

May 6, 1969

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3,442,279

SELF-BIASED PURE FLUID AMPLIFIER

Filed Oct. 19, 1966

Sheet 1 of 2

FIG. 1

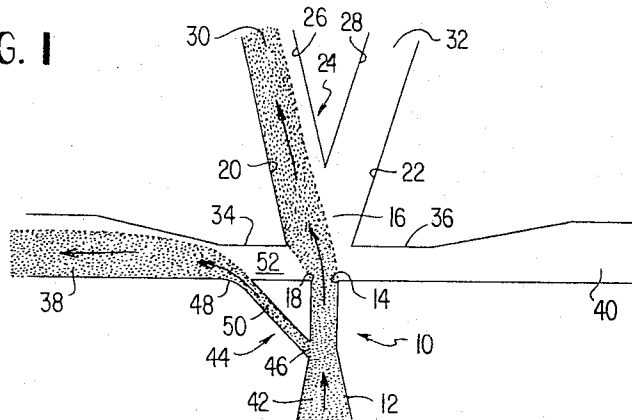


FIG. 2

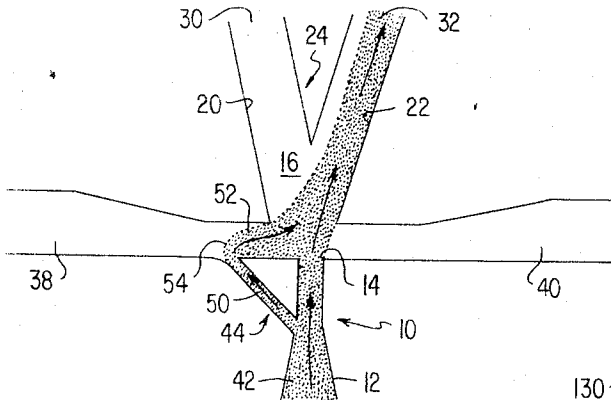


FIG. 3

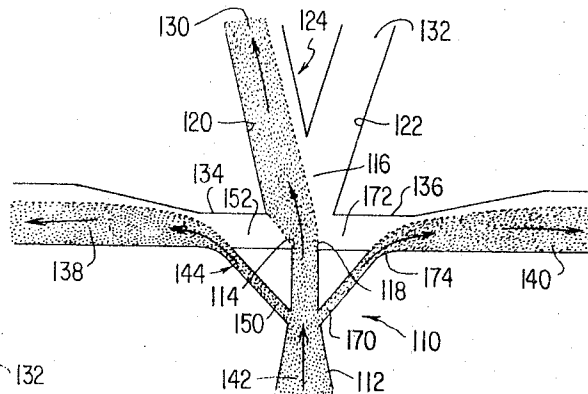
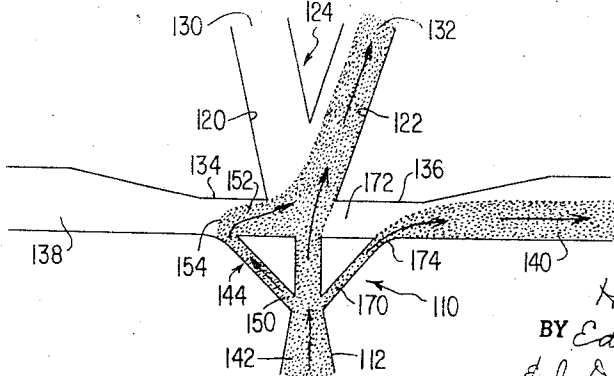


FIG. 4



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FIG. 5

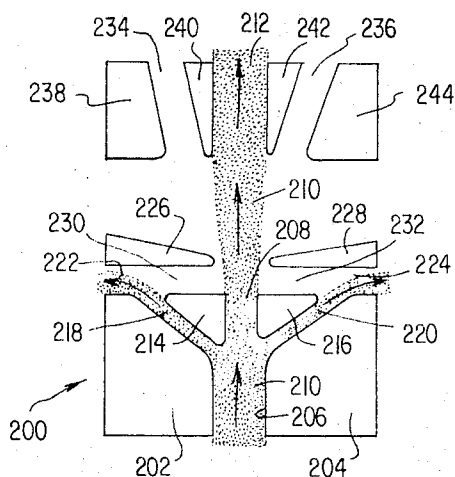
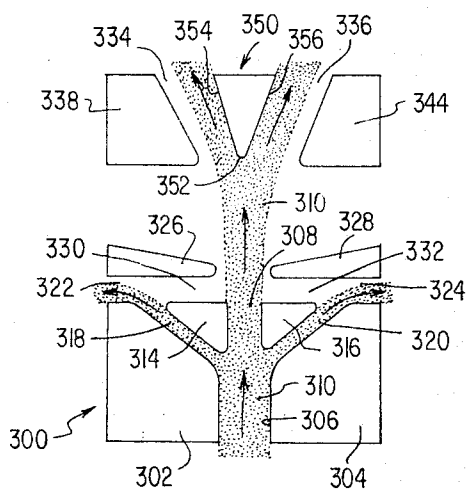


FIG. 6



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SELF-BIASED PURE FLUID AMPLIFIER

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7 Claims

ABSTRACT OF THE DISCLOSURE

In a fluid amplifier means are provided for passing a portion of the power stream through the control channel in a direction away from the interaction chamber in order to create a region of reduced pressure within the control nozzle to ensure passage of the power stream through the chamber and to the fluid outlet on the same side of the interaction chamber as the control channel. The means for accomplishing this function is a channel with one end connected slightly downstream of the power source and the other end connected to a control channel upstream of the interaction chamber. Such means may be provided for each control channel.

This invention relates to pure fluid amplifiers, and more particularly, to a pure fluid amplifier including means for self-biasing the power stream selectively to a preferred power stream outlet.

Fluid amplifiers have recently come into vogue and comprise, in general, a sealed amplifier interaction chamber normally including an end wall and two outwardly diverging side walls commonly referred to as the left and right side walls. A nozzle having an orifice in the end wall discharges a large energy fluid stream, normally referred to as the power stream, into the interaction chamber. A substantially V-shaped flow divider is provided along the opposite end wall with the sides of the divider being generally parallel to the left and right side walls of the chamber and acting to form therewith left and right output passages or outlets, respectively. Fluid control signals, in the form of control streams, are supplied by control nozzles to the interaction chamber, the nozzles being generally positioned perpendicular to the power nozzle and near the power stream inlet side of the chamber. The power stream, therefore, is deflected in the interaction chamber by interaction with the fluid of the control stream, the smaller energy of the control stream controlling the larger energy of the power stream and thus providing amplification. In such a device, since it has no moving parts, it is generally known as a "pure fluid amplifier."

A number of pure fluid amplifiers utilize the "boundary layer effect" to cause the power stream or jet to attach to one or the other of the side walls. This attachment is achieved by an entrainment action of the power jet wherein the power jet tends to entrain air trapped between it and the adjacent side wall with the effect becoming greater as the power jet approaches the adjacent side wall. While entrainment is normally instigated as a result of a positive deflection of a power stream due to either momentum exchange or a pressure differential between the control streams, the boundary layer effect may actually maintain the power stream in contact with the side walls even after cessation of the pressure differential or control stream impingement. This phenomenon is known as "lock on" and the power stream will be retained in this position within the interaction chamber adjacent the selective side wall until positively moved away from this side wall and in contact with the other side wall. The fluid amplifier therefore, acts as a bistable device and

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requires a certain level of control energy input to effect switching.

It is, therefore, an object of the present invention to provide a pure fluid amplifier which requires a minimum control pressure input to effectively switch the bistable device.

It is a further object of this invention to provide an improved fluid amplifier of this type which is characterized by a high input impedance.

It is a further object of this invention to provide an improved pure fluid amplifier in which the need for a separate biasing fluid for biasing the power stream into a preferred outlet is eliminated.

It is a further object of this invention to provide an improved pure fluid amplifier which utilizes a portion of the power stream itself as a biasing means for the amplifier.

It is a further object of this invention to provide an improved self-biased fluid amplifier of this type which may readily act as an oscillator by the mere addition of a single feedback loop, which has both high sensitivity and high frequency response while maintaining a good pressure recovery at the output side of the device.

Other objects of this invention will be pointed out in the following detailed description and claims and illustrated in the accompanying drawing which discloses, by way of example, the principle of the invention and the best mode which has been contemplated of applying that principle.

In the drawing:

FIGURE 1 is a schematic view of one embodiment of the self-biased fluid amplifier of the present invention in the absence of a control signal;

FIGURE 2 is a schematic view of the fluid amplifier shown in FIGURE 1 with a control signal applied to the left-hand control channel;

FIGURE 3 is a schematic view of a second embodiment of the pure fluid amplifier of the present invention including self-biasing means for both the left and right-hand control channels;

FIGURE 4 is a schematic view of the embodiment shown in FIGURE 3 with a control signal applied to the left-hand control channel;

FIGURE 5 is a schematic view of a third embodiment of the present invention as applied to a proportional amplifier;

FIGURE 6 is a schematic view of yet another embodiment of the present invention.

In general, the self-biased fluid amplifier of the present invention comprises in one form, a sealed amplifier interaction chamber including a power nozzle coupled to the chamber for directing a power stream into one end of the chamber. A pair of fluid outlets are coupled to the other end of the chamber and a control chamber including a control nozzle is coupled to the chamber between the power nozzle inlet and the outlets, to one side of the power stream. Means are provided for passing a portion of the power stream through the control channel in a direction away from the chamber to create a region of reduced pressure within the control nozzle to ensure passage of the power stream through the chamber and to the fluid outlet on the same side of the chamber as the control channel. The means for passing a portion of the power stream through the control channel comprises a bias channel having one end coupled to the power stream, upstream of the power nozzle inlet, and the other end fluid coupled to the control channel at a point remote from the interaction chamber. The channel is inclined at its coupling point to the control channel such that the bias flow passes freely from the bias channel into the control channel in a direction away from the interaction chamber.

Referring to the embodiment of FIGURES 1 and 2, the pure fluid amplifier, indicated generally at 10, is of the self-biasing type and includes a fluid supply nozzle 12 for delivering a power stream 42 to an amplifier interaction chamber 16 through power stream nozzle inlet or orifice 14 carried by the end wall 18 of the chamber. Chamber 16 opens up to form a left boundary wall 20 and a right boundary wall 22. Intermediate of the left and right side walls 20 and 22, there is provided a substantially V-shaped flow divider 24 disposed downstream a predetermined distance from the end wall 18. The sides 26 and 28 of the divider are generally parallel to the left and right side walls of the chamber. The regions between the sides of the divider 24 and the left and right side walls define left and right output passages or outlet channels 30 and 32, respectively. Fluid control signals are, in conventional manner, supplied by left-hand control nozzle 34 and right-hand control nozzle 36 to the interaction chamber 16 at generally right angles to the path of the power jet emanating from port 14. The control nozzles 34 and 36 are connected to the chamber adjacent the power stream inlet port 14. Left and right-hand control channels 38 and 40, respectively, are connected to the control nozzles 34 and 36 and act to selectively deliver control stream signals from sources (not shown) to the interaction chamber 16. In conventional fashion, the power stream 42 passes through the power nozzle 12 and enters interaction chamber 16 through inlet port 14 where it is directed by divider 24 into either left output channel or right-hand output channel 32. The fluid amplifier 10 as described to this point is quite conventional.

The present invention is directed to the self-biasing feature of the fluid amplifier and consists essentially of a diagonal, bias slot or channel 44 which has one end 46 coupled to the power stream 42 upstream of the power nozzle inlet orifice 40. The function of the bias slot or conduit 44 is to divert a portion of the power stream from the power nozzle and into a control chamber. The other end 48 of the bias slot is fluid coupled to the left control chamber 38 at a point remote from the interaction chamber 16. In this respect, the angled bias slot 44 opens up into the left-hand control channel at an angle such that the portion 50 of the power jet which is passing through the bias slot moves into the left-hand control channel in a direction away from the interaction chamber 16. With the slot being only a fraction of the width and depth of the power jet 42 and since it joins the control channel at such an angle, most of the flow through the slot flows out of the control channel away from the power jet 42 and interaction chamber 16.

As the power is turned on, the bias flow 50 and the main power stream 42 create a low pressure area 52 within the control nozzle 34, intermediate of interaction chamber 16 and the entrance point of the bias fluid 50 into the left-hand control channel 38. This reduced pressure area acts to entrain the power stream along the left-hand boundary wall 20 of the interaction chamber and maintain the power jet 42 within the left-hand output channel 30 in the absence of control signals. If, at this time, the pressure within the left-hand control channel 38 is raised slightly, the pressure will tend to divert the bias flow 50 from a direction out of the left-hand control channel 38 and move it through left-hand control nozzle 34 into interaction chamber 16.

Reference to FIGURE 2 shows the effect of a positive pressure signal applied to the end of the left-hand control channel 38. The bias flow 50 still passes, as indicated by the arrows, through the bias slot 44 but instead of moving away from the interaction chamber, the high pressure of the signal deflects the bias flow stream 50 at point 54 and moves it into the interaction chamber 16. This destroys the partial vacuum within area 52 and allows switching of the amplifier power stream from left-hand output channel 30 to right-hand output channel 32 along the right boundary wall 22. The switching pressure re-

quired is only a bucking pressure needed against that already present in the left-hand control channel 38. The bucking pressure is responsible for the bias flow 50 turning its direction in the control channel 38 and flowing back through control nozzle 34 into the power stream 42 discharging from power stream nozzle orifice 14.

The practicability of the self-biased fluid amplifier of the present invention may be easily observed, by assuming instead of a positive signal being applied at the open end of the left-hand control channel 38, the left-hand end of the channel 38 would simply be closed off. The bleed or bias flow 50 passing through the bias slot 44 would have nowhere to go and would most necessarily have to reverse itself and flow through the left-hand control nozzle 34 into the interaction chamber 16 resulting in switching of the control stream output from the left output channel 30 to the right output channel 32. If the assumption is made that the right-hand control channel 40 opens up to the atmosphere, it is further obvious that upon the removal of the blocking means across the outlet of the left-hand control channel 38, the passage of the bias flow 50 through the bias slot 44 will again result in a partial vacuum or a negative pressure appearing at 52 in left-hand control nozzle section 34 resulting in an immediate switch of the power stream 42 from the right-hand output channel 34 to the left-hand output channel 30. Since the embodiment of FIGURES 1 and 2 has a self-biased channel or slot 44 only on one side, the power jet stream will always return to the output channel adjacent to the control channel receiving the bias flow upon removal of the control signal. Note further that by applying sufficient negative pressure to the right-hand control channel 40, switching will occur in spite of the self-bias.

Self-biasing may be applied to both the left-hand and right-hand control channels of typical fluid amplifiers. Referring to the embodiment of FIGURES 3 and 4, it is noted that amplifier 110 is provided with a power nozzle 112 for directing a power stream 142 through the nozzle into an amplifier interaction chamber 116 with the nozzle orifice 114 positioned centrally of chamber end wall 118. Again, the interaction chamber 116 is characterized by left and right side walls 120 and 122, respectively, with divider member 124 forming, in conjunction with side walls 120 and 122, left and right output or outlet channels 130 and 132, respectively. Further, left-hand control nozzle 134 opens up into interaction chamber 116 and is coupled to a left-hand control channel 138 on the side away from the interaction chamber. Right-hand control nozzle 136 is positioned near the upstream end of interaction chamber 116 adjacent the power stream inlet orifice 114 and is fluid coupled to the right-hand control channel 140. Again, the left-hand control channel is coupled to the power stream 142 upstream of the power jet inlet orifice 114 by means of a bias slot or channel 144 which receives a portion of the power stream identified as bias flow 150. The bias slot 144 is inclined toward the outer end of the left-hand control channel such that flow of the biasing fluid 150 through the bias slot tends to create a low pressure area 152 within the left-hand control nozzle immediately to the left of interaction chamber 116. Unlike the previous embodiment, a second bias slot or channel 174 is provided and which has one end connected to the power jet stream 142 upstream of the power stream orifice or inlet 114 with the other end opening up into the right-hand control channel 140. A second portion of the power stream passes through the bias slot 174 in the form of bias flow 170 and moves in like manner in the absence of control signals into the right-hand control channel 140 and outwardly away from the interaction chamber 116 to also provide an area 172, within right-hand control nozzle 136, of reduced pressure.

When the power jet 142 is turned on, the fluid stream emanating from orifice 114, in passing through chamber

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116, will attach itself either to the left or right-hand boundary wall 120 or 122 depending upon chamber geometry. At the same time there is a small bias flow passing through respective bias slots 144 and 174 and into associated left and right-hand control channels 138 and 140. The principle of switching for either left or right-hand control channels is the same as the operation for the left-hand control channel of the FIGURE 1 embodiment. However, with a bias slot on each side of the amplifier connected to respective left-hand and right-hand control channels, the amplifier has stability in either position. For instance, assuming, in the absence of a control signal, that the power stream 142 is passing through the chamber and into the left-hand output channel 130, as indicated in FIGURE 3, the application of a positive pressure control signal to the left-hand control channel 138 results in flipping of the power stream from the left-hand output channel 130 to the right-hand output channel 132, as seen in FIGURE 4. Again, the appearance of a positive signal will tend to oppose the biasing flow 150 as it discharges from the control end of the bias slot into the control channel. It, therefore, reverses itself, as indicated at 154, and passes back through the left-hand control nozzle 134 and into chamber 116. This destroys the reduced pressure zone 152 within the left-hand control nozzle 134. At the same time, in the absence of a positive right-hand control signal, a portion of the power stream still passes as bias flow 170 through the right-hand bias slot 174 and into the right-hand control channel 140. This maintains the reduced pressure zone 172 between chamber 116 and the right-hand control channel 140 and does not really effect the flipping of the power stream from left-hand output channel 130 to right-hand output channel 132. The power stream 142 now hugs the right boundary wall 120 and upon cessation of the positive signal on the outer end of the left-hand control channel 138, the power stream will remain attached to the right-hand boundary wall 122 and pass through the right-hand output channel 132. Thus, unlike the FIGURE 1 embodiment, upon the cessation of a control signal there will be no tendency for the power stream to revert or switch back to the original channel. The switching process is aided somewhat by the bias flow of the side being switched in addition to the destruction of the reduced pressure zone, such as 152, within the control nozzle which is at that point acting to receive the bias flow as it is diverted back into the interaction chamber.

The present invention has further application to fluid amplifiers of the proportional type. Proportional amplifiers incorporating the self-biasing means of the present invention have particular application for systems in which it is desirable to impedance match the control channel for the self-biased proportional amplifier and the control source. Referring to FIGURE 5, there is shown schematically a pure fluid amplifier of the proportional type. The amplifier 200 includes left and right-hand channel defining members 202-204, forming a power stream nozzle 206 including a control nozzle inlet 208 for directing the control stream 210 toward a central power stream outlet 212. Secondary members 214 and 216 further act in conjunction with members 202 and 204 to define the power stream nozzle 206 while at the same time defining respective left and right-hand bias channels 218 and 220, respectively. The bias channels open up into control channels 222 and 224 which are oriented at right angles to the main power stream 210 and are formed by elongated, triangular shaped, left and right-hand members 226 and 228, respectively. The rather high impedance of the control channels 222 and 224, created by members 226 and 228, insures the direct impingement of the control signals onto the main power stream 210.

In like manner to the previous embodiments, the small portions of the power stream which are diverted through the left and right-hand bias channels 218 and 220, act to produce reduced pressure areas at 230 and 234 between

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the main power stream 210 at its nozzle inlet area 208 and the points where the inclined bias channels intersect respective control channels. In the embodiment of FIGURE 5, there is a tendency of both control channels to deflect the power stream 210 from the central outlet 212 toward the left-hand outlet channel 234 or right-hand outlet channel 236. The equal and opposite effect maintains the power stream in the central outlet 212 in the absence of a control signal. The left-hand outlet channel is defined by fixed members 238 and 240, while right-hand outlet 236 is defined by members 242 and 244. All three power stream outlets 212, 234 and 236 are spaced downstream of the power stream inlet 208 a distance in the order of six times the width of the power stream inlet 208, in conventional fluid amplifier fashion. The effect of an increased pressure on either control channel is identical to that described with respect to the prior embodiments. For instance, increasing the pressure on the control channel 222, on the outlet side thereof, causes the bias flow passing through bias channel 218 to reverse itself within the control channel and move back toward the main power stream at its exit point 208 from the inlet nozzle 206 and to thereby deflect the power stream 210 from the central outlet 212 to the right-hand outlet 236. This effect is actually aided by the low pressure area 232 existing between the power stream 210 and the right-hand control channel 224 at the point of entrance of the right-hand bias channel 220. Upon cessation of a control pressure on the left-hand control channel 222, the power stream will tend to return to the position shown in FIGURE 5 and pass outwardly through the central outlet 212.

Referring to FIGURE 6, there is shown a slight variation in the proportional fluid amplifier 300 which utilizes the self-biasing technique of the present invention. In this case, instead of having three spaced outlets, downstream of the main power nozzle inlet, there are provided a pair of outlets in the manner of the embodiment of FIGURES 1 and 3 including a centrally located splitter. Again, the schematic representation includes a pair of block members 302 and 304 cooperating with block members 314 and 316 to define a power stream nozzle 306 including power stream nozzle inlet 308. Members 314 and 316 further cooperate with members 302 and 304 to define inclined left and right-hand bias channels 318 and 320, respectively, which open up into right-hand control channels 322 and 324, respectively. The narrow, triangular shaped elements 326 and 328 positioned on opposite sides of the power stream 310 as it passes through nozzle inlet 308 act in conjunction with members 302 and 314 on the left-hand side and 304 and 316 on the right-hand side to define high impedance control channels 322 and 332. The power stream 310, from a source (not shown) in the absence of a control signal, is biased as to pass directly toward splitter 350 which includes converging outer surfaces 354 and 356 forming the splitter apex 352 which acts to separate the power stream 310 and normally divert equal portions through left and right-hand outlets 334 and 336, respectively. The outlets are formed by splitter member 350 and respective left and right-hand channel forming members 338 and 344. As shown, in the absence of a control signal, small portions of the main power stream 310 pass through bias channels 318 and 320, respectively, into control channels 322 and 324 to produce equal and opposite low pressure areas 330 and 332 which tend equally to divert the power stream to the outlet nearest the respective control channels and maintain it centered with splitter 350. Proportional amplification is achieved in response to a control pressure differential across the control channels 322 and 324. In the same sense as the previous embodiment, the increase in control channel pressure, for instance, in control channel 324, causes the bias flow to reverse itself within the control channel and pass through low pressure area 332 and toward the main power stream 310 and the interaction therewith tends to cause the volume of the power stream

passing through right-hand outlet 336 to diminish and the volume passing through left-hand outlet 334 to increase. Again, the continued presence of the reduced pressure area 330 within the left-hand channel 322 tends to draw the power stream toward the left-hand outlet 334. Further, cessation of the positive pressure being applied to right-hand control channel 324 results in the return of the power stream to the centered position shown in FIGURE 5 with equal volumes of flow passing through both left and right-hand outlets 334 and 336.

From the above description, it is obvious that the present invention, in all forms provides a fluid amplifier having a high input impedance. The only requirement to achieve switching is the application of a relatively low pressure to the control input. Since the power jet channel of the amplifier provides all the required flow, the present improved fluid amplifier is exceedingly useful when the device is fed by another having a very limited flow. For instance, in circuits, such as computers, a clock pulse is usually required to switch many units at one time requiring a large amount of flow. If the amplifier is being switched of the self-biased type of the present invention, only a small pressure from a small clock would be needed to perform a multiple switching process.

Further, it is conventional with small fluid devices to normally entrain through the controls. This often results in the clogging of channels as a result of small particles entrained due to environmental conditions. Since the present invention is characterized by some flow out of the channels as a result of the bias slot flow path, no entrainment in the control exists, eliminating the possibility of clogged channels. The principles of the present invention may be easily applied to an oscillator by modifying the pure fluid amplifiers shown through the addition of a single feedback loop. The principles may be further applied to a fluid "NOR" or other similar fluid devices. The characteristics are determined by the size and number and angles of the bias slot. For instance, in a typical "NOR" unit, only one self-biasing slot for the power jet channel to the control channel would be required and a regular high input impedance amplifier would have slots from the power jet channel to each control channel. Thus, most normal existing fluid amplifiers may be converted to the self-biasing type by the simple addition of one or more bias slots incorporating the advantages enumerated with respect to the embodiment shown.

While the invention has been shown as applied to fluid amplifiers in schematic form, the fluid amplifiers themselves may be conveniently 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 and the multiple fluid passages or channels. The exact manner in which the amplifier is assembled through the use of multiple plates does not form a part of the invention and any conventional technique may be utilized. The invention has broad application to pure fluid amplifiers or to fluid amplifiers which include moving parts.

What is claimed is:

1. A self-biased fluid amplifier comprising:

at least two fluid outlets, a power nozzle for directing a power stream toward said fluid outlets spaced downstream thereof, a control channel including a control nozzle positioned between said power nozzle inlet and said outlets and to one side of said power

stream for directing a control stream toward and in intersecting relation with said power stream, and biasing means for passing a portion of said power stream through said control channel contiguous to said control nozzle in a direction away from said main power stream to thereby create a region of reduced pressure within said control nozzle to cause said power stream to pass to the fluid outlet nearest said control channel.

2. The fluid amplifier is claimed in claim 1 wherein said biasing means including a bias channel having one end coupled to said power stream, upstream of said power nozzle inlet.

3. The fluid amplifier as claimed in claim 2 wherein said bias channel has the other end fluid coupled to said control channel at a point remote from said power stream nozzle inlet.

4. The pure fluid amplifier as claimed in claim 3 wherein said bias channel is inclined at the point of fluid coupling to said control channel such that the bias flow from said bias channel passes into said control channel in a direction away from main power stream.

5. A self-biased fluid amplifier comprising:

a power nozzle, at least two spaced fluid outlets positioned downstream of said power nozzle inlet, said power nozzle directing a power stream toward said outlets, opposed control channels including associated control nozzles positioned between said power nozzle inlet and said outlets, on opposite sides of said power stream for directing control streams toward and in intersecting relation with said power stream, and means for directing portions of said power stream through respective control channels contiguous to said control nozzles in a direction away from said main power stream to create areas of reduced pressure between said main power stream and said control channel tending to bias said main power stream toward the outlet closest to a respective control channel.

6. The fluid amplifier as claimed in claim 5 wherein said means for directing a portion of said power stream into said control channel comprises bias channels, each having one end fluid coupled to the power stream, upstream of said power nozzle inlet, and having the other end fluid coupled to respective control channels at a point remote from said main power stream nozzle inlet.

7. The pure fluid amplifier as claimed in claim 6 wherein said bias channel is inclined with respect to said control channel axis such that incoming bias channel flow passes freely into said control channel in a direction away from said interaction channel.

References Cited

UNITED STATES PATENTS

3,144,208	8/1964	Severson	137—81.5
3,153,934	10/1964	Reilly	137—81.5
3,170,476	2/1965	Reilly	137—81.5
3,191,858	6/1965	Sowers	137—81.5
3,220,428	11/1965	Wilkerson	137—81.5
3,233,522	2/1966	Stern	137—81.5
3,241,669	3/1966	Schonfeld et al.	137—81.5

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