

Feb. 14, 1967

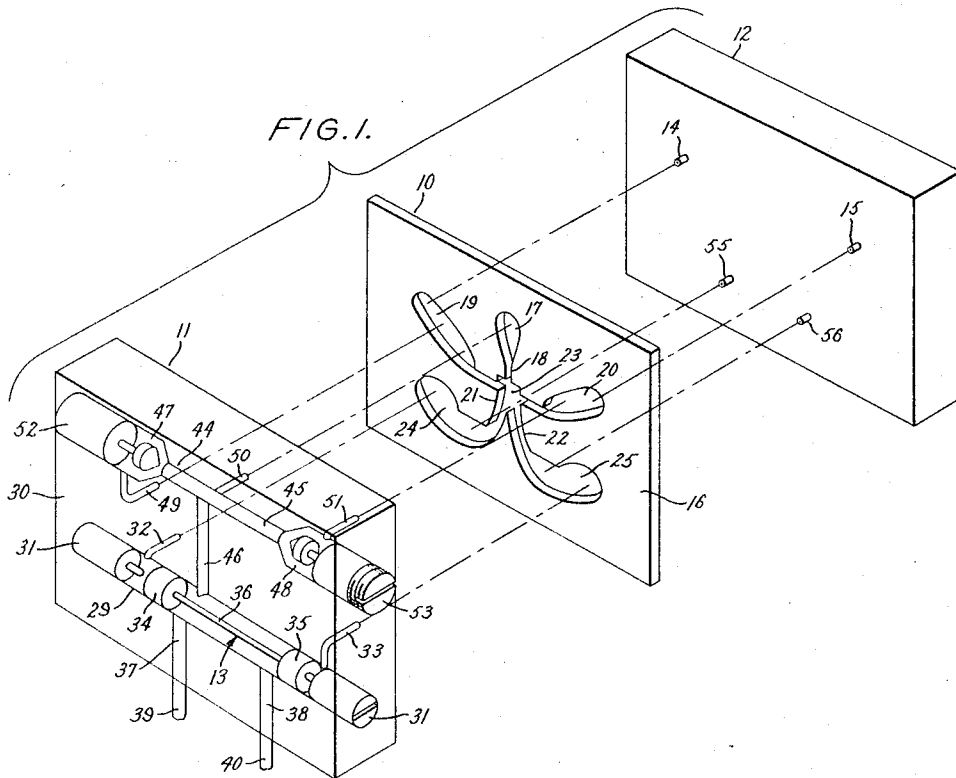
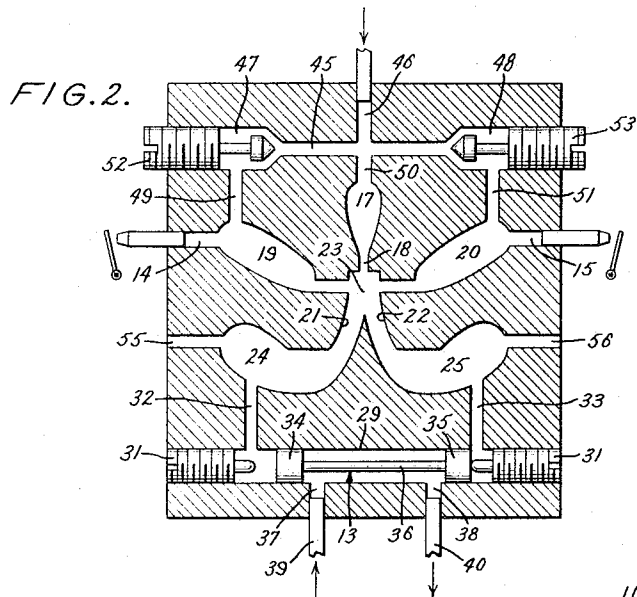
R. B. WILKERSON

3,304,049

FLUID CONTROL DEVICES

Original Filed Jan. 9, 1963

2 Sheets-Sheet 1



INVENTOR:
ROBERT B. WILKERSON,
BY *David M. Schiller*
ATTORNEY.

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FIG. 3.

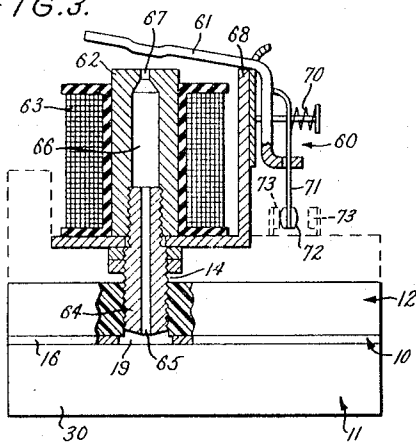


FIG. 6.

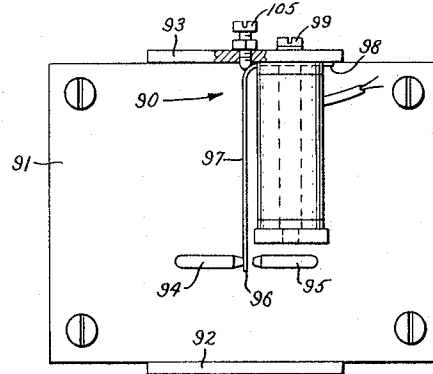


FIG. 5.

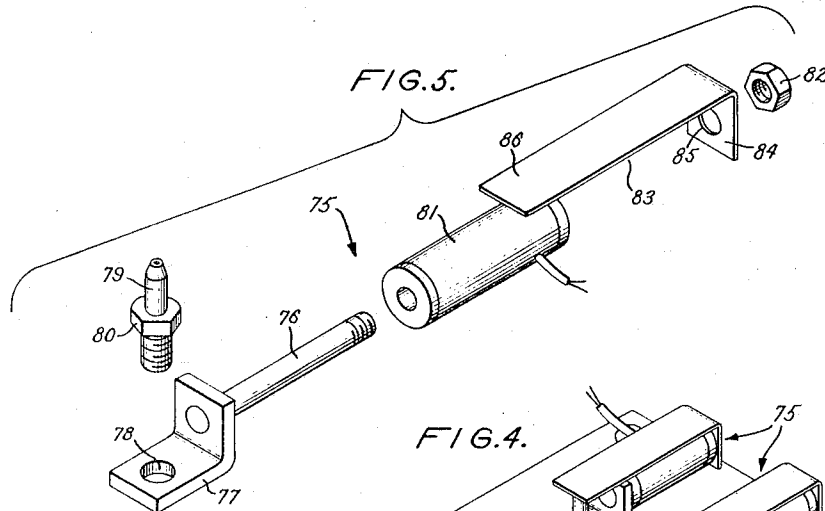


FIG. 4.

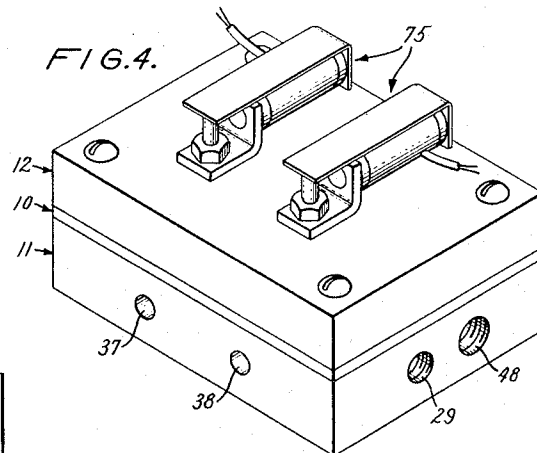
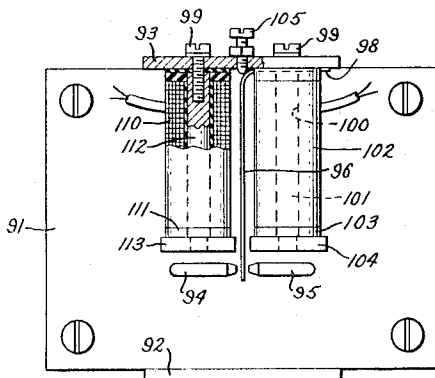


FIG. 7.



INVENTOR:
ROBERT B. WILKERSON,
BY *David M. Schiller*
ATTORNEY.

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3,304,049

FLUID CONTROL DEVICES

Robert B. Wilkerson, Bloomington, Ill., assignor to General Electric Company, a corporation of New York
Original application Jan. 9, 1963, Ser. No. 250,448.
Divided and this application Sept. 1, 1965, Ser. No. 493,605

3 Claims. (Cl. 251—139)

This is a division of application Serial No. 250,448, filed January 9, 1963.

This invention relates to fluid control devices and has particular relation to fluid amplifiers.

Fluid amplifiers are currently finding wide application in various fields due primarily to their reliability, temperature insensitivity, shock resistance, and ease of fabrication. These devices may be employed as digital and analog computing elements and also can be utilized as power devices to operate pistons and the like. Fluid amplifiers may be operated equally as well as pneumatic devices employing a compressible fluid, such as gas or air, or as hydraulic devices utilizing incompressible fluids, such as water or oil.

Two basic types of fluid amplifiers exist, the first being commonly referred to as the momentum exchange type wherein a main or power fluid jet is deflected by one or more control jets directed laterally at the power jet. The power jet is normally directed midway between two fluid receivers and is deflected relative to the receivers by an amount proportional to the net sideways momentum of the control jets. This device is accordingly sometimes referred to as a proportional or analog device.

The second type of amplifier is generally known as a boundary layer or Coanda effect device. In this latter device the power jet is deflected by the action of side walls of an interaction chamber which are shaped in such a way that the power jet will attach to one or the other of the side walls but not to both of the side walls. This operation is brought about by the entrainment action of the power jet wherein the power jet tends to entrain air trapped between it and an adjacent side wall, the entrainment becoming more effective as the power jet approaches the adjacent side wall. This type of device is basically a two position device and for this reason is referred to as a digital device.

Both the analog and digital type of amplifier can be employed as power devices to drive comparatively large loads such as spool type valves and the like which are operatively connected to the fluid receivers. In such power applications it is very desirable that the fluid control device be of inexpensive and compact construction with a minimum number of parts which are readily fabricated. It is also advantageous that the load be operated in response to application of a very low level input signal to the device, such as the electrical output signal from an electronic or magnetic static control system. It is further desirable in such devices that provision be made for supplying the fluid amplifier with fluid derived from the working fluid introduced into the load cylinder so that the device is self-energized.

It is therefore a primary object of the present invention to provide a novel and improved fluid control device which is of compact and inexpensive construction employing a minimum number of parts.

It is another object of the invention to provide a novel and improved fluid control device which is self-energized and which is designed for operating comparatively large loads.

It is a further object of the invention to provide a novel and improved fluid control device capable of operating comparatively large loads in response to very low level input signals.

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It is still another object of the invention to provide a novel and improved fluid control device designed for operating a load within a load cylinder and including a fluid amplifier which is supplied with pressure fluid through the load cylinder from working fluid introduced into the load cylinder.

It is a still further object of the invention to provide novel and improved input means for controlling the position of a fluid jet in a fluid amplifier.

In carrying out the invention in one form a fluid control device is provided designed primarily for employment as a power device to operate comparatively large loads such as reciprocable valves. The device includes a fluid amplifier section having a nozzle for generating a jet of fluid, such as air, the axis of the nozzle extending along a path midway between two fluid receiving load passages. The fluid amplifier is preferably of the boundary layer type and includes a pair of control chambers for receiving pressure fluid for controlling attachment and detachment of the jet relative to a pair of side walls of an interaction chamber located between the nozzle and the fluid receiving passages.

The device additionally includes a valve section including a valve cylinder containing a reciprocable spool valve for controlling the flow of pressure fluid between a pair of supply and output passages communicating with the cylinder. The cylinder is in communication with an auxiliary passage which contains a pair of opposed adjustable valves and which is connected in communication with the jet nozzle and with the control chambers of the fluid amplifier. With this arrangement the device is self-energized, the fluid for the control chambers and the fluid for the power jet of the fluid amplifier being furnished by the working fluid supplied to the valve cylinder.

In a pneumatic device constructed according to the present invention and employing air as the fluid, the control chambers of the fluid amplifier are connected to communicate with the atmosphere, and for this purpose a cover section is provided containing control passages which connect the control chambers of the fluid amplifier to atmosphere, the cover section overlying one side of the fluid amplifier section which is sandwiched between the cover section and the valve section. If desired, these three sections may be independent of one another and may be detachably secured to one another in any suitable manner. Control of the device is readily obtained by opening and restricting the control passages in the cover section to vary the fluid pressure in the control chambers of the fluid amplifier. This may be accomplished by a variety of arrangements.

According to a further aspect of the invention control of the device is effected by operation of means having a part which is disposed adjacent one or more of the control passages in the cover section and which is movable to open and restrict the control passage. The means may assume various forms and in one form comprises a relay having a magnetic core containing a bleed orifice which communicates with one of the control passages and which is opened and closed in response to movement of an armature resulting from energization and deenergization of a coil. By such arrangement the spool valve is reciprocated in response to a very low level of energization of the relay coil.

Other objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagrammatic view in perspective illustrating a fluid control device constructed according to the invention;

FIG. 2 is a diagrammatic view of the device of FIG. 1 flattened out in a common plane showing particularly the fluid connections in the device;

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FIG. 3 is a diagrammatic view showing in particular one form of relay for controlling operation of the device of FIGS. 1 and 2;

FIG. 4 is a diagrammatic view in perspective showing a solenoid arrangement for controlling operation of the device of FIGS. 1 and 2;

FIG. 5 is an exploded view in perspective showing parts of one of the solenoids of FIG. 4;

FIG. 6 is a view in top plan showing a solenoid arrangement different than that shown in FIGS. 4 and 5 and employing a single coil; and

FIG. 7 is a view similar to FIG. 6 showing the device of FIG. 6 with a double coil arrangement.

Referring now to the drawings there is illustrated in FIG. 1 an embodiment of the invention in the form of a boundary layer type fluid control device consisting of three sections including a fluid amplifier section 10, a valve section 11, and a cover section 12, the section 10 being sandwiched between the sections 11 and 12. The sections 10-12 may be separately formed and detachably secured to each other in any suitable manner, or the fluid amplifier 10 may be formed as an integral part of either the valve section 11 or the cover section 12.

In general, pressure fluid applied to the amplifier section 10 operates a suitable load device in the valve section 11, such as a reciprocal valve 13, in response to selective opening and restriction of control input conduits or passages 14 and 15 located in the cover section 12 and opening to atmosphere. The fluid employed in the device may be of any suitable character, a compressible fluid, such as air or gas, being capable of use to provide a pneumatic device, or an incompressible fluid, such as oil or water, being also usable to provide a hydraulic device. In the illustrated embodiment it will be assumed that the fluid constitutes air to provide a pneumatic control device.

The present invention is applicable to control devices employing fluid amplifiers of either the boundary layer type or the momentum exchange type, and the invention will be described with reference to a control device utilizing a boundary layer type fluid amplifier. In the illustrated embodiment the amplifier section 10 includes a plate 16 formed of any suitable material, such as metal, plastic or the like, which is slotted in a unique configuration to provide the boundary layer amplifier. The plate 16 is formed with a main pressure fluid receiving opening 17 having a restricted neck 18 defining a nozzle from which issues a jet of fluid, the fluid being derived from a pressure fluid source and applied to the opening 17 in a manner more fully described hereinafter.

In order to control the direction of flow of the jet the plate 16 is formed with a pair of control chambers 19 and 20 opening at areas adjacent the nozzle 18 and on opposite sides of the axis of the nozzle. The chambers 19 and 20 are adapted to receive pressure fluid from any suitable source which cooperates with boundary layer regions adjacent side walls 21 and 22 of an interaction chamber 23 to control deflection of the jet issuing from the nozzle 18.

As is understood in the art, the fluid jet issuing from the nozzle 18 normally is attached to one or the other of the side walls 21 and 22 in the absence of control fluid pressure applied to the chambers 19 and 20, and will enter one of two fluid receiving passages 24 and 25 which are formed in the plate 16 and which are connected in communication with a valve cylinder 29 formed in the valve section 11 as will presently appear. Let it be assumed that the jet is initially attached to the side wall 21. If fluid pressure is introduced into the control chamber 19 and is increased above a certain value, then the jet will be detached from the wall 21 and will be flipped into attachment with the wall 22, the jet remaining in the attached condition even after removal of fluid pressure from the chamber 19. To detach the jet from the wall 22 fluid pressure must be introduced into the chamber 20 and increased above a certain level

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at which time the jet will detach from the wall 22 and will flip into attachment with the wall 21. The above described attaching and detaching actions of the jet occur very rapidly in response to very small fluid pressures in chambers 19 and 20.

In the illustrated embodiment the valve section 11 is in the form of a rectangular block 30 of any suitable material, such as plastic, metal or the like and includes therein a plurality of passages for fluid. One of the passages in the block 30 constitutes the valve cylinder 29 which contains the valve 13, the valve 13 being reciprocal in the cylinder 29 between a pair of combination plugs and stops 31 adjustably positioned in the ends of cylinder 29. The block 30 is formed with a pair of spaced parallel passages 32 and 33 which communicate with the cylinder 29 and which open at one side of the block 30 to communicate with the load passages 24 and 25 formed in the amplifier plate 16 when the plate 16 and block 30 are operatively secured together. The valve 13 includes a pair of spaced lands 34 and 35 located between the passages 32 and 33 for any position of the valve and connected by a reduced central section 36. The lands 34 and 35 appear as piston loads to fluid entering the cylinder 29 through the passages 32 and 33 and the valve 13 will be displaced in a direction dependent upon which of the passages 32 and 33 is receiving fluid from the amplifier section 10.

The valve 13 controls the flow of fluid between a supply passage 37 and an output passage 38 formed in the block 30 in spaced parallel relation to extend between the cylinder 29 and one side of the block 30. Supply and output conduits 39 and 40 are attached to the passages 37 and 38 in any suitable manner and fluid under pressure is conducted through the supply conduit 39 from a suitable source of pressure fluid (not shown). The passages 37 and 38 are conveniently formed with internal threads to threadably receive the conduits 39 and 40.

As best shown in FIG. 2 and lands 34 and 35 of the valve 13 are spaced from the adjacent open ends of the passages 37 and 38 when the valve is in its right-hand position which results when fluid flows into the cylinder 29 through the passage 32 from the load passage 24 of the amplifier 10. For this condition fluid under pressure flows through the conduit 39, the passage 37, the cylinder 29, the passage 38 and the conduit 40 to a suitable load device (not shown). When the jet of fluid issuing from nozzle 18 of the amplifier 10 is deflected to enter the load passage 25, the valve 13 will be shifted toward the left from its position illustrated in FIG. 2 so that the land 34 will engage the stop 31 to position the land 35 over the open end of the output passage 38. For this condition fluid under pressure flowing through the conduit 39 is prevented from flowing out the passage 38 and the conduit 40.

As previously stated fluid under pressure is applied to the opening 17 and to the control chambers 19 and 20 of the amplifier 10 and the pressure of fluid applied to chambers 19 and 20 is employed to control the direction of deflection of the fluid jet issuing from the nozzle 18. Fluid applied to the opening 17 and to the chambers 19 and 20 may be supplied from any suitable source of pressure fluid, and in the present invention the control device is self-energized wherein the fluid applied to the opening 17 and to the chambers 19 and 20 is derived from the fluid supplied to the cylinder 29. In order to accomplish this desirable arrangement the block 30 is formed with a plurality of passages which conduct fluid from the cylinder 29 to the opening 17 and to the control chambers 19 and 20. In the embodiment of FIG. 1 the block 30 is formed with an elongated passage 44 parallel to the cylinder 29 and including a central restricted portion 45 connected to the cylinder 29 by a passage 46, and a pair of enlarged end portions 47 and 48 which open at opposite ends of the block 30. The block includes also three spaced parallel passages 49, 50 and 51 extending generally perpendicular to the passage portions 45, 47 and 48,

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the passages 49 and 51 communicating with the passage portions 47 and 48 and opening at one side of the block 30, and the passage 50 communicating with the passage portion 45 and opening at the same side of the block 30. When the block 30 and the amplifier 10 are operatively positioned, the passages 49 and 51 open respectively into the control chambers 19 and 20 and the passage 50 opens into the opening 17 of the plate 16.

It is observed that with the above-described arrangement fluid under pressure is continuously supplied to the control chambers 19 and 20 and to the opening 17 of the plate 16 from the supply conduit 39 in the block 30. In order to permit adjustment of the fluid pressure in the control chambers 19 and 20 and in the interaction chamber 23 a pair of adjustable valves 52 and 53 shown in the form of needle type valves are threadably received within the end passages 47 and 48 to permit variation of the amount of fluid flowing from the central passage 45 through the passages 49 and 51 and thence to the control chambers 19 and 20. For example, if the valve 53 is screwed into the block 30 by a distance greater than the valve 52, a smaller amount of fluid is permitted to flow through the passage 51 than through the passage 49 whereby the pressure of fluid applied to the control chamber 19 is greater than that applied to the chamber 20. This results in attachment of the jet of fluid issuing from nozzle 18 to the side wall 22 whereby the jet passes through the load passage 25 and through the passage 33 into the cylinder 29 to displace the valve 13 toward the left as viewed in FIG. 2. As will presently appear, adjustment of the fluid pressure in chamber 23 is controllable by arrangements other than the valves 52 and 53 and the passages 49 and 51.

In order to permit venting of fluid from the device a pair of spaced parallel vent passages 55 and 56 are provided in the cover section 12 each of which opens at opposite sides of the cover section. When the cover section 12 and the amplifier plate 16 are operatively positioned, the open ends of the vent passages 55 and 56 adjacent the plate 16 are placed in communication with the load passages 24 and 25 in the illustrated embodiment and serve to conduct fluid to atmosphere from the load passages in the event that the cylinder cannot receive the fluid supplied to it causing fluid to back up in the load passages. The vent passages may be located in other regions of the amplifier plate 16 than those shown. For example, the vent passages may be located in the interaction chamber 23. In addition, the vent passages 55 and 56 may be utilized to control fluid pressure in the chamber 23. For this purpose the valves 52 and 53 and the passages 49 and 51 may be omitted, and means provided to controllably restrict the vent passages 55 and 56. In such an arrangement the end portions 42 and 48 of the passage 44 would be plugged and fluid pressure would be applied to the passages 14 and 15.

The control passages 14 and 15 are provided for the purpose of permitting control of the pressure of fluid in the control chambers 19 and 20, and to therefore permit control of the position of the jet issuing from the nozzle 18. Pressure of fluid in the chambers 19 and 20 may be controlled either by opening normally closed or restricted passages 14 and 15, by closing or restricting normally open passages 14 and 15, or by introducing pressure fluid into the passages 14 and 15. For example, let it be assumed that both passages 14 and 15 are normally open and that the valve 52 is withdrawn from the passage 47 to a greater extent than the valve 43 so that pressure of fluid in control chamber 19 is greater than that in control chamber 20. With this assumption the fluid jet issuing from nozzle 18 is attached to the side wall 22 to enter load passage 25 and displace the valve 13 toward the left as viewed in FIG. 2. If the control passage 15 is now closed, or if pressure fluid is introduced into the passage 15, pressure of fluid in the chamber 20 will increase above pressure of fluid in chamber 19 with the result that the jet

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will be detached from side wall 22 and will be flipped into attachment with side wall 21 to effect displacement of the valve 13 to its illustrated position. If the control passage 15 is subsequently opened, the jet will detach from the side wall 21 and return to the side wall 22 to displace the valve 13 toward the left as viewed in FIG. 2.

Other operational modes of the fluid control device are possible. For example, by initially providing substantially equal pressures of fluid in the control chambers 19 and 20 the device can be made bistable. To illustrate this, assume that the pressures of the control chambers 19 and 20 are equalized and that both of the control passages 14 and 15 are open. If the passage 14 is now closed, pressure of fluid in chamber 19 will increase and the jet will flip to the wall 22 if previously attached to wall 21, and will enter the load passage 25. Due to the pressure conditions in the interaction chamber 23, opening of the passage 14 will result in the jet remaining attached to the side wall 22 until the other passage 15 is closed. When the passage 15 is closed, the jet will flip to the wall 21 and will enter the load passage 24. In devices which employ such bistable operation the needle valves 52 and 53 can be eliminated since they are not needed to effect an unbalance of pressure in the chambers 19 and 20.

The above methods of control are referred to as normally open operational modes of the device wherein jet deflection is effected by closing normally open passages 14 and 15, and it is appreciated that the device can be operated under normally closed conditions as well wherein jet deflection is effected by opening normally closed passages 14 and 15. To illustrate this, assume that fluid pressures in the control chambers 19 and 20 are equalized to provide bistable operation, and that the passages 14 and 15 are normally closed. If the passage 14 is opened, pressure of fluid in chamber 19 will be reduced below that in chamber 20 with the result that the jet will flip to the side wall 21 if previously attached to wall 22 and will enter the passage 24. The jet will remain in such position even though the passage 14 is subsequently closed until the passage 15 is opened at which time the jet will flip to the side wall 22.

According to the invention, improved means are provided for controllably restricting the passages 14 and 15 to control the position of the jet in the plate 16. In one aspect of the present invention this is accomplished by electrically operated means requiring a very low level electrical input to effect displacement of the valve 13. Referring now to FIG. 3 there is illustrated one embodiment of the invention in the form of a relay 60 mounted on the fluid control device and including a magnetic armature 61 movable relative to a magnetic core 62 in response to energization of an electroconductive coil 63 surrounding the core 62 for controllably restricting a selected one of the control passages 14 and 15. For this purpose a retaining screw 64 is screwed into a selected one of the passages 14 and 15, the screw 64 being formed with an opening 65 extending throughout its length which communicates with an opening 66 which is formed in the magnetic core 62 and which threadably receives the screw 64. The opening 66 terminates at its upper end in a small bleeder orifice 67 adapted to be opened and closed by movement of the armature 61 relative to the core.

The armature 61 is pivotally supported by a supporting frame 68 and is biased to an elevated position illustrated in FIG. 3 wherein the orifice 67 is open by means of a bias spring 70 which also urges a contact carrier 71 toward the left as viewed in FIG. 3. According to a further aspect of the invention the contact carrier 71 supports a movable contact 72 which moves between a pair of spaced fixed contacts 73 in response to movements of the armature 61 for effecting an additional control operation. The coil 63 of the relay 60 may be energized from any suitable voltage source. For example, the relay 60 described herein can be energized from the out-

put circuits of magnetic or semiconductor static control systems through intermediate amplifiers or relays. A very low level input, such as approximately 50 milliwatts, is all that is required to move the armature 61 and effect displacement of the valve 13. It can be appreciated that to provide bistable operation, another relay similar to the relay 60 must be provided to control a bleeder orifice in communication with the passage 15.

Referring now to FIGS. 4 and 5 there is illustrated a different control arrangement than that shown in FIG. 3. In FIG. 4 there is shown a pair of similar solenoids 75 to provide bistable operation with each of the solenoids 75 being of different construction than the relay 60 of FIG. 3. Each solenoid 75 includes an elongated cylindrical core 76 attached at one end to an L-shaped bracket 77 having an opening 78 through which extends a nozzle 79 into threaded engagement with one of the passages 14 and 15. A nut 80 is threaded on the nozzle 79 to retain the bracket 77 against the upper surface of the cover section 12.

The solenoid 75 includes a coil 81 adapted to be slipped on to the core 76 and retained thereon by means of a nut 82 which is threaded on the threaded end of the core 76. In order to open and close the passage 14 or 15 to control deflection of the fluid jet in the amplifier 10 there is provided a generally L-shaped thin magnetic reed 83 formed of spring material and having a short arm 84 with an opening 85 therein adapted to receive the core 76, the long arm 86 of the reed extending generally parallel to the core to overlie the end of the nozzle 79 when the reed is operatively positioned on the core. The long arm 86 of the reed is normally spaced from the end of the nozzle 79 so that the nozzle 79 and the associated passage 14 or 15 are open, and is deflected downwardly against the nozzle 79 to close the nozzle and the associated passage in response to energization of the coil 81. When the coil 81 is subsequently deenergized, the arm 86 of the reed will return to its normal spaced position.

Referring now to FIGS. 6 and 7 an electromagnetic controller is provided which differs from the relay 60 and the solenoid 75 previously described. The device of FIGS. 6 and 7 is represented generally by the numeral 90 and is designed for employment with control devices which are arranged for bistable operation. As will presently appear, the device 90 employs a single magnetic reed adapted for single coil operation on either side (FIG. 6), or double coil operation (FIG. 7).

The device 90 includes a flat plate 91 adapted to be secured to the outer surface of the cover section 12 and including a pair of opposed upstanding brackets 92 and 93. Intermediate the brackets 92 and 93 are a pair of generally L-shaped nozzles 94 and 95 having first open ends extending through the plate 91 into the passages 14 and 15 respectively, and having second open ends in spaced confronting relation on opposite sides of the end of a long arm 96 of an L-shaped magnetic reed 97 having also a short arm 98. The reed 97 is secured to the bracket 93 by means of a screw 99 (FIG. 7) which extends through openings in the bracket 93 and in the short arm 98 into threaded engagement with an opening 100 formed in a cylindrical magnetic core 101. A coil 102 is mounted on a bobbin 103 which surrounds the core 101 and which mounts a magnetic pole 104 adjacent the outer end of the core 101 when the bobbin is operatively positioned.

Provision is made for adjusting the reed 97 so that the long arm 96 thereof closes a selected one of the nozzles

94 and 95 or is centered midway between the two nozzles when the coil 102 is deenergized. Lateral adjustment of the long arm 96 of the reed is readily accomplished by rotating a screw 105 which is threaded into an opening of the bracket 93 and which extends into engagement with the joint between the arms 96 and 98 of the reed.

In FIG. 7 the double coil arrangement is shown including a coil 110, a bobbin 111, a magnetic core 112 and a magnetic pole 113 corresponding to the items 101-104 previously described. In this double coil arrangement the arm 96 of the reed 97 is adjusted by rotation of the screw 105 so that arm 96 is in a normal position midway between the nozzles 94 and 95 when both of the coils 102 and 110 are deenergized.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A self-mounting fluid control device for controlling the flow of fluid from a passage comprising an elongated retaining member having an opening extending therethrough, said retaining member being adapted for reception within the passage to be supported thereby, a generally L-shaped support frame having a pair of legs, one of said legs having an aperture therein through which passes said retaining member, a magnetic core having an opening extending therethrough, said opening being formed as a bleeder orifice at one end and receiving said retaining member at the other end so that said core is fixedly supported by said retaining member, a coil surrounding said core, a magnetic armature pivotally supported at the free end of the other of said legs of said support frame which other leg extends generally parallel to said core, and resilient means biasing said armature with respect to said support frame whereby said armature is normally biased to uncover said orifice, and is pivoted to cover said orifice when said coil is energized to stop the flow of fluid from the passage through said orifice.

2. The self-mounting fluid control device defined in claim 1 wherein said retaining member is cylindrical and is externally threaded, and the passage and said opening in said magnetic core are cylindrical and threaded, whereby said core is threaded onto said retaining member and said retaining member is threaded into the passage to mount said fluid control device.

3. The self-mounting fluid control device defined in claim 1 wherein said armature supports a movable contact in proximity to a fixed contact, such that energization and deenergization of said coil causes said movable contact to be moved between open and closed positions relative to the fixed contact.

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M. CARY NELSON, *Primary Examiner*.

R. C. MILLER, *Assistant Examiner*.