toward the other, thus permitting a greater flow of fluid through one nozzle than through the other, thus creating less back pressure in the fluid passing to the former than to the latter. It will be understood that the end portions of the armature adjacent the nozzle tips function as flow restriction baffles and because of their rigid connection with the armature always move in correspondence with the movement of the armature.

The interior of the cover 40 is filled with hydraulic oil or other fluid at substantially the same pressure as exists in other parts of the amplifier down stream from the nozzle, and consequently, and of this fluid in proximity to the magnetic parts of the amplifier would readily deposit their magnetic dirt particles on any of such magnetic or magnetized surfaces. In order to reduce the deposit of magnetic dirt particles on magnetic parts of the mechanism to a minimum, I have made provisions for returning the flow discharged from the nozzles back to the drain or discharge duct 16 without passing into the motor chamber, enclosed by the cover 40, although, of course, when the amplifier is initially started oil or other fluid will fill the motor chamber. In order to accomplish this result, I have provided about each nozzle a fixed sleeve 50, that shown being arranged concentrically with the nozzle and spaced therefrom to form between this sleeve and the nozzle a return passage through which hydraulic fluid may pass to a duct 51 suitably formed in the base or body portion 19. This passage 51 connects with a passage 52 leading to the annular groove 20 in the body portion 19, and this annular groove 20 connects with the discharge duct or passage 16. Consequently, it will be obvious that after the chamber within the cover or lid 40 is filled with hydraulic fluid, practically all of the fluid discharged by the nozzles 37 will pass into the space between the nozzles and the sleeves 50, and thence out of the amplifier.

In order to avoid to the maximum extent any interference by the sleeves 50 with the action of the nozzles on the armature 39, the upper edges of the sleeves 50 are spaced slightly below the tops of the nozzles 37, so that the upper ends of the sleeves do not contact the armature, and furthermore, the upper ends of the sleeves are preferably beveled, as shown at 54, so as to reduce to the minimum any interference of the upper ends of these sleeves with the free motion of the armature 39.

The passage or duct 33 terminates in a pair of downwardly extending passages 56 which terminate in the bore of the body 19 beyond the opposite ends of the spool 18. These passages may contain restrictors 57. For most valve operating requirements these restrictors are not necessary, but they can be provided to attenuate the dynamic response of the valve at high frequencies because of the velocity damping that these restrictors provide.

If the restrictors 57 are disregarded, then it may be considered that the fluid pressure throughout the fluid volume, herein also called the nozzle chamber, lying between a flow restrictor 34, the tip of a nozzle 37 and the end of the valve spool is very nearly constant for any instant of time because the outlet from this space or nozzle chamber at the nozzle tip is a restricted opening and the velocity of fluid within this space is very low, the restriction being caused by the presence of the armature 39 normally floating within .001 of an inch of the nozzle tip.

Fluid passing through the variable restrictions between the nozzle and armature travels down through the passages within the cylindrical sleeves 50 through a fluid restrictor 58 and out of the drain port 16. This flow restrictor is also not absolutely essential to the performance of the amplifier, but it maintains a pressure in the nozzle drain space and motor chamber which seems to minimize the effect of the system drain pressure fluctuations on valve performance. The pressure in the nozzle drain passages within the sleeves 50 and motor cap 40 may, for example, be about 200 pounds per square inch. The nozzle chamber pressures are usually on the order of 550 pounds per square inch for the zero signal condition with approximately 2000 pounds per square inch system pressure being applied.

The coil 42 has terminal rods 60 which extend through an insulating plate 61 suitably secured to the cover 40 to close an opening formed therein.

It will be noted that the pole piece 43 is arranged above the armature and the pole piece 44 below the armature and the permanent magnets are so located that the north seeking end of each bears against the same pole piece. Consequently one of the pole pieces becomes north and the other south. The armature 39 is constructed of a low hysteresis material which is magnetic, and it is of course desirable to locate the armature in the middle of the space between the pole pieces. The armature is limited in its travel toward the face of the lower pole piece 44 by the tips of the nozzles 37 which are preferably made of a hard non-magnetic material such as hardened beryllium copper. Movement of the armature in the opposite direction is limited, for example, by means of shims 64 of a non-magnetic material such as brass which may be mounted on the armature or on the pole piece 43. These limits allow the armature to operate only in the middle 30 percent of the total air gap between the pole pieces. If, for example, this gap is .020 inch, then the armature will move only in a space of approximately .006 inch. This centering of the armature in the air gap may be effected in any suitable or desired manner, and in the construction shown by way of example, the armature is held in place by means of springs 63 which are connected with the armature near each end thereof. It is important that the spring rates of the support springs 63 is approximately equal to the armature force-deflection rate caused by the action of the permanent magnetic field on the armature at each air gap, in order that these two rates can cancel each other out. With these conditions in effect, it will be understood that the armature may be positioned at any point within its operating range of either air gap without the application of any substantial change in force. In other words, the armature practically floats in the air gaps.

Considering the operating forces acting on the armature at either end thereof, they are the force caused by the

difference in pressure between the passages leading to the nozzle, i. e., the nozzle chamber, and the nozzle drain passages including those within the sleeves 50, acting on an effective area of the armature which nearly equals that of the sharp-edged nozzle opening, said force being a linear function of the pressure differential since the effective area remains nearly constant for all normal positions of the armature 39. The biasing force applied by the support springs 63 is required to set the zero signal pressure level in the passages leading to the nozzle, and since this spring rate is nearly cancelled by the armature rate, as mentioned above, the resultant force is therefore nearly a constant biasing force for all armature positions. The force on the armature caused by magnetic flux unbalance in the air gap due to flow of current in the coil 42 resulting from an electric signal determines the polarity of the armature depending upon the direction of the current flowing in the coil. This determines toward which pole piece face the armature is attracted. The magnitude of this force is a linear function of the current below the saturation level.

Consideration of the forces mentioned shows that each of the bodies of fluid in the passages of the instrument leading to the nozzles maintains a pressure which is nearly a linear function of the current or in-put signal in the coil. The polarity is such that when one end of the armature is attracted toward a nozzle because of a signal applied to the coil, then the other end is attracted away from its nozzle. As a result, the difference in pressures between the fluid in the two passages leading to the nozzles is always a linear function of the applied electric signal (below the saturation level).

The liquid in the passages leading to the nozzles acts on their respective ends of the valve spool 18 so that the resultant driving force on the spool is a linear function of the electric signal. This spool driving force is opposed by the centering springs 24 and 25 which have a linear spring rate so that the displacement of the spool from its center position is also a linear function of the electric signal. In turn the flow area of each port is a linear function of the spool travel, and therefore, of the signal applied to the coil. The travel of the piston 11, however, is not necessarily at a velocity proportional to the electric signal, since the external applied loads on the piston may be fluctuating, as well as the system pressure of the actuating fluid. If system pressure is held constant and no load is exerted on the strut the velocity of travel of the piston 11 is proportional to the signal.

In order to adjust the valve after assembly of the same, the cover 40 is removed and the system pressure which may, for example, be 1000 pounds per square inch is applied to the passage 15 while the spool 22 is locked in its zero position by any suitable means, such as special end caps (not shown) which replace the end cap 29 at one end of the spool and an end cap 66 which is secured on the other end of the body portion 19 and against which the spring 25 reacts. The pressures of the fluid in the passages leading to the nozzles are then adjusted by loosening the spring retaining screws 68 slightly. These screws preferably pass through slots in the upper ends of the spring 63. These ends of the springs are, consequently, adjusted vertically until the desired back pressure is reached, for example, when the pressure of the fluid in both passages leading to the nozzles are at 350 pounds per square inch. The springs are also adjusted so that the pressures acting on opposite ends of the valve spool are equal. The screws are then tightened to lock the springs in position. The cover 40 may then be installed and the system pressure applied. With zero signal in the coil 42, the set screw 27 is also set to position the valve spool in the zero position so that no fluid emerges from either side through the passages 14. The valve and the electro-hydraulic amplifier are then in adjustment.

The springs are mounted on the bracket 47 which is of

non-magnetic material, such as brass, and which also acts as a clamp to hold the pole pieces, the magnets and the coil with the spool 41 all in place and clamped to the body 19 in any suitable manner, for example, by means of the screws shown. The nozzles 37 must, of course, be of equal tip area and the bases of the nozzles are pressed into apertures in the body portion 19. The various flow restrictors are also pressed into their passages in the body.

A slightly modified construction of the nozzles is shown in Figs. 4 and 5, in which the nozzle 71 has a passage 70 forming a part of the nozzle chamber. A slidable cap 72 is mounted to move vertically on the nozzle, this cap having a central knob or projection 73 which bears against the undersurface of the armature 39. A light spring 74 normally urges the cap 73 into engagement with the undersurface of the armature. The cap is made of a non-magnetic material and is as light as possible in weight, and consequently, the spring 74 is also so light that it does not materially affect the operation of the amplifier. The fluid discharged by the nozzles, consequently, does not contact the armature but the discharge of fluid from the nozzles is nevertheless controlled by the position of the armature and the cap 72. The nozzles are provided with suitable holes or passages 75 similar to those shown in Fig. 1 and terminating in an annular groove in the nozzle in registration with the fluid discharge passage 51.

Since the pressure of fluid within the cover or lid 40 must be substantially equal to the pressure of fluid discharged from the nozzles, it will be obvious that with a construction such as shown in Fig. 1, in which the cylinder 50 which extends about the valve is open at its upper end, sufficient actuating fluid can flow into the chamber over the upper edge of the sleeve 50 to maintain the desired pressure relationship. With a construction such as shown in Figs. 4 and 5, in which a closed cap 72 is employed, it is necessary to provide other means for supplying fluid to the space within the cover or dome 40, and for this purpose, I have shown in Figs. 6 and 7 means for accomplishing this result, and at the same time removing magnetic dirt or foreign material from the fluid. In this construction, I have provided a shallow recess or chamber 78 in the upper surface of the base or body 19 of the instrument which is connected with the discharge passage 51 by means of a connecting passage or duct 79. This chamber 78 is arranged below the lower pole piece 44 and extends beyond the opposite ends of this pole piece, so that fluid may be discharged from the ends of this chamber into the other chamber within the cover 40. Consequently, fluid discharged from the nozzle passes from the discharge passage 51 upwardly into the chamber 78 and to the motor chamber. The advantage of this construction is that the actuating fluid passes into close proximity to the lower pole piece which is strongly magnetized so that magnetic particles in the fluid will attach themselves to a non-critical area of this pole piece. The chamber 78 is amply large enough so that there is no danger that sufficient of these magnetic particles will accumulate in the passage 78 to interfere in any way with the correct operation of the instrument, particularly since no fluid flows through this chamber during the normal operation of the amplifier.

Another modified construction is shown in Fig. 8, in which a nozzle 80 is enclosed in a fixed cap 81. This cap has an axially extending aperture in the upper portion thereof in which a plunger 82 is slidably arranged. This plunger is directly above the discharge orifice of the nozzle 80 and also contacts with the armature 39. Consequently, when the armature is moved upwardly, due to a signal in the coil of the instrument, the plunger 82 is permitted to rise and thus cause a larger quantity of fluid to be discharged from the nozzle 80. This plunger is very small and light and does not interfere in any way with the operation of the instrument. The nozzle pres-

sure is sufficient to make the plunger 82 follow the armature at all times. This type of nozzle construction must of course be used in connection with the amplifier shown in Figs. 6 and 7, in which a passage is provided connecting the space within the cap 40 with nozzle drain passage.

My improved electro-hydraulic amplifier may be used without change to operate a pressure control type of servo valve. This application of the amplifier is illustrated in Fig. 6. The flow control valve shown in Fig. 6 is different from that shown in Fig. 1, in that the valve spool 85 is mounted so that it floats to a position in which the total pressure forces at each end are in balance, whereas in Fig. 1, the spool took positions proportional to the electric signal. The force balance on the spool 85, Fig. 6, is controlled by the electric signal in a linear manner, but the position of the spool is now a combined linear function of the external load pressure from the piston rod 12 and the amplifier signal.

The difference between the pressures of the cylinder passages 14 consequently is a linear function of the applied electric signal, and the flow from the cylinder ports is continually adjusted to maintain this relationship.

In the construction shown in Fig. 6, the pressures in the nozzle chambers or passages leading to the nozzles are still admitted to equal areas at each end of the spool, but also acting on another small area at each end of the spool are the cylinder port pressures communicated in the polarity shown. The small diameter end portion 86 at each end of the spool 85 has a close running fit in end caps 87, and these caps in turn fit closely in the bore 88 of the body 19. The hydraulic fluid at cylinder port pressures are transmitted from the passages 14 by means of ducts or passages 90 and 91 leading to annular grooves 92 in the end caps 87 from which the actuating fluid passes into spaces in these caps beyond the ends of the small ends of the spool 85.

The pressure control valve is adjusted in the same manner as described in connection with the flow control valve except that there is no centering spring adjustment for the spool.

The coil 42 in either of the constructions shown can be a single coil, as indicated, or it can be of the push-pull type wherein the magnetic force acting on the armature will have magnitude and means proportional to the differential current between the two windings of the coil.

The amplifier described has the advantage that even large fluctuations in inlet pressure of the operating fluid are compensated for by the fact that the construction is symmetrical in design. Consequently, any increase or decrease in fluid pressure will act equally on both ends of the armature, and therefore produce no movement of the valve spools 18 and 85. The amplifier is not sensitive to external vibration because of the low mass of the armature and due to the fact that both nozzles are mounted on the same side of the armature, so that a displacement of the armature, due to shock load, would cause the same change in said pressure at each nozzle, so that the difference in flow of fluid through the nozzles which controls the nozzle chamber pressure differential which is the out-put of the amplifier, remains unchanged. The temperature compensation is also good because of the symmetrical design with both nozzles on the same face of the armature. The materials used in the construction can be selected with very nearly equal thermal expansion coefficients.

The most important feature of my improved electro-hydraulic amplifier is its ability to automatically pass particles of dirt up to nearly .006 inch greatest dimension without malfunctioning. This is possible because of the floating armature feature mentioned where the armature rate cancels the supporting spring rate, and also because the nozzles are mounted on the same side of the armature. When particles of dirt arrive at a nozzle end, such dirt particles partly plug the space or restriction between the nozzle and the armature, which is normally no greater

than .001 inch even with a full signal applied. When a dirt particle is thus lodged, the nozzle chamber pressure begins to increase, thus disturbing the force balance so that the armature tends to move away from the nozzle until the force balance is re-established. Since the armature can travel a total of .006 inch away from the nozzle before the shim 64 contacts the upper pole piece, there is every possibility that foreign particles up to this size will escape. The operation of the valve in a closed loop servo system also tends to utilize the full available armature travel to free particles of dirt. The nozzles therefore have a self-cleaning feature.

It is also an important feature of my improved amplifier that because of the cylinders or caps arranged about the nozzles, the flow of hydraulic fluid through the motor chamber within the cover 40 is stopped so that magnetic dirt cannot adhere to vital motor areas. Also the provision of the magnetic trap formed by the passage 78 is an important feature in enabling the amplifier to operate continuously without being interrupted by the accumulation of magnetic foreign matter.

The construction described can be produced more economically and with less skilled labor than has been possible with devices of this nature which have heretofore been made. For example, it is not necessary with this construction that the two nozzles 47 be positioned exactly at the same level since a slight amount of difference in height of the two nozzles will do no harm since this will be readily compensated for by positioning the armature 39. On the other hand, with amplifiers of this type in which the nozzles are located at opposite sides of an armature, a clearance of nearly .001 of an inch must be equally provided between each nozzle and the armature in order to make the instrument operative.

It will of course be obvious that the hydraulic fluid used in connection with this instrument may be either of liquid or gaseous form.

It will be obvious that various changes in the details, materials and arrangements of parts which have been herein described and illustrated in order to explain the nature of the invention may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

I claim as my invention:

1. In an electro-hydraulic servo valve, a coil for receiving electric signals, an armature about which said coil extends for magnetizing said armature when a signal is received by said coil, said armature being in the form of a thin plate extending beyond the opposite ends of said coil, two pairs of magnetic poles of opposite polarity, one pair extending into close proximity to said armature beyond one end of said coil and the other pair extending into close proximity to said armature at the opposite end of said coil, fluid discharge nozzles terminating in close proximity to said armature at opposite ends of said coil and acting on the same face of said armature, means for resiliently locating the opposite ends of said armature normally in positions in which said armature is disposed in close proximity to both nozzles, said armature when magnetized by a signal in said coil swinging toward one of said magnetic poles and away from a nozzle, and means actuated by the difference in flow of fluid through said nozzles for amplifying the power developed by said coil.

2. In an electro-hydraulic servo valve including an armature, pole pieces acting on opposite faces of said armature, spring means holding said armature approximately midway of said pole pieces, an electric coil which may be energized to cause said armature to be attracted to one of said pole pieces, and a fluid discharge nozzle having its discharge end terminating in close proximity to said armature, that improvement which comprises a part extending about said nozzle in spaced relation thereto and forming a passage about said nozzle through which fluid discharged by said nozzle is directed, means

connecting with said space for withdrawing fluid from said space without coming in contact with said pole pieces, said part extending about said nozzle being rigidly secured in fixed relation to said nozzle and having its upper end closed, an aperture in said upper end, and a plug movable in said aperture and interposed between said nozzle and said armature.

3. An electro-hydraulic amplifier including a coil for receiving electric signals, an armature about which said coil extends for magnetizing said armature when a signal is received by said coil, said armature being in the form of a thin plate extending through said coil, magnetic members having poles of opposite polarity at opposite faces of said armature and in close proximity thereto, a fluid discharge nozzle arranged to discharge operating fluid at a rate controlled by the position of said armature, a cover enclosing a space about said pole pieces, said armature and said nozzle and formed to contain fluid at the pressure of that discharged from said nozzle, a part extending about said nozzle and spaced therefrom to form a passage for fluid discharged from said nozzle, and a chamber connected with said passage and terminating in said space for conducting fluid to said space, said chamber having one wall thereof formed by one of said magnetic members, whereby magnetic particles contained in the fluid passing through said chamber will become attached by magnetism to said magnetic members.

4. In an electro-hydraulic servo valve: a housing; a pair of fluid discharge nozzles mounted in said housing in spaced generally parallel relationship, said nozzles having pressure chambers therein connected with restricted passageways leading to a system source of fluid under pressure; means connected to said pressure chambers and responsive to the differential pressure between said chambers for controlling the operation of said valve; a pair of flow restriction baffles, one for each of said nozzles; means mounting said baffles in said housing adjacent the tips of said nozzles, said means including a resilient member holding said baffles in limited floating relationship to said tips for movement substantially towards and away from said tips and permitting simultaneous movement of said baffles in the same direction relative to said tips upon a change in the pressure of said system source; an electrical signal coil mounted in said housing; an elongated armature extending through said coil and adapted to be longitudinally polarized in accordance with the direction of signal current flow through said coil; two pairs of magnetic pole pieces mounted in said housing, each including poles of opposite polarity spaced apart at the end portions of said armature, the pole pieces of one polarity being arranged on one side of said armature and the pole pieces of opposite polarity being arranged on the opposite side of said armature, said armature being moved towards one pole at one end portion and towards the pole of opposite polarity at the other end portion when a signal is applied to said coil; and means rigidly interconnecting said baffles with said armature for movement in accordance with the movement of the end portions of said armature towards one of said nozzles and away from the other of said nozzles when a signal is applied to said coil.

5. In an electro-hydraulic servo valve: a housing; a pair of fluid discharge nozzles mounted in said housing in spaced relationship, said nozzles having pressure cham-

bers therein connected with restricted passageways leading to a system source of fluid under pressure; means connected to said pressure chambers and responsive to the differential pressure between said chambers for controlling the operation of said valve; a pair of flow restriction baffles, one for each of said nozzles; means mounting said baffles in said housing adjacent the tips of said nozzles, said means including a resilient member holding said baffles in limited floating relationship to said tips for movement substantially towards and away from said tips and permitting simultaneous movement of said baffles in the same direction relative to said tips upon a change in the pressure of said system source; and reversible motor means connected to said baffles and adapted to exert a couple tending to move one of said baffles towards its adjacent nozzle and the other of said baffles away from its adjacent nozzle when energized by an electrical signal.

6. In an electro-hydraulic servo valve having an electrical signal coil, an armature extending through said coil for movement in accordance with the signal on said coil, and a fluid discharge nozzle having its outer discharge end directed towards said armature: a part extending about said nozzle in spaced relationship thereto and defining a passageway therebetween for fluid discharged from said nozzle; return conduit means connected to said part and open to said passageway; a cap portion rigidly connected to the outer end of said part and closing towards said nozzle discharge end; and a plunger positioned between said armature and said nozzle discharge end for movement with said armature and freely movable through said cap portion, whereby fluid discharged from said nozzle impinges against said plunger and is directed outwardly into said cap portion.

7. In an electro-hydraulic servo valve having an electrical signal coil, an armature extending through said coil for movement in accordance with the signal on said coil, and a fluid discharge nozzle having its outer discharge end directed towards said armature: a sleeve extending about said nozzle in spaced relationship thereto and substantially coextensive with the discharge end thereof, said sleeve defining with said nozzle an annular passageway for fluid discharged from said nozzle; return conduit means connected to the inner end of said sleeve and open to said passageway; a cap portion rigidly connected to the outer end of said part and closing towards said nozzle discharge end; and a plunger positioned between said armature and said nozzle discharge end for movement with said armature, said plunger being in the form of a circular pin freely movable through said cap portion and having an end surface covering the opening in said nozzle discharge end and movable towards and away therefrom in accordance with the movement of said armature.

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FOREIGN PATENTS

390,550	Germany	Feb. 20, 1924
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