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FLUID DIGITAL POSITIONER

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2 Sheets-Sheet 1

FIG. 1

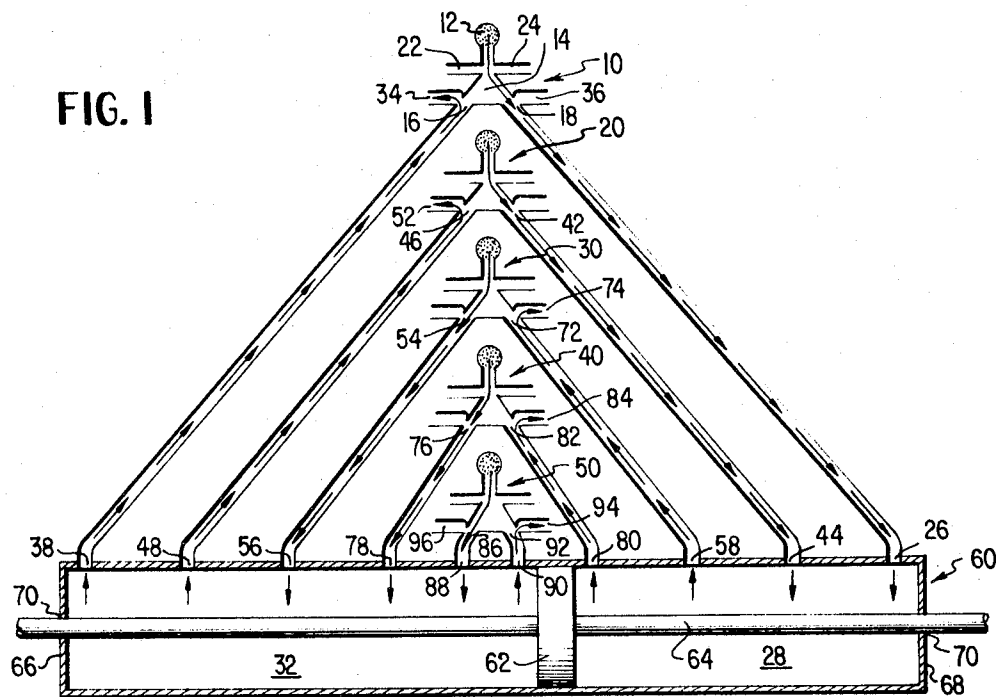
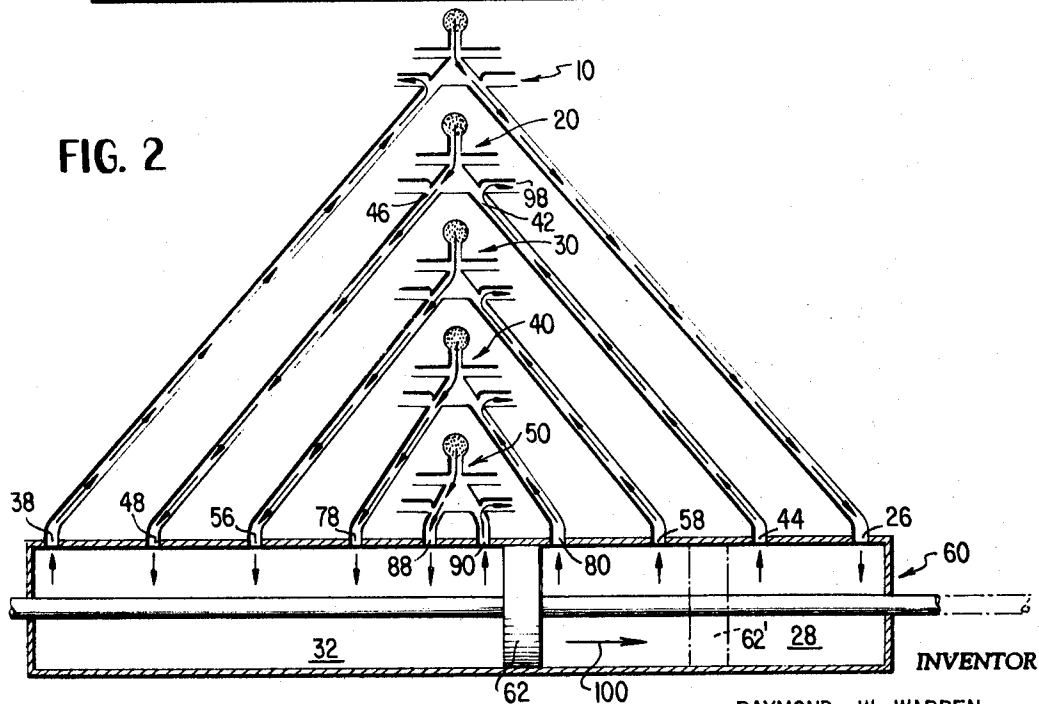


FIG. 2



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1

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FLUID DIGITAL POSITIONER

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This invention relates to a fluid digital positioner and more particularly to a digital positioner which is variably positioned in response to switching of one or more of a plurality of bleed type, bistable wall interaction amplifiers.

Digital positioners have long incorporated fluidic means for variably positioning the same. All known fluid operated, digital positioners employ movable valve members and other elements which tend to affect the reliability of operation and at the same time increase the response time of the positioner.

It is, therefore, a primary object of the present invention to provide a fluid operated digital positioner which is extremely simple and reliable and yet able to produce sophisticated control functions.

It is a further object of this invention to provide a fluid digital positioner whose position is controlled by a plurality of fluid amplifiers of the bistable type.

It is a further object of this invention to provide an improved fluid digital positioner which is characterized by the absence of moving parts.

Other objects of this invention will be pointed out in the following detailed description and claims and illustrated in the accompanying drawings which disclose, by way of example, the principle of this invention and the best modes which have been contemplated of applying that principle.

In the drawings:

FIGURE 1 is a schematic, elevational view of one form of the fluid digital positioner of the present invention.

FIGURE 2 is a schematic, elevational view of the fluid digital positioner shown in FIGURE 1 after switching of one of the bistable fluid amplifiers providing the fluid input to the positioner.

FIGURE 3 is a schematic view of a second embodiment of the fluid digital positioner of the present invention as applied to the sensing of a shock wave within a compressible high velocity fluid.

In general, the invention is directed to a digital fluid positioner system which includes a casing forming a closed fluid working chamber including a wall member carried thereby and movable longitudinally therein. A plurality of bistable fluid amplifiers are provided which include plural power stream outlets. Means are provided for coupling at least one outlet of each fluid amplifier to the working chamber at points spaced longitudinally along the casing. Means are further provided for biasing the movable wall to a first position within the casing. Digital fluid input means selectively switch the fluid amplifiers whereby the movable wall member shifts longitudinally from a first position to a second position to maintain a like number of fluid amplifiers delivering to and receiving fluid from the working chamber.

In one form, the wall member separates the closed casing into opposed fluid working chambers. Both outlets of each fluid amplifier are coupled to the casing on opposite sides of the casing center line such that when the movable wall member is centrally positioned within the casing, one amplifier outlet is carrying fluid flow to one working chamber, while receiving fluid from the second working chamber.

In a second embodiment, only one outlet of each amplifier is coupled to the elongated casing. The second outlet of each fluid amplifier acts as a bleed and means are pro-

2

vided for normally biasing the amplifier power stream to the bleed outlet. The amplifier fluid outlets each connected to the casing are selectively coupled to a working chamber while the other working chamber receives biasing fluid to set the positioner wall member at an initial position.

Referring to FIGURE 1, there is shown schematically a plurality of fluid amplifiers 10, 20, 30, 40 and 50 for controlling the position of the fluid positioner. The amplifiers are of the bistable, bleed, wall interaction type which feed fluid into and receive fluid from a closed elongated casing 60, in the form of a cylinder. Casing 60 carries internally, a piston 62, which is slidable longitudinally of the cylinder. In this regard, the piston 62 has coupled thereto an axially extending piston rod 64 extending outwardly of left-hand and right-hand ends 66 and 68. Appropriate apertures 70, carried by the end walls 66 and 68, allow the rod 64 to slide therethrough, being fluid sealed with respect to the casing end walls.

The fluid amplifiers are all identical; for instance, fluid amplifier 10 includes a power stream inlet port 12 for directing the power stream selectively through interaction chamber 14 to left and right-hand outlets 16 and 18 under normal bistable operation. Left and right-hand control ports 22 and 24 control which fluid outlet receives the power stream. In this case, left-hand control port 22, being last pulsed, causes the power stream to pass through outlet 18 in the direction indicated by the arrows. The right-hand amplifier outlet 18 is fluid coupled to working chamber 28 by port 26. The piston 62 divides the casing interior into right-hand working chamber 28 and a left-hand working chamber 32. Each fluid amplifier is provided with appropriate left and right-hand bleeds; for instance, amplifier 10 includes a left-hand bleed 34 and right-hand bleed 36. In this regard, under the conditions shown in FIGURE 1, fluid is being removed from left-hand working chamber 32 through fluid outlet connection 38, the fluid returning to fluid amplifier 10 and passing out through bleed 34.

The remaining fluid amplifiers are identically connected to the cylinder 60. The power stream for each amplifier may be selectively passed through either amplifier right or left-hand outlets. For instance, fluid amplifier 20 has its power stream exiting through fluid outlet 42 and by means of cylinder port 44 enters the right-hand working chamber 28. The left-hand fluid outlet 46 for the same amplifier receives fluid from left-hand working chamber 32 through casing port 48, the return fluid exiting through bleed 52. For fluid amplifier 30, the power stream passes from the amplifier through left-hand outlet 54 and enters left-hand working chamber 32 through port 56. Return fluid passes from right-hand working chamber 28 through port 58 to fluid outlet 72 at the right-hand bleed 74. All casing ports are in line, but spaced longitudinally along the casing wall.

Fluid amplifier 40 delivers its power stream through left-hand outlet 76 to the left-hand working chamber 32 through port 78. On the opposite side of the positioner piston 62, chamber 28 delivers fluid through port 80 and right-hand amplifier outlet 82 to the right-hand bleed 84. Again, with regard to fluid amplifier 50, the power stream exits from the amplifier interaction chamber through left-hand amplifier outlet 86 and casing port 88 to the left-hand working chamber 32. Unlike the previous amplifiers, port 90 acts to fluid couple amplifier outlet 92 such that fluid from the same working chamber 32 exits through amplifier 50 by means of amplifier port 92 and bleed 94.

In the operation of the fluid digital positioner, the piston 62 always tries to move so that the flow in and the flow out to respective working chambers on each side of the piston are equal. Thus, for left-hand positioner chamber

3

32, flow enters the chamber through positioner ports 56, 78 and 88 and leaves the left-hand chamber through spaced positioner ports 38, 48 and 90. On the right-hand side of the piston within working chamber 28, fluid enters the extreme right-hand ports 26 and 44 and exits to the fluid amplifiers through ports 58 and 80. Obviously, if both outputs of an amplifier are on the same side of the piston, switching from one outlet to the other does not affect the piston position. This may be readily seen when viewing FIGURE 1, in that assuming bistable amplifier 50 switches, the power stream from the amplifier will then pass through right-hand fluid outlet 92, and port 90 into the left-hand chamber 32 and out of port 88, through amplifier outlet 86 to the left-hand bleed 96. This will, of course, not affect the ratio of inlets to outlets for the left-hand working chamber 32 and the piston 62 will remain in the position shown in FIGURE 1. Only the bistable amplifiers that have an output on both sides of the piston affect the system while in the amplifiers that have both outputs on the same side of the system cancel themselves.

Referring to FIGURE 2, the positioner is shown under conditions in which an amplifier having outlets on both sides of the piston, has its power stream switched from one amplifier outlet to the other. Under the conditions shown, fluid amplifiers 10, 30, 40 and 50 remain unswitched while amplifier 20 switches. The power stream of amplifier 20 now passes through amplifier outlet 46 and enters right-hand working chamber 32 through port 48. Since the power stream is passing through left-hand outlet 46, right-hand outlet 42 acts as a fluid return for right-hand chamber 28, fluid passing through cylinder port 44 through outlet 42 to the right-hand bleed 98. Assuming instantaneously that piston 62 is in the same position as under the conditions of FIGURE 1, it is noted that within the left-hand working chamber 32, fluid is moving into the working chamber through ports 48, 56, 78 and 88, while fluid is exiting from the chamber through ports 90, 38 and 98. Likewise, on the opposite side of the piston within working chamber 28, fluid is entering the chamber through the extreme right-hand port 26 and is passing from the chamber to respective fluid amplifiers through ports 44, 58 and 80. Since the piston 62 always tries to move so that the flow in and out of each side of the piston is equal, the piston 62 will move as indicated by the arrow 100 to the dotted line position 62'. In this position, there are on the left-hand side of the piston within working chamber 32, a like number of ports receiving fluid as those allowing fluid to discharge from the chamber. Ports 48, 56, 78 and 88 are discharging fluid into the chamber, while ports 38, 90, 80 and 58 are receiving fluid and returning the same to respective amplifiers for discharge through associated bleed ports. On the right-hand side of the chamber, port 26 allows a single fluid stream to enter from fluid amplifier 10, while fluid is being discharged from the right-hand working chamber 28 through port 44 to fluid amplifier bleed 98 of fluid amplifier 20.

From the above, it is obvious that if the positioning sequence is operated from the end of the cylinder 60 toward the center, the piston will move each time a bistable fluid amplifier or element is flipped.

While the invention has been shown as applied to fluid amplifiers in schematic form, the fluid amplifiers themselves may be conventionally built of stacked sheets including outer, imperforate sheets acting to sandwich an inner sheet, incorporating by molding or etching, the required geometry to form the interaction chamber for each amplifier and the multiple fluid passages or channels. The exact manner in which the amplifier is assembled through the use of the multiple plates and its mode of connection to the elongated casing or cylinder 60 forming a major element of the digital positioner does not form a part of this invention and any conventional technique may be utilized. The invention has equal application to pure

4

fluid amplifiers or to fluid amplifiers which include moving elements.

The embodiment shown in FIGURES 1 and 2 constitutes an extremely simplified system in which the fluid positioner itself comprises a piston movable longitudinally within a cylindrical casing with opposed forces acting upon the piston in the form of right-hand and left-hand working chambers. The dual outlets of each amplifier are normally connected to associated, opposed chambers. Fluid passes from the amplifier to one chamber and is received by the amplifier from the other chamber and discharges through an adjoining bleed. Reference to FIGURE 3 shows a second embodiment of the invention in which there is provided a single working chamber connected to the fluid amplifier. The working chamber acts against a set biasing force which has an equal and opposite effect upon the movable wall or piston member. The piston will remain in a desired set position in the absence of an unlike number of fluid inlet and outlet connections to the amplifier, in like manner to the operation of the first embodiment.

Specifically, the multi-step fluid digital positioner is employed in conjunction with a shock wave sensor to maintain the position of the shock wave at a desired position with respect to a fluid flow diffuser. It is noted that spaced members 102 and 104 define a flow path for a compressible fluid moving at high velocity and in the direction shown by arrow 106. A shock wave 108 is created between the spaced members. The velocity of the fluid to the left of the shock wave is less than Mach 1 while that to the right is greater than Mach 1. In this case, the pressure of high velocity fluid to the left is of higher pressure than the fluid to the right of shock wave. The fluid positioner in this embodiment may, therefore, be used to control the position of the shock wave at 108 within the diffuser, such as normally present in supersonic aircraft.

The fluoric shock positioner control system may be so designed as to maintain a given shock position by controlling, through the use of vents, the diffuser back pressure. Basically, the system operates by using the change in pressure across the shock wave 108 to trigger the series of fluid amplifiers identified from left to right as 110, 112, 114, 116, 118 and 120. The number of amplifiers actuated corresponds to the axial location of the shock wave. The total output of the amplifiers is used to move the piston 122 of the fluid digital positioner. The piston displacement, a direct function of shock wave position, controls engine bleed flow and pressure and, therefore, shock location. In the embodiment shown, the piston 122 always tries to assume a position wherein an equal number of amplifiers acting as sensors discharging out of the driving side of the piston as are discharging into the driving side.

In this respect, the positioner casing member 100 is provided with an enlarged bore section 124 which receives piston 122 having an enlarged diameter wall section 126 in the order of the diameter of bore 124. A reduced diameter section 128 immediately to the left acts in conjunction with end wall 130 to define a fluid working chamber 132 which may be selectively coupled to a single outlet from each fluid amplifier through slide valve 210. The reduced diameter piston section 128 is hollow to define a bias chamber 134 which receives a set fluid pressure through line 136 acting as indicated by arrows 138 on the forward wall 140 against the pressurized fluid within working chamber 132. The fluid within chamber 132 acts on the annular wall 142 of the piston, as indicated by arrows 144. Movement of piston members 122 to the left tends to close pressure relief doors (not shown) downstream of the shock wave 108. Likewise, movement of the piston 122 to the right tends to open the relief doors.

The sensors are of the identical wall attachment pure fluid, bistable acting type as shown in the FIGURE 1

embodiment, or alternatively, may include moving parts if desired. The fluid amplifiers must act as bistable switches in response to digital pulse input. All of the fluid amplifiers are the same. For instance, the left-hand fluid amplifier 110 includes a power stream inlet port 150 delivering fluid selectively to left-hand amplifier outlet 152 or right-hand amplifier outlet 154 depending upon which control nozzle 156 or 158 has last been pulsed. A pair of left and right-hand ports 160 and 162 are provided. The right-hand port 162 acts normally as the bias control means for maintaining power stream flow through left-hand vent outlet 152 in the absence of a pressure differential across associated left and right-hand control nozzles 156 and 158.

For each of the fluid amplifiers 110, 112, etc., there are provided common control nozzle connections which open up at spaced points along the outer surface of flow defining duct means 104. The spaced control nozzle connections are identified as 164, 166, 168, 170, 172, 174, and 176, respectively, from left to right.

Feedback control is provided for each fluid amplifier by means of a fluid connection between the right-hand power stream outlet of one amplifier and a left-hand port of the fluid amplifier to the left or downstream of that amplifier. For instance, the left-hand feedback control port 160 of amplifier 110 is connected to right-hand power stream outlets 190 of amplifier 112 by feedback channel 224. Likewise, feedback channel 222 connects the right-hand power stream outlet 194 of amplifier 114 to the left-hand feedback control port of amplifier 112. A fluid connection 228 couples right-hand power stream outlet 198 of amplifier 116 to left-hand feedback control port of amplifier 114. Feedback channels 230 and 232 function in like manner for amplifiers 118 and 120, respectively.

Each amplifier includes a curved bleed outlet such as outlet 151 for amplifier 110. For the other amplifiers, from left to right, bleed outlets 153, 155, 157, 159 and 161 are provided, respectively.

Unlike the previous embodiment, both of the power stream outlets of each amplifier are not connected to opposed working chambers of the digital positioner itself, but in each case the left-hand power stream outlet for each amplifier acts as a vent. In addition to vent 152 for amplifier 110, there is provided vent 178 for amplifier 112, vent 180 for amplifier 114, vent 182 for amplifier 116, vent 184 for amplifier 118 and vent 186 for amplifier 120. The right-hand outlet of each fluid amplifier is coupled to slide valve 210 at spaced longitudinal points.

The fluid digital positioning system employs movable slide valve 210 to selectively provide an initial set shock location. The function of the slide valve 210 is to fluid couple the ports 188, 192, 196, etc., and associated amplifier outlets carried thereby, to fixed ports 212, 214, 216, 218, 220 and 222 which open up into bore 124 of casing member 100. Assuming, for instance, that the slide valve 210 is positioned as shown, ports 188 and 212 are in line and the right-hand fluid amplifier outlet 154 is fluid coupled directly to the working chamber 132.

In operation, assuming that the shock wave 108 is initially in the position shown, it will be seen that the pressure differential across the control nozzle for amplifiers 110 and 112 is such that it will overcome the bias supplied to right-hand ports of these amplifiers to cause the power stream to switch from associated vents 152 and 178 to right-hand power outlets 154 and 190, respectively. Flow then passes, as indicated, through right-hand power stream outlets to the associated ports 188 and 192 carried by the slide valve 210 and through ports 212 and 214 carried by the positioner casing to allow pressure flow from the fluid amplifiers 110 and 112 into amplifier chamber 132. The fluid pressure, of course, acts against the biasing pressure within bias chamber 134. Under the operating principles of the instant invention, the piston 122 must move to the left until it uncovers a like number of amplifier fluid ports which will carry flow from the positioner working chamber 132 to the

amplifiers as ports which are delivering their power streams to the positioner working chamber. In this case, since amplifiers 110 and 112 are delivering flow to the working chamber 132, the next upstream amplifiers 114 and 116 act to receive flow from the working chamber and discharge it through their right-hand bleeds. In this case, once the piston 122 has moved to the left to uncover working chambers 216 and 218, it will stay in the position shown until there is a shift in the position of shock wave 108.

If now, the shock wave shifts to the right, so as to create a fluid pressure differential across sensing channels 168 and 170, the pure fluid amplifier 114 will switch in like manner to amplifiers 110 and 112. The power stream is no longer directed to vent 180 but passes through amplifier outlet 194 and associated ports 196 and 216 such that there will be an imbalance in the number of fluid inlet connections and outlet connections between the amplifiers and the chamber. Piston 122 moves further to the right. Instantaneously, ports 212, 214 and 216 will all be delivering fluid to the chamber and only port 218 will be directing fluid from the chamber to fluid amplifier 116. Necessarily, piston 122 must move to its extreme right position such that ports 220 and 222 will join port 218 in delivering fluid from the working chamber 132 to the extreme right-hand amplifiers 118 and 120.

It is, therefore, seen that during the operation, as the normal shock moves, the difference in pressure on the control ports will flip the bistable elements. If the movement of the shock is in the direction to retract the piston, that is, it is upstream, the difference in pressure due to the shock on the control channel for respective amplifiers flips each bistable element to the internal working surface of the piston. This retracts the piston against the said pressure until the piston uncovers the port to the adjacent bistable element. Flow out of the working chamber and through the bleed of the adjacent bistable element balances the internal pressure against said pressure and the piston is positioned at that particular port. The piston always positions itself so that inflow and outflow balance the said pressure in like manner to the embodiment of FIGURE 1. The slide valve 210 provides the manual control of the position of the normal shock at which the relief doors (not shown) start to open.

If a digital fluid positioner of the type shown in FIGURE 3 is employed in a shock wave sensing environment, the switching of an intermediate fluid amplifier without first switching the other amplifiers to the left thereof will have the effect of automatically switching all of the amplifiers to the left. The feedback control will act in opposition to the original bias and cause the power stream of the amplifiers to the left to switch from the left-hand vent outlets to the right-hand power stream outlets directing fluid to the positioner working chamber.

Again, in the second embodiment, the invention has been shown in schematic form. However, it is readily apparent that the pure fluid amplifiers themselves, as well as the digital positioner and its associated slide valve, are formed in conventional fashion. The specific structure of the amplifiers or the digital fluid positioner form no part of the present invention.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in the form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A fluid positioning system comprising a casing forming an enclosed fluid working chamber including a wall member movable longitudinally thereof, a plurality of bistable fluid amplifiers each having plural power stream outlets, means for coupling at least one outlet of each fluid amplifier to said working chamber at points spaced longitudinally along said casing, means for biasing said movable wall to a first position within said casing, and

means for selectively switching said fluid amplifiers whereby said movable wall member moves longitudinally from said first position to a second position to maintain a like number of fluid amplifiers delivering to and receiving fluid from said working chamber.

2. The system as claimed in claim 1 wherein each fluid amplifier includes bleed means for allowing fluid passing from said working chamber to said amplifier to be bled from said amplifier, while said amplifier power stream passes through said other amplifier outlet.

3. The system as claimed in claim 1 wherein each fluid amplifier has a single amplifier outlet coupled to said working chamber and said system further includes means for normally biasing said fluid amplifier power stream to said outlet not connected to said working chamber.

4. The system as claimed in claim 2 further including feedback means coupling a power stream outlet of one amplifier and a port associated with another fluid amplifier to effect automatic switching of a second amplifier in response to switching of said first amplifier.

5. The system as claimed in claim 1 wherein said means for coupling at least one outlet of each fluid amplifier to said working chamber at points spaced longitudinally of said casing includes an intermediate slide valve for selectively coupling said amplifier power stream outlets at various longitudinal positions along said casing.

6. The system as claimed in claim 1 wherein said means for biasing said movable wall to a first position comprises a second working chamber on the opposite side of said wall and acting in opposition to said first working chamber, and outlets of each fluid amplifier are coupled to respective working chambers when said wall is centered with respect to said casing.

7. A digital fluid positioner system comprising a closed, elongated casing carrying a longitudinally movable wall member acting to separate the casing into opposed fluid

working chambers, a plurality of bistable fluid amplifiers, each having a pair of fluid outlets, the fluid outlets for each amplifier being coupled to the casing at longitudinally spaced positions on opposite sides of said movable wall member when said wall member is positioned centrally of said casing, and means for selectively switching said fluid amplifiers whereby said movable wall member seeks a position longitudinally within said casing such that each working chamber has the same number of fluid outlets passing power stream fluid from said working chamber to said amplifiers as outlets delivering power stream fluid from the fluid amplifiers to the chamber itself.

8. The system as claimed in claim 7 wherein each fluid amplifier includes bleed means associated with each amplifier outlet, downstream of the power stream inlet to the amplifier, whereby power stream fluid returning from one working chamber through said amplifier outlet may be bled from the amplifier without affecting power stream flow from said amplifier to said other working chamber through said other amplifier outlet.

9. The system as claimed in claim 7 further including opposed control ports carried by each fluid amplifier on opposite sides of said power stream and each of said control ports adapted to pulse said power stream in response to digital input signals to effectively switch said power stream from said one amplifier outlet to said other amplifier outlet.

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