

[72] Inventor **Martyn V. Waddington**
West Seneca, N.Y.
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[73] Assignee **Moog Inc.**
East Aurora, N.Y.

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Primary Examiner—Alan Cohan
Attorney—Sommer, Weber & Gastel

[54] **DEFLECTABLE FREE JETSTREAM-TYPE TWO-STAGE SERVO VALVE**
9 Claims, 16 Drawing Figs.

[52] U.S. Cl..... 137/625.63,
137/625.64, 137/83
[51] Int. Cl..... F16k 11/00,
F15b 13/044
[50] Field of Search..... 137/83, 85,
625.62, 625.64, 625.63

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ABSTRACT: An easy to manufacture and service two-stage servo valve of the deflectable free jetstream-type is provided having a split body construction, part of which houses the second-stage or output valve spool which controls the flow of fluid through actuating ports with respect to supply and return ports, and the other part of which supports the jet deflector hydraulic amplifier and torque motor to constitute a separable first-stage assembly. Although there is mechanical force feedback between the valve spool and armature of the torque motor, the servo valve is so constructed that no feedback forces are transmitted through the jetstream deflector. This enables the deflector to be designed as a nonstructural element for ease of manufacture and made of a material having the desired physical characteristics such as one resistant to fluid erosion.

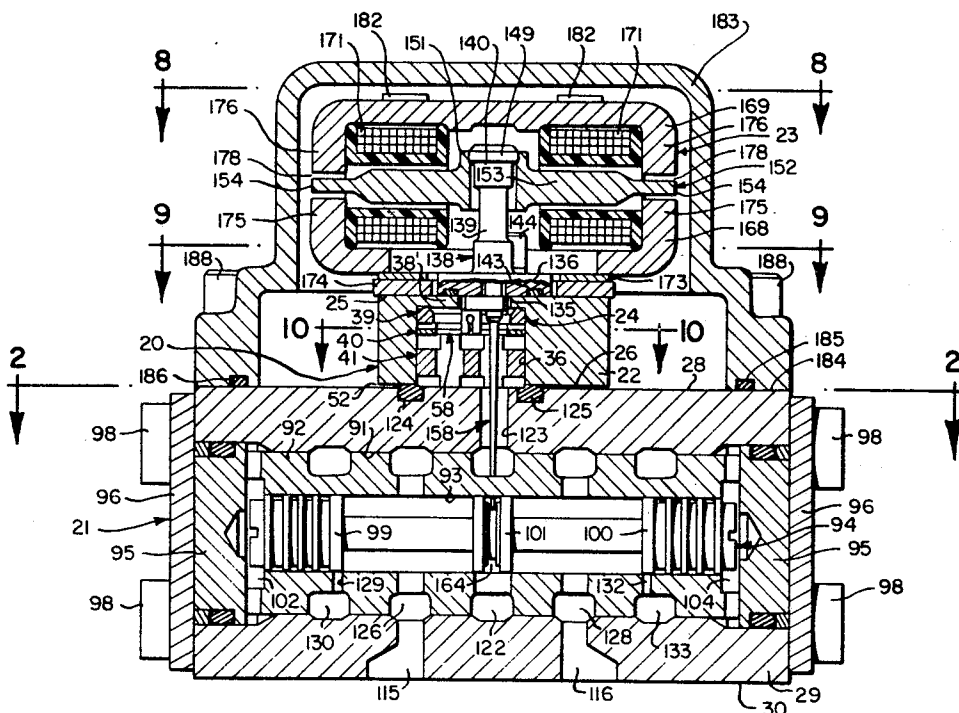


Fig. 1.

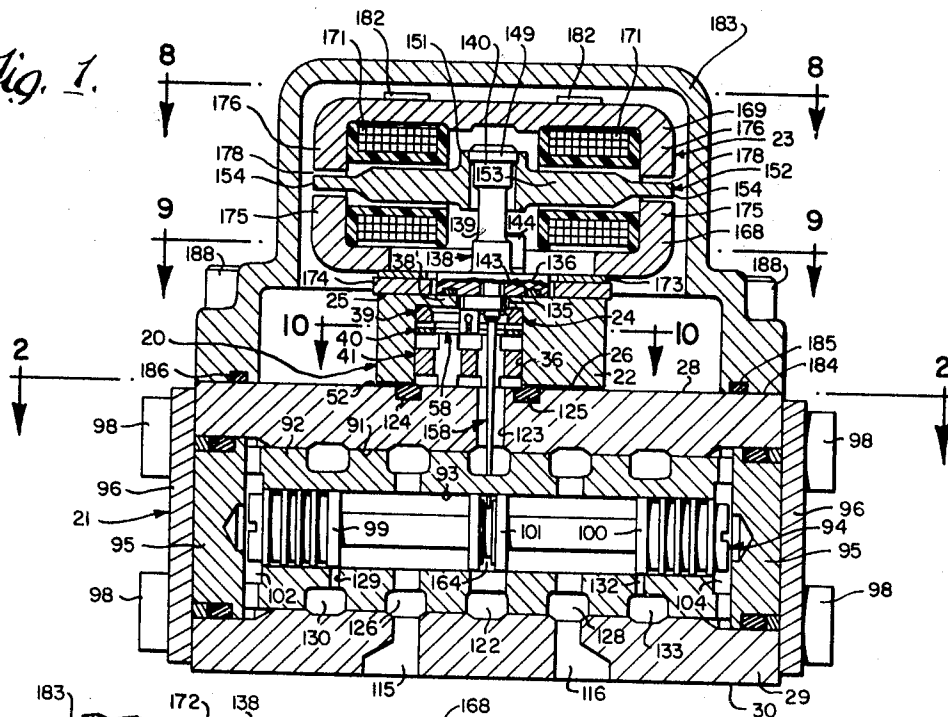


Fig. 3.

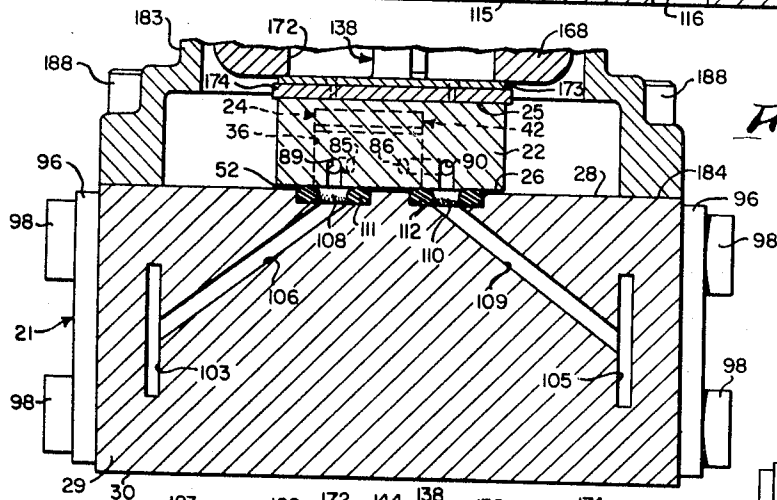


Fig. 2.

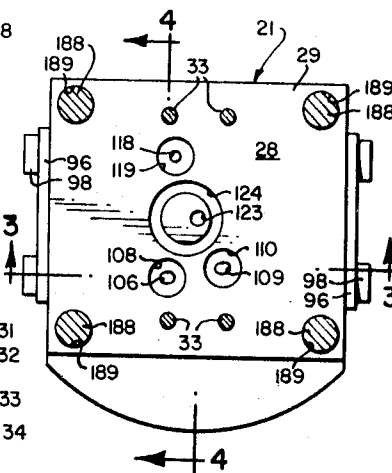
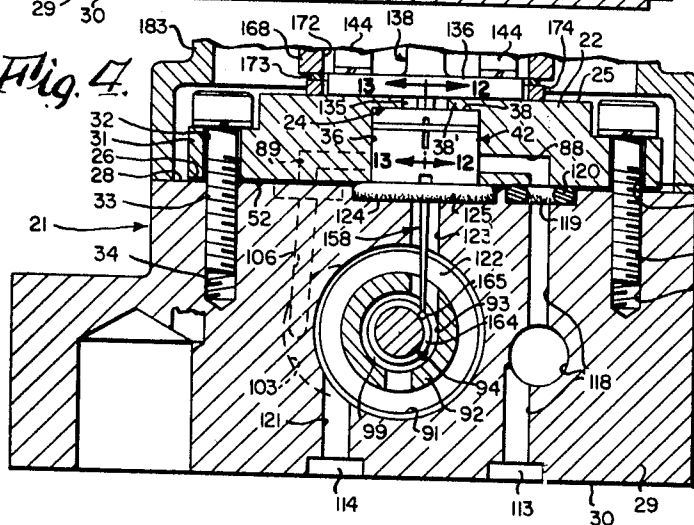


Fig. 4.



INVENTOR
 Martyn V. Waddington
 BY *Sommer & Weber*
 ATTORNEYS

Fig. 5.

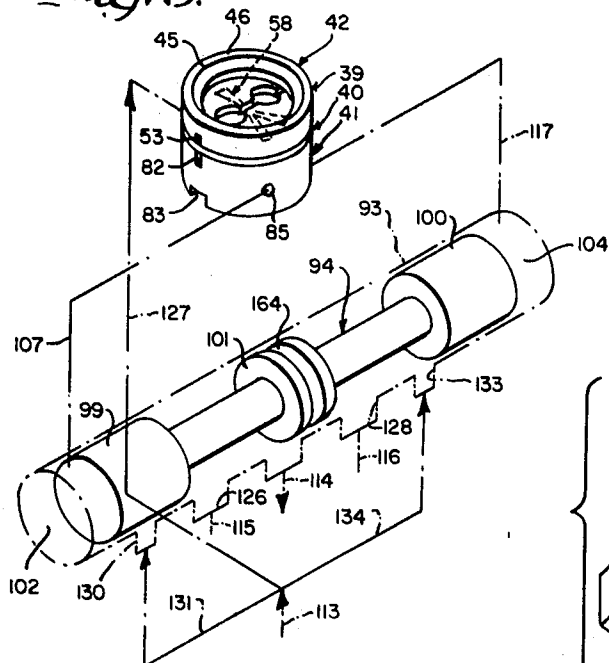


Fig. 7.

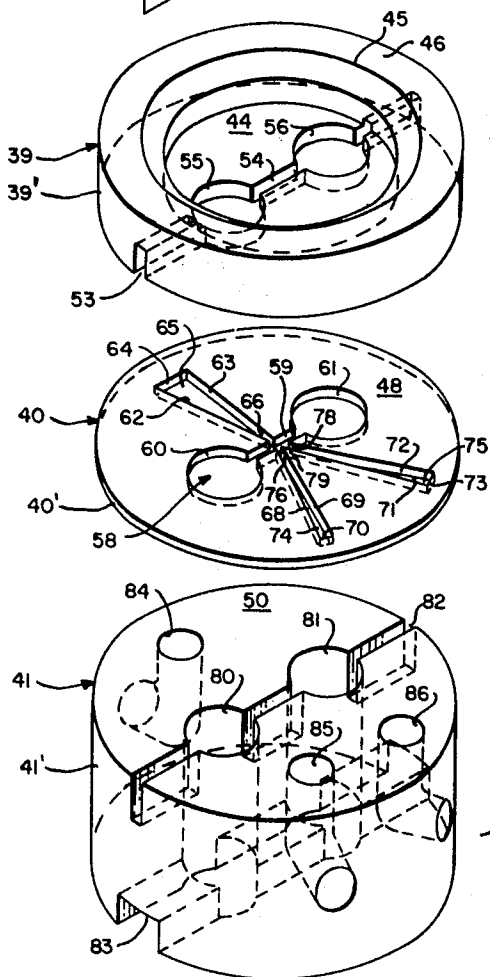
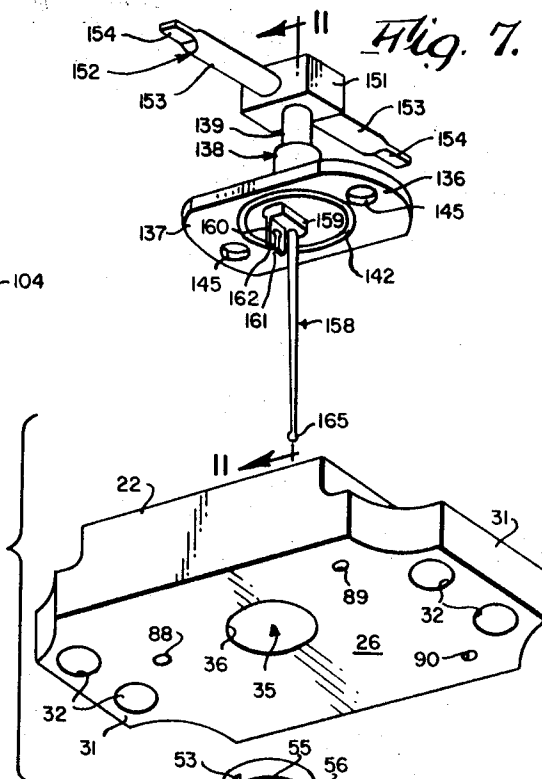


Fig. 6.

INVENTOR.

Martyn V. Waddington

BY

Sommer & Weber

ATTORNEYS

Fig. 8.

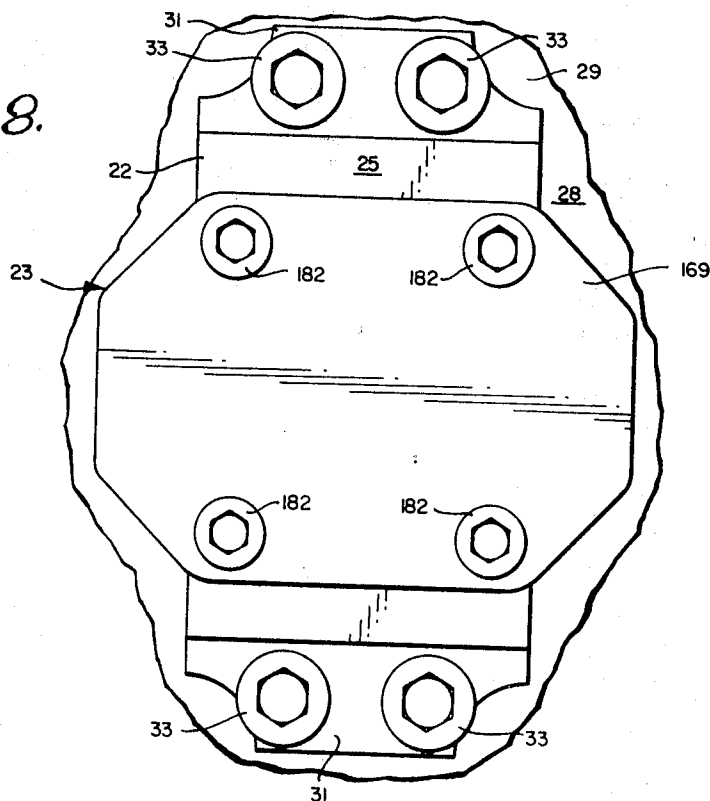
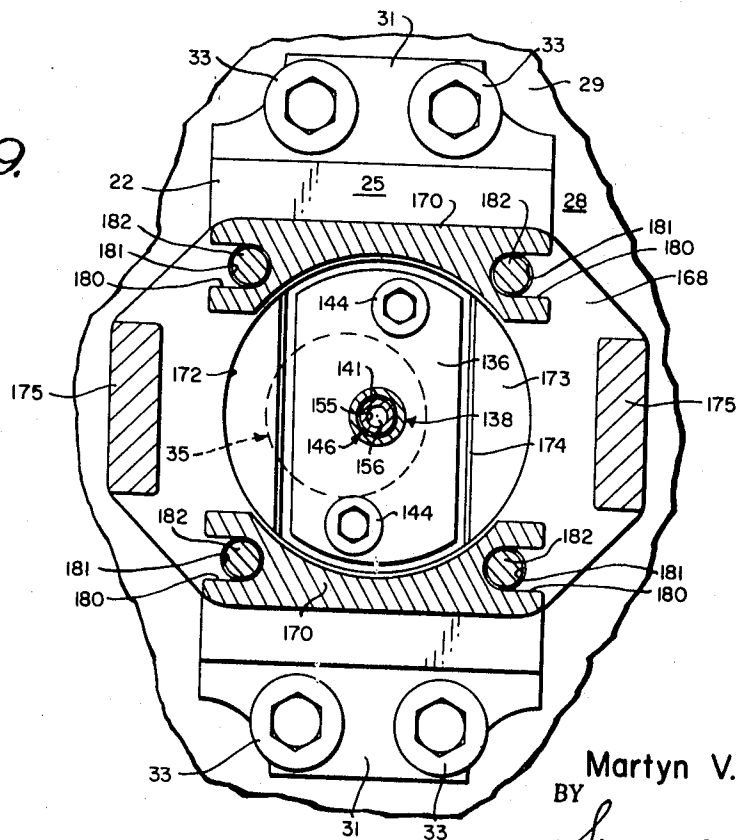
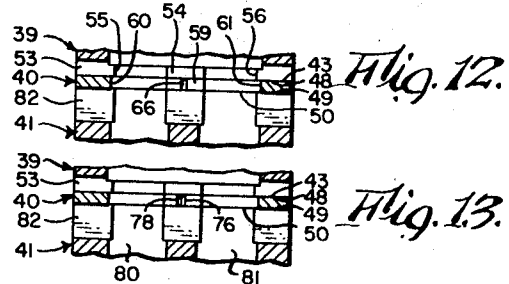
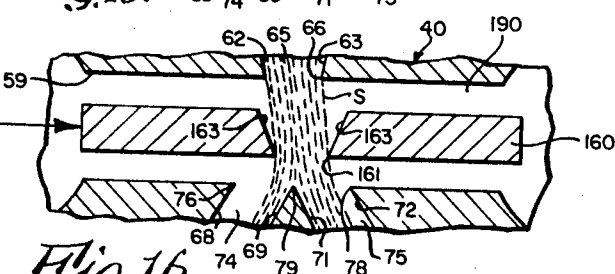
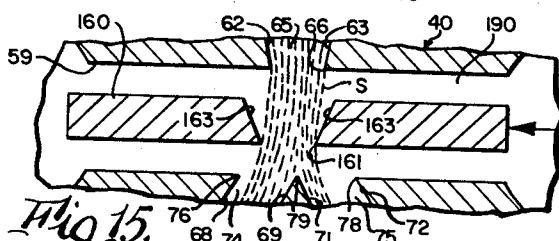
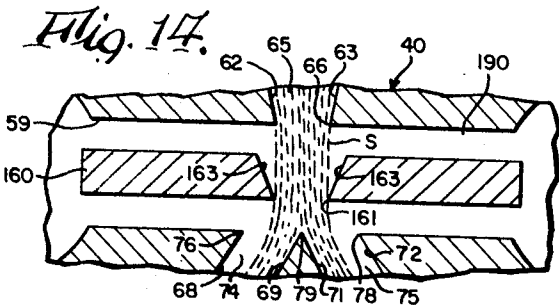
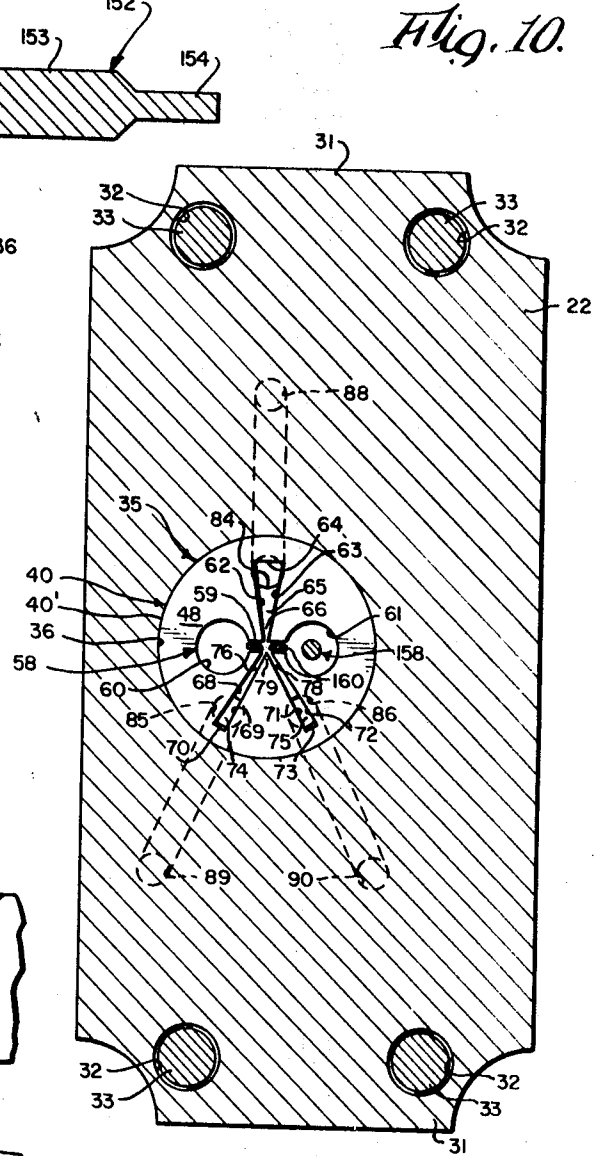
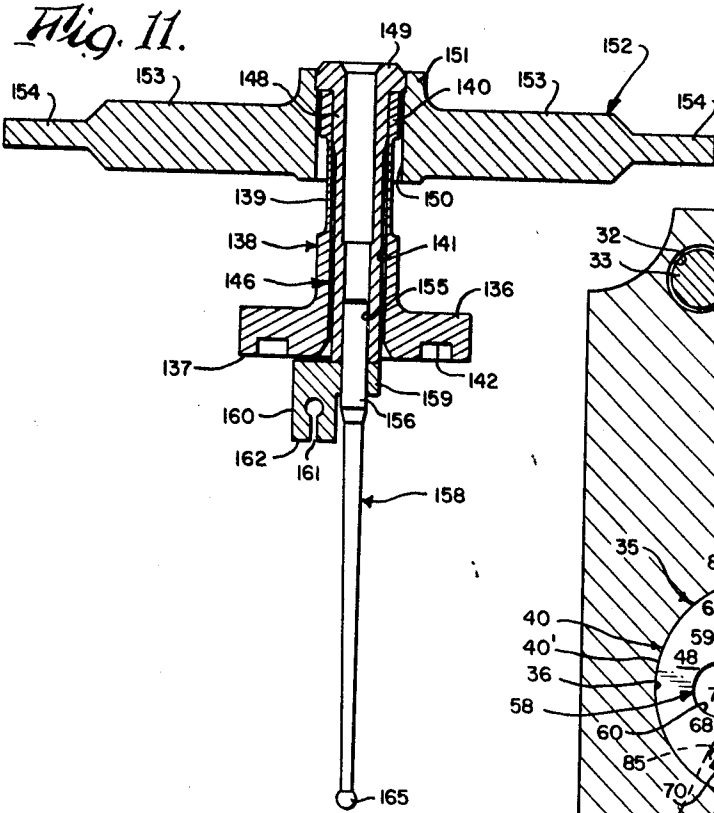


Fig. 9.



INVENTOR
Martyn V. Waddington
 BY *Sommer & Weber*
 ATTORNEYS



INVENTOR
 Martyn V. Waddington
 BY
Sommer & Weber
 ATTORNEYS

DEFLECTABLE FREE JETSTREAM-TYPE TWO-STAGE SERVO VALVE

BACKGROUND OF THE INVENTION

While deflectable free jetstream two-stage servo valves of the electrohydraulic type and having mechanical force feedback are known, the same as previously constructed were not fully satisfactory because relatively difficult and expensive to manufacture. For example, it is known to form the sidewalls of an ejector nozzle and receiver passages of the hydraulic amplifier in a single piece by forming an opening therethrough of proper configuration in order to achieve the advantage of a fixed geometry between the nozzle and passages. However, as heretofore practiced when covering such opening by end members to complete the top and bottom of the ejector nozzle and receiver passages, such end members were brazed to the intermediate member having the opening. This caused some of the brazing material to enter the opening and change the shape thereof. Also, the brazed material was corrodable by certain fluids that were handled by the servo valve.

As another example of a disadvantage of the prior art construction of such a servo valve, the jet deflector was formed as a web between a support and a feedback spring member so that the feedback forces had to be transmitted through the web element which because of this fact had to be designed sufficiently strong to withstand and transmit these forces. This resulted in needless massiveness for the jet deflector merely to be strong enough to transmit the feedback forces.

Further, the prior art servo valves of the type in question were not capable of being disassembled for servicing without destroying carefully adjusted orientation between various parts such as the stationary parts of the torque motor relative to the movable parts such as the armature and deflector.

SUMMARY OF THE INVENTION

The present invention relates to a deflectable free jetstream-type two-stage servo valve having mechanical force feedback which has an improved construction overcoming the aforementioned disadvantages of prior art valves of this same type.

More specifically, the inventive servo valve has the advantage of comprising a first-stage assembly separably from a second-stage assembly including a second-stage body. This first-stage assembly includes a first-stage body, deflector jet hydraulic amplifier means and also torque motor means all mounted on the first-stage body, and means securing the bodies together including removable fasteners. Such an arrangement allows ready disassembly so that the first-stage assembly can be separated from the second-stage assembly by removing the fasteners. This facilitates servicing in that the second-stage spool and bushing can be removed from the second-stage body for cleaning or replacement without disturbing the torque motor setup.

Another advantage of the inventive servo valve is that the deflector jet hydraulic amplifier means are so constructed that brazing of the various members is eliminated. Instead, these members are press-fitted into a recess provided in the first-stage body. This manner of mounting these members on such body not only eliminates the brazing heretofore required between such members, but also eliminates the need for special sealing means such as O-rings for sealing the opposing ends of fluid conducting communication conduits in the body and one of the members. Still further, secondary retention of the press-fitted assembly of members is provided by the manner of mounting the first-stage body on the second-stage body.

A further advantage of the inventive servo valve is that the jet deflector is provided as an offset element on the member supporting the same and one end of the feedback spring member, whereby the deflector can be a relatively thin-slotted nonstructural member so that no feedback loads are transmitted through the deflector. The provision of such an open-ended slot rather than a window-type opening closed on all

sides makes the deflector more readily machinable, especially when constructed of a material which is difficult to machine.

Another advantage of the inventive servo valve is that the jet deflector is constructed as a separate member the material of construction for which can be selected solely for its desirable attributes such as minimizing wear from fluid erosion. In this connection, many of the fluids handled by a valve of the type in question unavoidably contain abrasive particles which cause mechanical erosion when the fluid containing such particles impinges against a surface. Another advantage of having such jet deflector made as a separate part is that it can be readily replaced when worn excessively.

Other advantages of the present invention will be apparent from the following description of a preferred embodiment illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical substantially central longitudinal sectional view through a servo valve embodying a preferred form of the present invention.

FIG. 2 is a horizontal sectional view thereof on a reduced scale taken on line 2—2 of FIG. 1.

FIG. 3 is a fragmentary enlarged vertical longitudinal sectional view thereof taken on line 3—3 of FIG. 2.

FIG. 4 is a fragmentary vertical transverse sectional view thereof taken on line 4—4 of FIG. 2.

FIG. 5 is an exploded perspective view of the sandwiched members of the jet deflector hydraulic amplifier subassembly and the output stage valve spool, and showing schematically the relationship therebetween.

FIG. 6 is an exploded perspective view of the aforementioned members of the jet deflector hydraulic amplifier subassembly.

FIG. 7 is an enlarged exploded perspective view of part of the first-stage assembly including the first-stage body and jet deflector hydraulic amplifier and only the armature part of the torque motor.

FIG. 8 is a fragmentary enlarged horizontal sectional view of the servo valve shown in FIG. 1, this view being taken on line 8—8 thereof, and showing a top plan view of the upper plate piece of the torque motor.

FIG. 9 is a fragmentary enlarged horizontal sectional view of the servo valve as shown in FIG. 9, this view being taken on line 9—9 thereof, and showing partly in section and partly in elevation the lower pole piece of the torque motor and other related parts.

FIG. 10 is an enlarged horizontal sectional view of the first-stage assembly body of the servo valve shown in FIG. 1, this view being taken on line 10—10 thereof.

FIG. 11 is a vertical center sectional view of part of the first-stage assembly, and showing the torque motor armature, flexure tube, jet deflector and feedback spring members.

FIG. 12 is a fragmentary vertical sectional view of the first-stage assembly taken on line 12—12 of FIG. 4, and showing the discharge orifice of the ejector nozzle formed by the sandwich of members mounted on the first-stage body.

FIG. 13 is a similar fragmentary vertical sectional view but showing the entrance ports to the receiver passages, this view being taken on line 13—13 of FIG. 4.

FIG. 14 is a fragmentary enlarged horizontal sectional view of the jet deflector fluid amplifier, and depicting the flow of a free fluid jetstream from the fixed ejector nozzle toward and into fixed receiver passages and through the slotted opening in a movable deflector when the latter is in a null position as a result of no input control signal to the torque motor, such deflector being arranged for movement transversely of the direction of flow of the free fluid jetstream.

FIG. 15 is a view similar to FIG. 14 but illustrating the condition of the free fluid jetstream with respect to the receiver passages when an input control signal to the torque motor for the jet deflector causes the same to move transversely to the left.

FIG. 16 is a view similar to FIG. 15 but depicting the position of the jet deflector displaced transversely to the right in response to the different input control signal to the torque motor and showing a different relationship of the free fluid jet-stream with respect to the receiver passages.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The two-stage electrohydraulic servo valve embodying the present invention is shown as including a first-stage assembly represented generally by the numeral 20 and a second-stage assembly represented generally by the numeral 21. The first-stage assembly comprises a body 22, a torque motor represented generally by the numeral 23 mounted on such body, and a jet deflector hydraulic amplifier represented generally by the numeral 24 also mounted on such body.

The first-stage body 22 has upper and lower flat parallel surfaces 25 and 26, respectively. Lower surface 26 opposes and is spaced slightly above an upper flat surface 28 on second-stage body 29 which also has a lower flat surface 30 parallel to this upper surface. Body 22 is an elongated rectangular block which at each of its opposite ends has an integral outwardly extending attaching flange 31 provided with a pair of vertical holes 32, 32 through which fasteners such as screws 33, 33 extend. The shank of each of these screws is received in an internally threaded recess 34 provided in body 29 as shown in FIG. 4.

First-stage body 22 is provided with a cylindrical recess 35 leading upwardly from lower surface 26 with its axis perpendicular thereto, this recess having a cylindrical sidewall 36 and an end wall 38. Arranged in this recess are three superimposed members 39, 40 and 41 which constitute a subassembly of a jet deflector hydraulic amplifier, this subassembly being represented generally by the numeral 42 (FIG. 5). Each of these members 39-41 has a cylindrical periphery 39', 40' and 41' respectively, dimensioned in relation to cylindrical recess wall 36 that only lower end member 41 is press-fitted on this wall. Upper end member 39 is a plate having a lower flat surface 43, a recessed upper central surface 44 and an annular marginal reinforcing integral rib 45 upstanding from surface 44 and having an upper frustoconical surface 46 having a cone angle typically of about 5° with respect to the plane of lower surface 43. Surface 46 is lower at periphery 39' than at inner edge of this surface. Intermediate member 40 is a relatively thin disc having upper and lower flat parallel surfaces 48 and 49, respectively. Lower end member 41 is a cylindrical block having upper and lower flat parallel surfaces 50 and 51, respectively.

When members 39-41 are arranged in recess 35, upper surface 46 of the upper end member engages recess end face 38, the opposing surfaces 43 and 48 of the upper and intermediate members engage, and the opposing surfaces 49 and 50 engage. Lower surface 51 of lower end member 41 engages upper surface 28 on second-stage body 29. Lower end member 41 when press-fitted into recess 35 compressively loads members 39-41 transversely of their contacting faces 43, 48 and 49, 50. This forces frustoconical surface 46 against recess end face 38 which defines with upper surface 25 of body 22 a relatively thin web 38' of body material which acts as a spring to maintain the aforementioned compressive loading. This arrangement maintains such a spring loading even during dimensional changes of members 39-41 relative to body 22 due to varying thermal conditions, considering this body is made of aluminum and these members of steel and therefore have different coefficients of thermal expansion.

The vertical extent of these so sandwiched members 39-41 when arranged in recess 35 is such that it is slightly greater than the depth of this recess as measured axially between end wall 38 and surface 26 whereby lower surface 51 of lower end member 41 projects slightly outwardly beyond lower surface 26 on body 22. This leaves a slight clearance between surfaces 28 and 26 as indicated at 52. It will be seen that when fasteners 33 are tightened to drawn first-stage body 22

downwardly toward second-stage body 29 the sandwich of members 39-41 is clamped between recess end face 38 and body upper surface 28. This presses the various opposing and contacting surfaces of members 39-41, such as surfaces 43, 48 and 49, 50 firmly and sealingly together, thereby providing a secondary retention of subassembly 42 in recess 35. The primary retention of subassembly 42 is due to the press-fit of lower end member 41 in recess 35.

Referring to FIGS. 6 and 7, upper end member 39 is shown as horizontally traversed by a flat and parallel sided diametral groove 53 in lower surface 43 which has a depth greater than the spacing between surfaces 43 and 44 so as to form a slot 54 between these surfaces. This slot 54 near its opposite ends is intercepted by a pair of enlarged vertical cylindrical holes 55 and 56.

Intermediate member 40 is shown as having extending vertically therethrough an opening represented generally by the numeral 58. This opening has a central straight flat and parallel sided slot 59, the opposite ends of which terminate in enlarged vertical cylindrical holes 60 and 61. Slot 59 is shown as intercepted on one side by the closely spaced inner ends of a pair of convergent vertical flat sidewalls 62 and 63. A transverse end wall 64 closes the widely spaced outer ends of these sidewalls. Walls 62 and 63 are covered top and bottom by surfaces 43 and 50 jointly providing an ejector nozzle 65 having a discharge orifice 66.

The other side of slot 59 is shown as intercepted by the closely spaced inner ends of a first pair of convergent vertical flat sidewalls 68 and 69. A transverse end wall 7 closes the widely spaced outer ends of these sidewalls. On the same side slot 59 is also intercepted by a second pair of convergent vertical flat sidewalls 71 and 72, closed at their outer ends by a transverse end wall 73. Walls 69-70 and 71-73 are covered top and bottom by surfaces 43 and 50 jointly providing a pair of receiver passages 74 and 75 having entrance ports 76 and 78, respectively. Adjacent walls 69 and 71 of the receiver passages 74 and 75 join together to form a vertical apex ridge 79 which is disposed centrally with respect to the opposing discharge orifice 66 of ejector nozzle 65.

The advantage of forming intermediate member 40 as a one-piece element is that the geometry of the ejector nozzle 65 and receiver passage 74 and 75, insofar as their sidewall configurations are concerned, can be formed in one pass by electrical discharge machining. This permits inspection and test of the nozzle and receiver passages prior to installation in a servo valve. Also, there is the advantage of permitting a wide selection of materials for the intermediate member 40, as materials are not restricted to those that are easily machined. This permits the use of materials that exhibit low wear from fluid erosion such as stellite, tungsten carbide, and ceramic.

Lower end member 41 is shown as being thicker than either intermediate member 40 or upper end member 39 and has a pair of vertical cylindrical through holes 80 and 81 intercepted at their upper ends by a transverse horizontal flat and parallel sided diametral groove 82 and at their lower ends by a wider transverse horizontal flat and parallel sided diametral groove 83. Slots 82 and 83 are vertically aligned.

When members 39-41 are assembled, their cylindrical holes 55, 60, 80 register as do also the other cylindrical holes 56, 61, 81. Slots 54, 59 and groove 82 also are in vertical alignment.

Lower end member 41 is also shown as having an elbow-shaped supply conduit 84 terminating at its upper end in surface 50 and at its lower end in periphery 41'. On the opposite side of slot 82, member 41 has a pair of elbow-shaped conduits 85 and 86 severally termination at their upper ends in surface 50 and at their lower ends in periphery 41'. The upper ends of conduits 84-86 communicate with nozzle 65 and receiver passages 74 and 75, respectively, as depicted in FIG. 10.

As shown in FIG. 4, first-stage body 22 has an elbow-shaped conduit 88 one end of which terminates in the cylindrical wall 36 of recess 35 opposite the lower end of elbow-shaped conduit 84 in lower end member 50, and the other end of which terminates in lower surface 26 of this body. As best shown in

FIG. 3, body 22 is also provided with two additional elbow-shaped conduits 89 and 90 severally terminating at one end in cylindrical wall 36 of recess 35 and at their other ends in lower surface 26 of this body. Conduits 89 and 90 are arranged circumferentially spaced from each other.

The hydraulic amplifier subassembly 42 is retained in body recess 35 primarily by the press-fit of its member 39-41 on recess wall 36. This has the advantage of eliminating brazed joints between these members. There is the added advantage, in the case of lower end member 41, of eliminating the need for special seal means such as O-rings across the joints between communication conduits 84, 88 or 85, 89 or 86, 90.

Referring to FIGS. 1, 3 and 4, second-stage body 29 is shown as provided with a horizontal hole 91 extending therethrough in which valve bushing 92 is arranged. This bushing in turn has a horizontal cylindrical bore 93 in which a valve spool represented generally by the numeral 94 is slidably arranged. The opposite ends of body hole 91 are shown as being slightly enlarged to receive severally a seal plug 95 retained in position by a plate 96 fastened to body 29 by a plurality of screws 98.

Valve spool 94 is shown as having two end lobes 99, 100 and an intermediate or central lobe 101. The space between left end plug 95 and left spool land 99 provides a spool end chamber 102 which communicates with an arcuate recess 103 formed in body 29. At the opposite end of the spool, the right end land 100 and the right plug 95 provide a right spool end chamber 104 which communicated with an arcuate recess 105 formed in body 29.

As shown in FIG. 3, recess 103 communicates with one end of the conduit 106 formed in body 29 the opposite end of which leads to an communicates with a cylindrical recess 108 in upper surface 28 of this body. Recess 108 communicates with conduit 89. The other recess 105 is shown as communicating with one end of another conduit 109 formed in body 29 the opposite end of which leads to an communicates with another cylindrical recess 110 provided in upper surface 28. Recess 110 communicates with conduit 90. Arranged in recess 108 is an annular seal such as an O-ring 111 which sealingly engages lower surface 26 of body 22 and surrounds the lower end of conduit 89. In this manner this conduit 89 is placed in fluid conducting communication through recess 108, conduit 106 and recess 103, with left spool end chamber 102. This course of communication is represented schematically by line 107 in FIG. 5. Arranged in the other cylindrical recess 110 is another annular seal such as an O-ring 112 which sealingly engages lower surface 26 of body 22 and surrounds the lower end of conduit 90. Thus, conduit 90 is placed in fluid conducting communication with right spool end chamber 104 via recess 110, conduit 109 and recess 105. This course of communication is represented schematically by line 117 in FIG. 5.

A pressure port 113, return port 114 and two actuating ports 115 and 116 are arranged in lower surface 30 of body 29, as shown in FIGS. 1 and 4. Pressure port 113 communicates via a substantially vertical conduit 118 with a cylindrical recess 119 provided in upper surface 28 of body 29. An annular seal ring such as an O-ring 120 is arranged in the recess and surrounds the lower end of conduit 88 in first-stage body 22. In this manner, conduit 88 is placed in fluid conducting communication with pressure port 113 via recess 119 and conduit 118. This course of communication is represented schematically by line 127 in FIG. 5.

Return ports 114 is shown as communicating with the lower end of a vertical conduit 121, the upper end of which communicates with an annular recess 122 formed jointly by hole 91 in body 29 and bushing 92. This manner recess in turn communicates with the lower end of a vertical hole 123 which leads to an terminates in upper surface 28 of body 29. Eccentrically arranged with respect to this vertical hole 123 is a circular groove 124 recessed in upper surface 28 of body 29. This groove partially overlaps the lower open end of cylindrical recess 35 in first-stage body 22. Arranged in this groove and

partially engaged by lower surface 26 of body 22 adjacent the mouth of cylindrical recess 35, is an annular seal such as an O-ring 125. This O-ring sealingly engage opposing surfaces 26 and 28 when screw 33 are tightened to prevent leakage outwardly through the slight clearance 52 that exists between these surfaces.

Left actuating port 115 is shown as communicating via communicating passages collectively represented by the numeral 126 with the portion of bore 93 between left hand 99 and center land 101. Right actuating port is similarly shown as communicating via collective passages 128 with the portion of bore 93 between right land 100 and center land 101.

The inner axially facing end face of left land 99 is shown as disposed adjacent one side of a flat-sided metering port 129 arranged in bushing 92. This port extends radially and communicates with an annular space 130 suitably serviced by pressurized fluid supplied through pressure port 113, as represented schematically by line 131 in FIG. 5. Adjacent the axially facing inner end face of right land 100 is a metering port 132 provided in bushing 92 which communicates with an annular space 133 suitably serviced by pressurized fluid supplied by pressure port 113, as represented schematically by line 134 in FIG. 5.

First-stage body 22 is shown as having a vertical hole 135 extending between upper surface 25 and recess end face 38. Covering this hole is an annular vertically thickened attaching flange 136 of a flexure tube member represented generally by the numeral 138 which also includes an upright thin-walled cylindrical flexible section 139, a thickened collar 140 at the upper end thereof and a vertical through bore 141. The bottom flat surface 137 of this attaching flange 136 is shown as having an annular groove 142 to accommodate an annular seal such as an O-ring 143 which sealingly bears against upper surface 25 of first-stage body 22. This attaching flange is secured by a pair of diametrically opposed screws 144, 144 to body 22, the shanks of these screws severally extending through holes 145, 145 provided in this flange and received in threaded recesses provided in this body.

As shown in FIG. 11, a tubular deflector support member represented generally by the numeral 146 comprises a thickened plug section 148 adjacent its upper end and an out-turned annular flange 149 at its upper extremity. This flange seats on the upper end of collar 140 and plug section 148 is inserted in this collar, being suitably sealed thereto. The periphery of flange 149 is arranged in and is suitably sealed to the wall of a vertical hole 150 in the central part 151 of a horizontally disposed armature member represented generally by the numeral 152. This armature member has laterally extending wing parts 153, 153 on opposite sides of the central part 151 individually terminating at its outer end in a flattened tip 154.

Inasmuch as tubular deflector support member 146 is rigidly connected to armature member 152 and is arranged with its elongated axis at right angles thereto, this deflector support member acts as an arm for the armature. These members 146 and 152 pivot together as a unit by flexing of thin-walled section 139. The lower end of member 146 has a cylindrical socket 155 into which a cylindrical axial extension 156 is sealingly press-fitted. Extension 156 is shown as being a cylindrical plug portion formed integrally on the upper end of a vertically elongated feedback spring member represented generally by the numeral 158 and thereby cantilever-mounts the upper end of the vertically disposed feedback spring member. A portion of the lower part of the plug portion 156 of the feedback spring member 158 extends downwardly below the lower end of tubular deflector support member 146. On this exposed lower portion is press-fitted a lateral extension part 159. Depending from this lateral extension part and offset laterally with respect to feedback spring member is a jet deflector 160. This jet deflector is in the form of a relatively thin plate, vertically disposed and having a slotted opening 161 which extends upwardly from the lower edge 162 of this plate for substantially the full height of the jet deflector.

Deflector 160 is arranged at least partially within slots 54 and 59 of the hydraulic amplifier subassembly 42. On the side of this deflector facing the discharge orifice 66 of ejector nozzle 65, the deflector opening 161 is provided with inclined sidewalls 163, 163 which are convergently directed toward apex ridge 79 between the entrance ports 76, 78 of the receiver passages 74, 75. This jet deflector opening 161 is adapted to receive the entire free jetstream S discharged from the ejector nozzle and directed toward the receiver passages, as depicted in FIGS. 14-16.

The advantages of making lateral extension 159 and deflector 160 as a one-piece part and separate from support member 146 are that this part can be made of the desired fluid erosion resistant material, such as one of those previously mentioned, can be machined more easily especially with the provision of open-ended slot 161, and can be replaced if worn. As already noted, deflector 160 is a nonstructural element and therefore can be made small which leads to a reduction in size of the hydraulic amplifier members 39-41.

Referring to FIGS. 1 and 4, lateral extension part 159 of deflector support member 146 is movably arranged in hole 135 in first-stage body 22. Feedback spring member 158 is shown as extending downwardly through the registering enlarged cylindrical holes 56, 61 and 81, and thereby extends completely through the hydraulic amplifier subassembly 42. This feedback spring member continues to extend downwardly through enlarged hole 123 in second-stage body 29 and generally tangentially into an annular groove 164 provided in central land 101 on valve spool 94. The lower end of this feedback spring member preferably is formed with an integral ball 165 which has a substantially frictionless rolling contact on the sidewalls which define groove 164. In this manner, the lower end of this feedback spring member is constrained to move with valve spool 94 as it moves axially within stationary bushing 92.

Armature member 152 is a part of the torque motor 23 which also includes a lower pole piece 168, an upper pole piece 169, a pair of permanent magnets 170, 170 and a pair of coils 171, 171. As shown in FIG. 9, lower pole piece 168 is ring-shaped member having a central vertical hole 172 extending therethrough which surrounds flexure tube member 138. This lower pole piece is shown as supported in a slightly elevated position, substantially the vertical thickness of the attaching flange 136 of flexure tube member 138, by a pair of superimposed ring-shaped shims 173 and 174 arranged on upper surface 25 of first-stage body 22.

Lower pole piece 168 has lateral extensions terminating in upturned elements 175, 175 which are spaced from and opposed to similar downturned elements 176, 176 formed integrally on upper pole piece 169. These spaces form airgaps 178, 178 in which armature tips 154 are movably arranged. Permanent magnet members 170 are arranged between pole pieces 168, 169 and each has a semicylindrical recess 180 at opposite ends which registers with a hole 181 provided in the upper and lower pole pieces, four such holes 181 being shown in lower pole piece in FIG. 9. In each such hole is disposed a fastener such as a screw 182 the shank of which extends downwardly through these aligned holes and the recesses in the permanent magnets, the lower end portions of these shanks being received in threaded recesses provided on first-stage body 22 as depicted in FIG. 2. Surrounding each armature wing 153 is a coil 171 which is also clamped in position by the screws 182 which hold the assembly of pole pieces and permanent magnets together.

A cap 183 is shown as covering the first-stage assembly 20. This cap has a flat lower edge 184 provided with a continuous annular groove 185 in which an annular seal such as an O-ring 186 is arranged which sealingly engages upper surface 28 of second-stage body 29. A series of fasteners such as screws 188, four being shown, one at each corner, removably secures the cap to this body. These screws severally extend through holes provided in attaching flanges at the corners of the cap and have their threaded shanks screwed into internally threaded recesses 189 provided in body 29.

It will be seen that by first removing screws 188, then removing cap 183 and thereafter removing screws 33, the first-stage assembly 20 can be removed as a unit, the lower end portion of the feedback spring member being raised out of spool groove 164 and through vertical hole 123. Thereafter, screws 98 holding end caps 96 in position on body 29 can be removed, the seal plugs 95 removed, and the bushing 92 and valve spool 94 removed for cleaning or replacement. Following such servicing the second-stage assembly can be reassembled and joined to the first-stage assembly by reversing the procedure just described.

During such removal and replacement of the first-stage assembly 20, it will be noted that there was no change in the relative orientation of parts of the torque motor 23 relative to one another or to the flexure tube member 138, or this member relative to the first-stage body 22, or the jet deflector hydraulic amplifier subassembly 42 relative to this body.

OPERATION

Assuming no signal input to torque motor 23, deflector 160 is in a centered or null position with respect to the discharge orifice 66 of ejector nozzle 65. The free jetstream S flowing across space 190 formed jointly by slots 54 and 59 will be split evenly by apex ridge 79 to provide equal pressures in receiver passages 74 and 75, as depicted in FIG. 14.

Assuming now that an electrical signal is put into the coils 171 of torque motor 23, as well understood by those skilled in the art, of such a magnitude and sense so as to cause armature member 152 to pivot in a clockwise direction as viewed in FIG. 1, the jet deflector will be shifted to the left, as depicted in FIG. 15. This causes more of the free jetstream S to be directed toward receiver passage 74 than the other receiver passage 75. As a consequence, a pressure differential between these passages is established which is applied via lines 107, 117 (FIG. 5) to the ends of the valve spool 94, the higher pressure being in left spool end chamber 102 and causes the valve spool to shift from its null position depicted in FIG. 1 rightwardly. This will establish communication via line 134 (FIG. 5) between pressure port 113 and right actuating port 116, and left actuating port 115 will be vented to return port 114.

Assuming now that a signal is put into torque motor 23 of such a magnitude and sense as to cause the jet deflector 160 to shift from its null position to the right, as viewed in FIG. 1 and depicted in FIG. 16, it will be seen that more of the free jetstream S is directed to flow into receiver passage 75 than into receiver passage 74. A pressure differential is developed in spool end chambers with the dominant pressure in right spool end chamber 104 as compared to left spool end chamber 102. This causes valve spool 94 to shift to the left as viewed in FIG. 1. This will establish communication via line 131 (FIG. 5) between pressure port 113 and left actuating port 115, and right actuating port 116 will be vented to return port 114.

During such axial displacement of valve spool 94, the lower end of the feedback spring member 158 moves therewith to flex this member causing a force to be fed back to the armature to balance the force induced by the electrical input to torque motor 23, returning the armature member 152 to a centered position and thereby jet deflector 160 to a centered position. In this manner, the valve can continue to control a predetermined rate of flow with respect to actuating ports even though the armature and deflector are in their centered positions. When the signal input is terminated, feedback spring member 158 will return valve spool 94 to a null position, as understood by those skilled.

What is claimed is:

1. In a deflectable free jetstream type two-stage servovalve having a second-stage assembly including a second-stage body having fluid pressure, return and actuating ports, the improvement which comprises a separable first-stage assembly including a first-stage body having a first surface and a recess in said first surface provided by a cylindrical wall, deflector jet hydraulic amplifier means mounted on said first-stage body

and torque motor means mounted on said first-stage body and operatively associated with said hydraulic amplifier means, and means securing said bodies together including removable fasteners, said deflector jet hydraulic amplifier means including two end members and an intermediate member superimposed upon one another and arranged in said recess, that one of said members adjacent said first surface having a cylindrical periphery press-fitted on said wall, the intermediate one of said members having an opening extending therethrough covered on one side by said one of said end members and on the other side by the other of said end members, said opening being shaped to provide in conjunction with the covering afforded by said end members a fixed ejector nozzle having a discharge orifice and a pair of fixed receiver passages having entrance ports opposite to and spaced from said orifice, said bodies and said one of said end members having conduits therein for communicatively connecting said nozzle upstream of its said orifice with said pressure port and further having conduits communicatively connected to said receiver passages downstream of their said entrance ports and operatively associated with said actuating ports and still further having conduits communicatively connecting the space between said orifice and entrance ports with said return port, whereby said nozzle is arranged to discharge a free jetstream of fluid across said space toward said receiver passages, said deflector jet hydraulic amplifier means also including a deflector arranged at least partly in said space to deflect said stream relative to said entrance ports and operatively associated with said torque motor means so as to be movably responsive thereto.

2. A servovalve according to claim 1 wherein said second-stage body has a second surface, said first-stage body is arranged relative to said second-stage body such that said first surface is opposite and spaced from said second surface, said first-stage body has an end face at the inner end of said recess, said other of said end members engages said end face, said one of said end members protrudes from said recess beyond said first surface and engages said second surface, and said fasteners when tightened clamp the superimposed members between said end face and second surface.

3. A servovalve according to claim 2 wherein said first-stage body has another surface which defines with said end face a spring element to maintain the compressive loading on said members even during dimensional changes of said members

relative to said first-stage body due to varying thermal conditions.

4. In a deflectable free jetstream type two-stage servovalve having a first stage assembly including a first-stage body, torque motor means mounted on said first-stage body and including an armature, and hydraulic amplifier means mounted on said first-stage body and including a free jetstream deflector movable with said armature and in response to a signal input to said torque motor means, a second-stage assembly including a second-stage body and an output valve slide arranged in said second-stage body and movable in response to the movement of said deflector, and mechanical force feedback means operatively interposed between said deflector and valve slide including a feedback spring member, the improvement which comprises means providing said deflector as an offset element on a deflector support member movable with said armature and having an opening receiving said stream, said feedback spring member being elongated and having one end cantilever-mounted on said deflector support member and also having its other end constrained to move with said valve slide.

5. A servovalve according to claim 4 wherein said deflector is an element separate from said deflector support member and is rigidly attached thereto.

6. A servovalve according to claim 5 wherein said deflector is a plate having a slot therein leading to one edge thereof and providing the stream receiving opening.

7. A servovalve according to claim 4 further comprising a flexure tube member partially surrounding said deflector support member and at one end supporting the same and said armature and at its other end having an attaching flange secured to said first-stage body.

8. A servovalve according to claim 4 wherein said torque motor means including pole pieces separated by permanent magnets and fasteners securing said pole pieces to said first-stage body and clamping said permanent magnets therebetween.

9. A servovalve according to claim 7 wherein said torque motor means includes pole pieces separated by permanent magnets, one of said pole pieces being ring-shaped and surrounding said flexure tube member, and fasteners securing said pole pieces to said first-stage body and clamping said permanent magnets therebetween.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,612,103 Dated October 12, 1971

Inventor(s) Martyn V. Waddington

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

In the abstract, line 3, after the comma insert --one--.

Column 2, line 43, "plate" should read --pole--.

Column 3, line 3, "the" should read --a--.

Column 3, line 44, after "at" (second occurrence) insert--the--

Column 4, line 34, "69" should read --68--;

Column 4, line 67, "termination" should read --terminating--.

Column 5, line 12, "communication" should read --communicating--

Column 5, line 37, "an" should read --and--.

Column 6, line 4, "screw" should read --screws--;

Column 6, line 9, "hand" should read --land--.

Column 7, line 61, "on" should read --in--.

Column 8, line 67, after "skilled" insert --in the art--.

Signed and sealed this 18th day of April 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents