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[54] **HIGH GAIN MONOSTABLE FLUIDIC SWITCHING DEVICE**
8 Claims, 4 Drawing Figs.

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[50] Field of Search 137/81.5; 261/36

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ABSTRACT: A high gain monostable fluid amplifier serves as a metering valve in which a fluid stream can be deflected from a primary receiver to an alternate receiver by means of control pulses. The frequency and duration of the control pulses provide means for varying the amount of fluid delivered to the alternate receiver. Auxiliary control slots employed in the interaction region provide rapid response to the presence and absence of a control pulse and provide sharp cutoff when switching from the auxiliary receiver to the primary receiver. The control slots are arranged to oppose wall attachment in the primary receiver when a control pulse is present and to assist wall attachment in the primary receiver in the absence of a control pulse. In the preferred form, the metered fluid is liquid and the control fluid is gas, for example, a liquid fuel metered by an air signal.

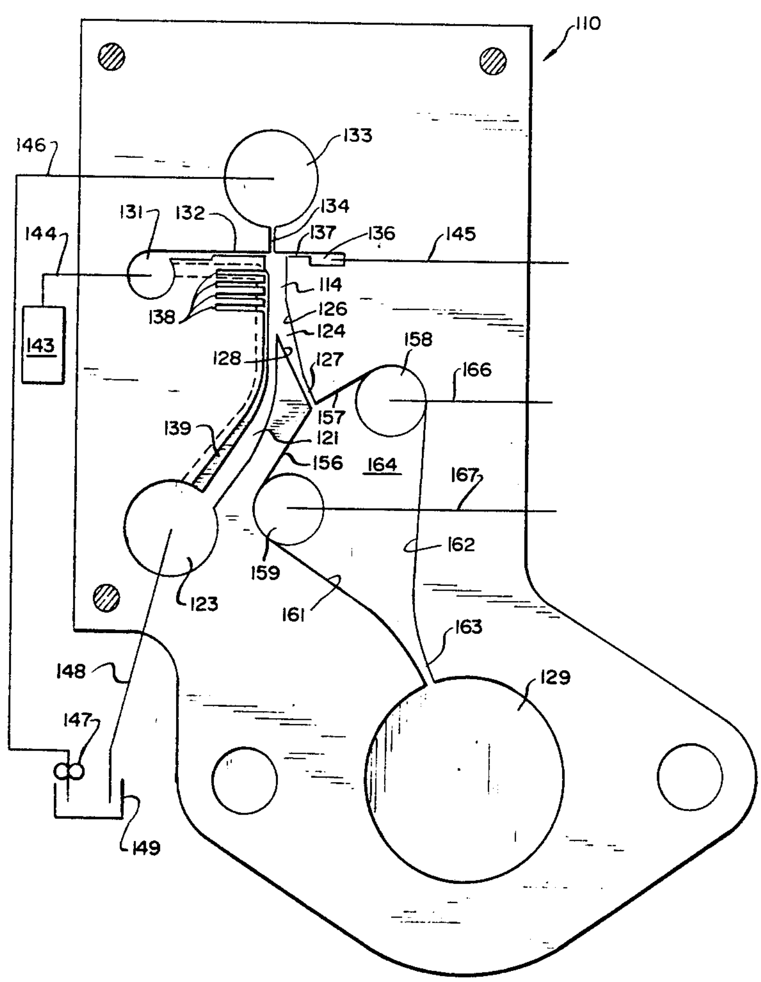


FIG. 1

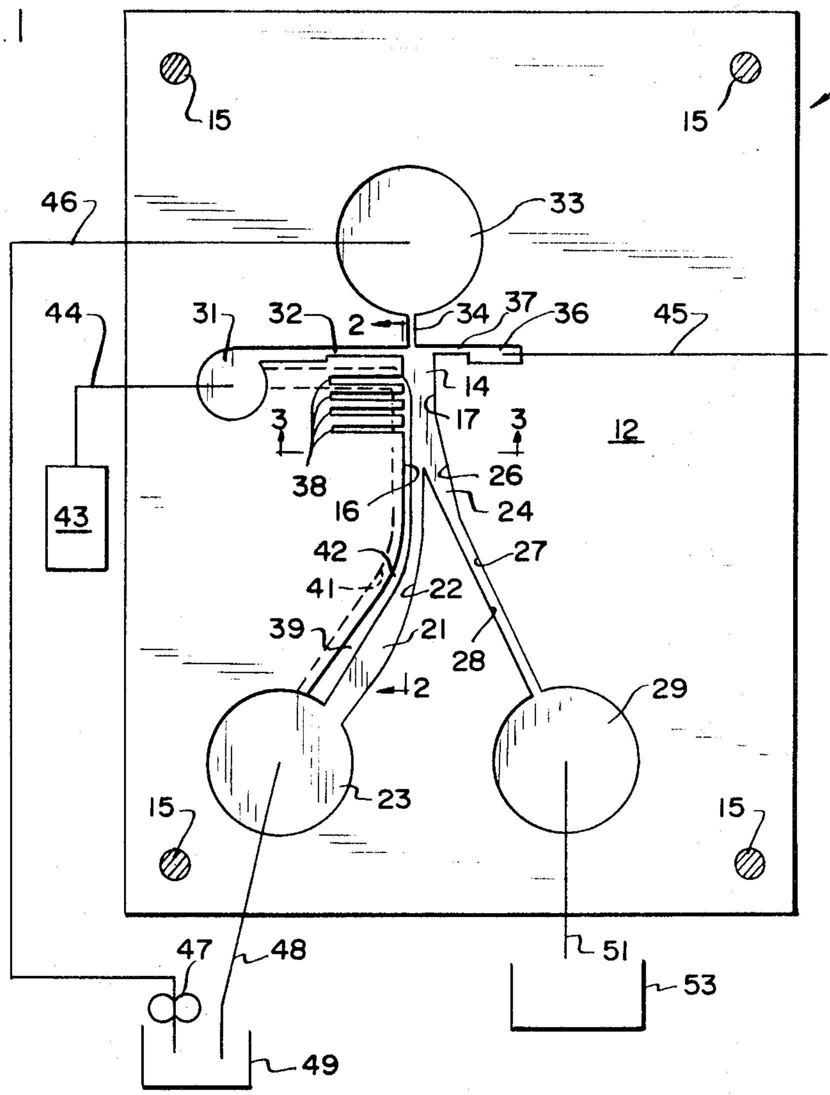


FIG. 2

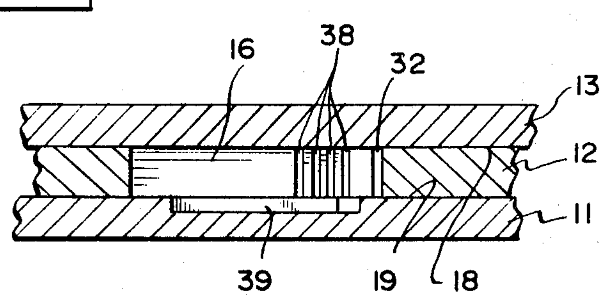
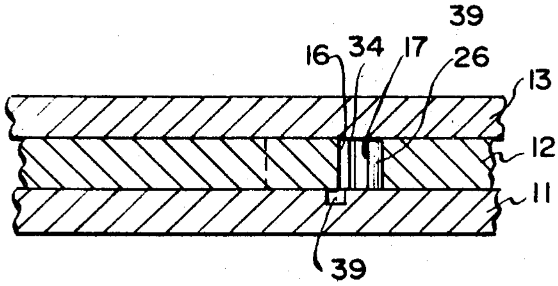


FIG. 3



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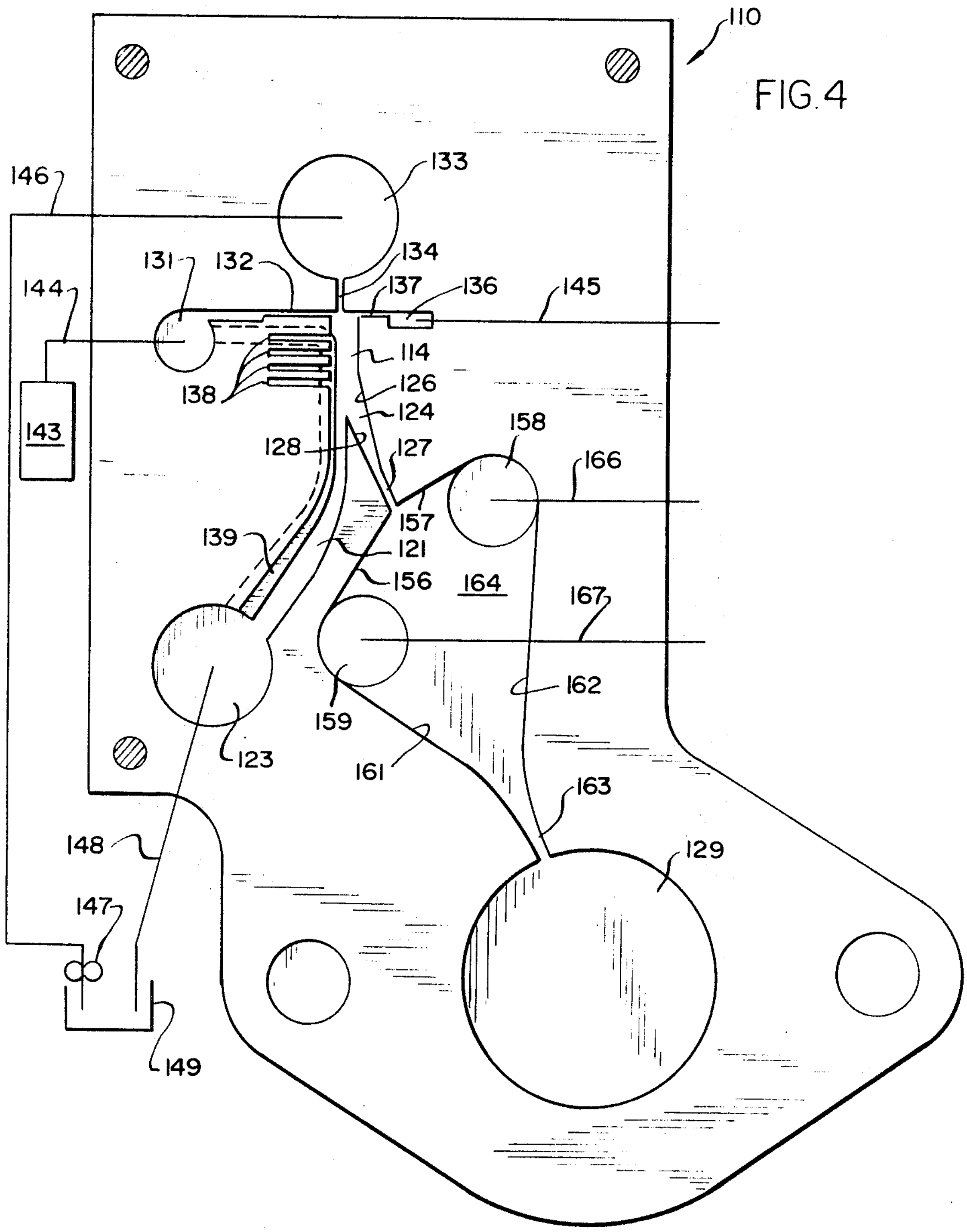

FIG. 4

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HIGH GAIN MONOSTABLE FLUIDIC SWITCHING DEVICE

SUMMARY OF THE INVENTION

The present invention relates generally to fluid logic elements and more particularly to a digital-type amplifier.

Fluid amplifier devices, in general, have the capability of selectively deflecting a fluid stream among alternate receivers, in response to the application of fluid pressure signals. It is an object of the present invention to provide a fluid amplifier for metering the fluid delivered to a selected receiver in accordance with a fluid pressure control signal. A further object is to provide a fluid amplifier which substantially excludes flow to a selected receiver in the absence of a control signal. A further object of the invention is to provide a fluid amplifier in which the behavior of the fluid stream is closely controlled by the fluid pressure control signal which may be applied in the form of pulses of varying duration or frequency. A still further object is to provide a fluid amplifier in which a relatively high energy fluid stream such as a liquid can be controlled by a relatively low energy control signal such as air. A still further object is to provide a fluid amplifier for metering a fluid stream to alternate receivers in which the receivers are subjected to substantially different pressure conditions. An additional object is to provide a fluid amplifier for metering liquid fuel delivered to a negative pressure region, such as the intake system of an internal combustion engine, by means of a control signal such as air pulses corresponding to the speed and load of the engine. Other objects and advantages of the invention will become apparent from the following description together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of an amplifier according to the present invention, with portions removed to reveal the internal passages therein;

FIG. 2 is a fragmentary section view taken along the line 2–2 of FIG. 1;

FIG. 3 is a fragmentary section view taken along the line 3–3 of FIG. 1; and

FIG. 4 is a plan view similar to FIG. 1, of an alternate embodiment of the fluid amplifier of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now in more detail to the drawings and particularly FIGS. 1, 2 and 3 thereof, the reference character **10** generally indicates a fluid switching device according to the present invention. The body of switching device **10** may include a stack of plates **11**, **12**, **13** of a fluid impervious material such as plastic, in which the various fluid passages described hereinafter are formed. The plates are secured to each other as by cap screws **15** to form a fluid impervious body.

A fluid interaction chamber **14** is defined in part by walls **16**, **17** in plate **12** and by the inner surfaces **18**, **19** of plates **11** and **13**. A first receiver duct **21** extends from interaction chamber **14** sharing the common wall **16** and having the spaced wall **22**. First receiver duct **21** terminates in the first outlet port **23**. A second receiver duct **24** is defined in part by the wall portions **26**, **27**, **28** and extends from the interaction chamber **14** to the second outlet port **29**.

A control chamber **31** is formed in plate **12** and communicates with interaction chamber **14** by means of a control nozzle **32** extending transversely through wall **16**. A supply chamber **33** includes a power nozzle **34** extending substantially parallel to wall **16** and opening into interaction chamber **14** opposite first receiver duct **21**. An ambient chamber **36** and nozzle **37** are arranged oppositely to control chamber **31** and nozzle **32** and communicate with interaction chamber **14** through wall portion **17**.

A group of control slots **38**, here shown as four in number, open through wall **16** into interaction chamber **14** at an angle with respect to power jet **34**. Control slots **38** act as auxiliary control nozzles aiding in switching flow between receivers **21** and **24**. An auxiliary control channel **39** is defined in part by wall portions **41**, **42** and communicates with control slots **38**. Auxiliary control channel **39** also communicates with control chamber **31**, with first outlet port **23** and with the common attachment wall **16**. For convenience, auxiliary channel **39** is here shown as a single continuous slot formed in bottom plate **11**, however, the channel may be formed in plate **12** if desired, or a pair of channels may be formed in plates **11** and **13** if desired. Auxiliary channel **39** need not be a single continuous passage, but may be in the form of separate channels communicating control slots **38** with other portions of the device.

When amplifier **10** is used for metering, fluid is diverted into receiver **24** for a given time interval, it is therefore important that fluid be excluded from receiver **24** at the end of the time interval which is measured in terms of duration of the control pulse in chamber **31**. The amplifier is geometrically biased to switch fluid back to first receiver **21** in the absence of a control pulse. In order to achieve sharp cutoff when switching the fluid stream from receiver **24** back to the first receiver **21**, it is important that one of the auxiliary slots **38** be connected to a downstream portion of receiver **21**. When the control pulse is terminated, fluid returns to receiver **21**, and the flow of fluid in receiver **21** tends to purge or scavenge the control slot resulting in evacuation along the attachment wall in the interaction chamber. This evacuation of the attachment wall supplements the return of the fluid stream to first receiver **21**.

While not essential to the metering function, it is nevertheless desirable to switch the fluid stream quickly into receiver **24** when a control pulse is initiated. It is therefore desirable that at least one of the control slots **38** be connected to the control chamber **31**. Thus when a control pulse is initiated in control chamber **31**, control jets issue from control nozzle **32** and from the connected control slot **38** which then functions as a supplementary or auxiliary control nozzle. The supplementary jet issuing from the control slot **38** provides a bubble or wedge of air along the attachment wall **16** which spoils the wall attachment of the liquid jet issuing from power nozzle **34**. At the same time, the control jet issuing from control nozzle **32** interacts with the liquid jet issuing from power nozzle **34** switching the liquid stream into receiver **24**.

As shown in the drawing the control slots **38** are connected to both the downstream portion of receiver **21** and to the control chamber **31**, thus the control slots participate both in switching the stream into receiver **24** when a control pulse is initiated and in excluding the stream from receiver **24** when the control pulse is terminated. The comprehensive configuration shown in the drawing may be modified if desired, in order to provide a particular level of performance. For example, single or multiple control slots may be employed depending upon the energy level of the jet issuing from power nozzle **34** in proportion to the energy level of the control pulse. In other configurations, it may be desirable to connect one or more control slots to a downstream portion of receiver **21** without at the same time being connected to the control chamber **31**, or some of the control slots may be connected downstream of receiver **21** while others are connected with control chamber **31**. The number of slots employed and their connections to other portions of the device provide means for selecting desired switching characteristics of the device.

A circuit employing the switching device **10** is shown schematically in FIG. 1. A pulse generating apparatus **43** is connected to control chamber **31** by means of a conduit **44**. Pulse generating apparatus **43** may take many forms depending upon the metering function to be performed by the amplifier **10**. In its simplest form pulsing apparatus **43** can be a simple OFF - ON valve for regulating a fluid control pressure applied to control chamber **31**. On the other hand, pulsing apparatus **43** may involve more complex apparatus for supplying a control signal in which the frequency and/or the duration of the fluid pressure pulses are regulated in accordance with a selected condition or combination of conditions.

Supply chamber 33 is connected to a conduit 46 and pump 47 for supplying fluid under pressure to the switching device 10. First outlet port 23 is connected to a conduit 48 arranged to deliver fluid to the sump 49. Second outlet port 29 is connected to a conduit 51 for delivering fluid to an alternate receptacle 53. Ambient chamber 36 is vented to atmosphere by means of conduit 45. If desired, ambient chamber 36 may be connected to an adjustable source of fluid pressure for adjusting the switching bias of amplifier 10.

Considering now the operation of switching device 10 as shown in FIG. 1, fluid such as a liquid is supplied under pressure to supply chamber 33. Nozzle 34 projects a stream of fluid through interaction chamber 14 into first receiver duct 21 from which the fluid is conducted to sump 49 by means of first outlet port 23 and conduit 48. In the absence of a fluid control pressure in control chamber 31, the fluid stream from power nozzle 34 is directed toward first receiver duct 21. Movement of fluid in first receiver duct 21 tends to evacuate auxiliary channel 39 which in turn tends to evacuate control slots 38. Also, discharge of fluid through first outlet port 23 tends to evacuate auxiliary channel 39 and control slots 38 in the absence of a control fluid pressure in control chamber 31. Evacuation of control slots 38 tend to enhance wall attachment of the fluid stream to the wall 16 thus substantially excluding the fluid stream from second receiver duct 24. Thus, in the absence of a control signal, the fluid is recirculated to sump 49.

DESCRIPTION OF AN ALTERNATE EMBODIMENT

Referring now to FIG. 4, an alternate embodiment of the fluidic switching device of the present invention is shown, particularly adapted for use as a fuel metering device for an internal combustion engine.

The metering valve 110 is similar in many respects to the construction shown in FIG. 1, but having modifications in the second receiver duct. Metering valve 110 includes an interaction chamber 114, a first receiver duct 121, a first outlet port 123, a control chamber 131, control nozzle 132, supply chamber 133, power nozzle 134, ambient chamber 136, ambient nozzle 137, control slots 138 and auxiliary control channel 139. The above named portions of the device may be similar in construction and function to those described in connection with FIG. 1, to which reference should be made for a more detailed description.

Referring now to the modified second receiver duct 124, the wall portions 126, 128 converge toward each other forming a fluid restriction as indicated at 127.

The spaced walls of second receiver duct 124 then diverge from each other as indicated by portions 156, 157, encompassing a pair of laterally spaced vent ports 158, 159, The walls then reconverge toward each other as indicated by portions 161, 162 to form a second fluid restriction 163. The sidewall portions 156, 157, 161, 162 together with top and bottom plates (such as plates 11 and 13 of FIG. 1) form a vent chamber or isolation chamber 164 in second receiver duct 124 between interaction chamber 114 and second outlet port 129.

Referring now to the schematic circuit diagram shown in connection with metering valve 110, a fuel tank 149 and fuel pump 147 supply liquid fuel to supply chamber 133 by means of conduit 146. In the absence of a control signal, the fuel is recirculated back to tank 149 by means of first receiver duct 121, first outlet port 123 and return conduit 148. Interaction chamber 114 is vented to atmosphere or to a bias control by ambient chamber 136, nozzle 137 and conduit 145. Pulse generator 143 preferably provides a series of air pressure pulses in which the frequency of the pulses is a function of engine speed and the duration of a pulse is a function of engine load. This signal is conducted to control chamber 131 by means of conduit 144 and serves to deflect fuel issuing from power nozzle 134 into second receiver duct 124.

Second outlet port 129 is adapted for incorporation into the intake system of an internal combustion engine where it is subjected to negative pressures ranging from a few inches of water to several inches of mercury. The vent chamber 164 provides means for isolating such negative pressure conditions from the control pressure and biasing means acting in the interaction chamber.

In the absence of a control pressure, no flow occurs in second receiver 124. In this case negative pressure in second outlet port 129 results in the bleeding of air from vent ports 158, 159 and conduits 166, 167 through vent chamber 164 and second restriction 163 into the second outlet port while the first restriction 127 serves to isolate interaction chamber 114 from vent chamber 164. Thus in the absence of a control signal, fuel is returned through first receiver 121 even though second outlet port 129 is subjected to a high negative pressure.

When a control pressure signal is present, fuel is deflected into second receiver duct 124 issuing as a stream through restriction 127 into vent chamber 164. The converging wall portions 161, 162 of vent chamber 164 together with the negative pressure in second outlet port 129 in cooperation with the vent ports 158, 159 result in reformation of the fluid stream which then projects as a stream through restriction 163. The fluid stream thus projected into second outlet port 129 becomes dispersed in the intake air system for the internal combustion engine.

The foregoing description is directed to particular embodiments of the device which are capable of switching a liquid stream typical of internal combustion engine fuel by means of an air signal. The description is therefore exemplary of a preferred embodiment of the device for use with fluids of a particular density under a particular set of pressure conditions. Appropriate modifications will be suggested to those skilled in the art in view of the pressures and densities of the operating fluids with which the device is to be used.

What we claim is:

1. A fluid amplifier device capable of controlling a liquid jet by means of a gas control pulse, comprising a body member having defined therein a fluid interaction chamber, first and second receiver ducts communicating with said interaction chamber, a power nozzle communicating with said interaction chamber and aligned with said first receiver duct adapted to project a liquid jet through said interaction chamber, a first control nozzle angularly disposed with respect to said power nozzle opening into said interaction chamber adapted to project a gas jet into said interaction chamber, and auxiliary control means including at least one auxiliary control nozzle opening into said interaction chamber spaced downstream from said first control nozzle, and an auxiliary channel communicating said auxiliary control nozzle with a downstream portion of said first receiver duct.

2. A fluid amplifier according to claim 1, wherein said auxiliary channel communicates said auxiliary control nozzle with said first control nozzle and with said downstream portion of said first receiver duct.

3. A fluid amplifier according to claim 1, in which said interaction chamber and said first receiver duct have a common wall member, said first control nozzle and said auxiliary control nozzle opening through said common wall member into said interaction chamber, said auxiliary control nozzle also communicating with a portion of said wall member located in said first receiver duct.

4. A fluid amplifier according to claim 3, wherein said auxiliary channel extends along a portion of said common wall member in said interaction chamber and said first receiver duct, providing communication between said auxiliary control nozzle and said downstream portion of said first receiver duct.

5. A fluid amplifier according to claim 3, including a plurality of auxiliary control nozzles opening through said common wall member into said interaction chamber.

6. A fluid amplifier according to claim 5, including a control chamber connected to said first control nozzle, and an auxilia-

ry channel connected to said control chamber and extending along a portion of said common wall member communicating said plurality of auxiliary control nozzles with said control chamber and with a downstream portion of said first receiver duct.

7. A fluid amplifier device including an interaction chamber, a power nozzle opening into said interaction chamber, and first and second receiver ducts extending from said interaction chamber, said interaction chamber having biasing means associated therewith for normally directing fluid flow from said power nozzle into said first receiver duct, and having pressure control means associated therewith for selectively switching fluid flow into said second receiver duct, said second receiver duct being connected to an outlet port adapted for connection to a negative pressure region, said second receiver duct including a pair of spaced sidewall portions converging toward each other defining a first fluid restrictor, said sidewall portions diverging from each other defining an isolation chamber and reconverging toward each other defining a second fluid restrictor disposed between said interaction chamber and said outlet port, isolating said negative pressure region from said biasing means and control means, said second fluid restrictor being in substantial alignment with said first fluid restrictor, said isolation chamber including a pair of laterally spaced venting ports disposed on opposite sides of a line extending through said first and second restrictors.

8. A fluid amplifier according to claim 7, adapted for selectively delivering a measured charge of liquid fuel into said second receiver duct, said outlet port forming a portion of an air induction passage for an internal combustion engine, said isolation chamber including a pair of converging sidewall portions defining an outlet nozzle opening into said outlet port, said isolation chamber including a pair of laterally spaced venting ports arranged on opposite sides of said outlet nozzle, said venting ports and outlet nozzle providing means for projecting said charge of liquid fuel into said air induction passage for dispersal into an air stream.