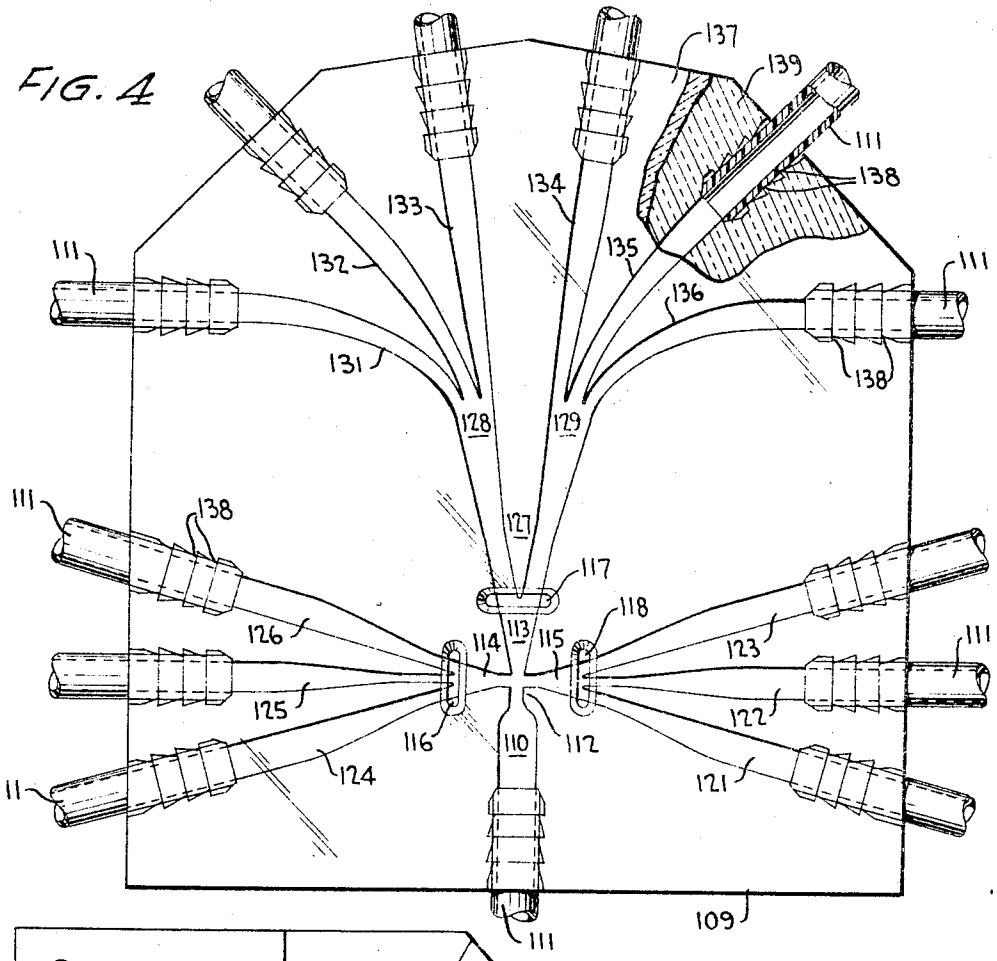
Sept. 13, 1966 R. W. WARREN 3,272,214

SELF-MATCHING FLUID ELEMENTS

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FIG. 4



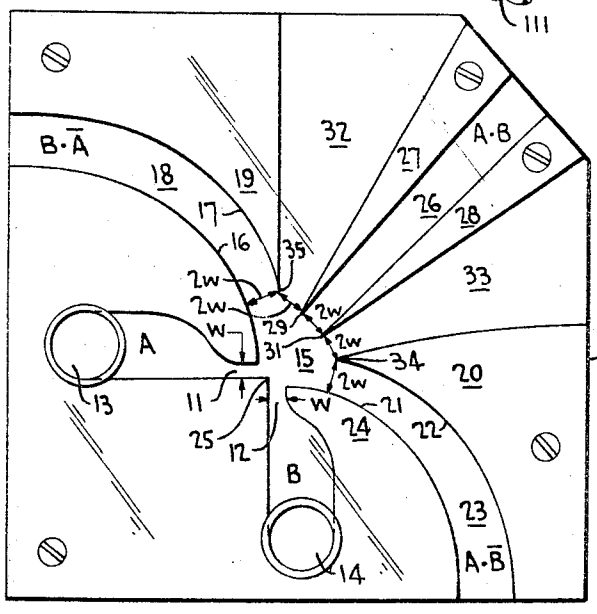


FIG. 1

INVENTOR,
RAYMOND W. WARREN

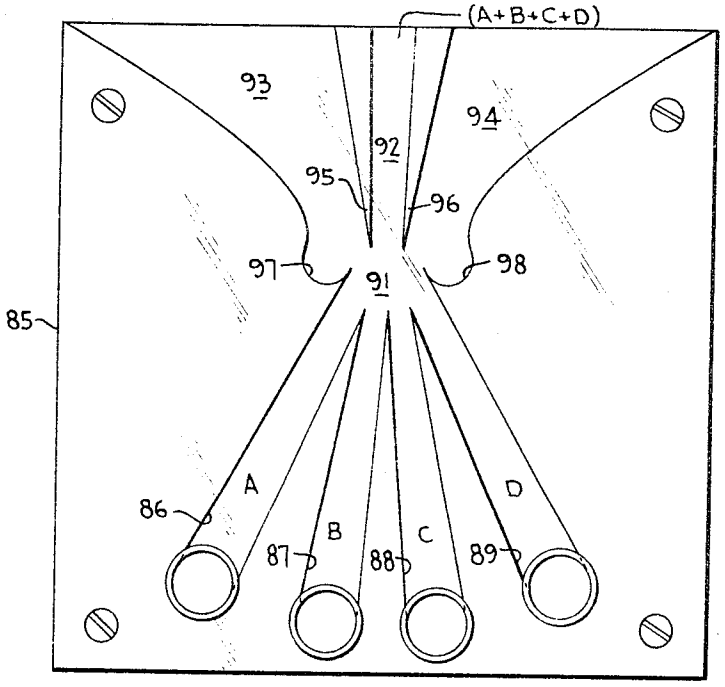
BY: Harry M. Saragovitz,
Edward J. Kelly,
Herbert Berl &
J. D. Edgerton

Sept. 13, 1966 R. W. WARREN 3,272,214

SELF-MATCHING FLUID ELEMENTS

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FIG. 2



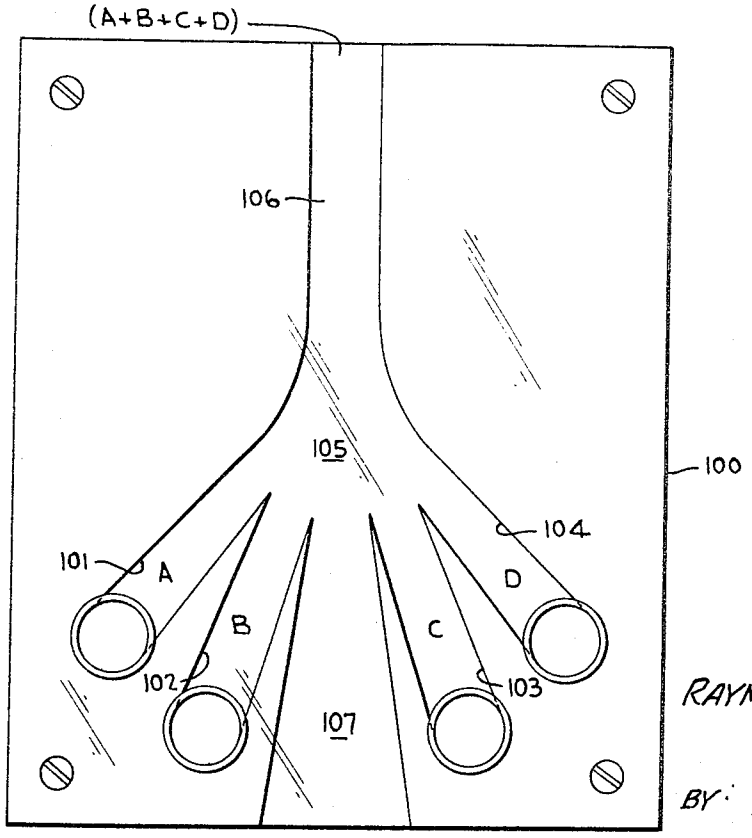


FIG. 3

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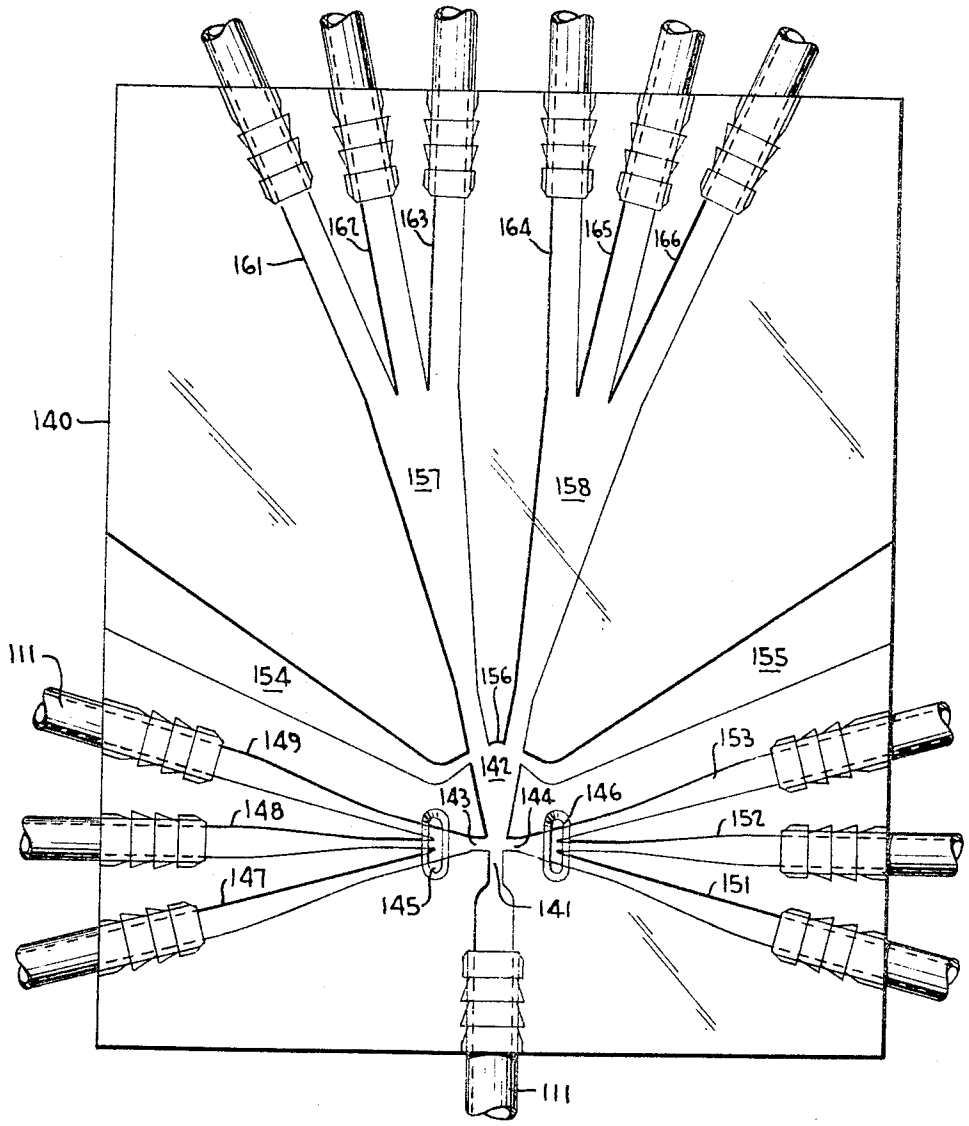
BY: Harry M. Saragovitz,
Edward J. Kelly,
Herbert Berl
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SELF-MATCHING FLUID ELEMENTS

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FIG. 5



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3,272,214

SELF-MATCHING FLUID ELEMENTS

Raymond W. Warren, McLean, Va., assignor to the United States of America as represented by the Secretary of the Army

Filed Oct. 2, 1963, Ser. No. 313,402
4 Claims. (Cl. 137—81.5)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to me of any royalty thereon.

This invention relates to fluid amplifiers and, more particularly, to impedance matched lock-on type fluid amplifier logic elements.

In the development of logic systems incorporating fluid amplification, it is necessary that the fluid elements produce their functions by being matchable to other elements or devices without excessive loss of operating pressures and without overloading any of the components. This is accomplished in this invention by maintaining the interaction chambers of these lock-on type amplifiers at ambient conditions. Most logic systems require the extensive use of logic elements, the most common being the flip-flop, or bistable element, the AND and the OR. For convenience of manufacture and assembly, it is desirable that all input and control jets be the same size and that all the power be applied with the same pressure. Assuming the above conveniences, if a long string of logic elements were connected in series with all power jets fed from the same pressure source with the only outputs being the extreme outputs, the pressure would build up in the system until only the last few units in a series would have sufficient pressure drop to cause the flow necessary for operation.

The most desirable situation would be to have the same constant pressure drop across each power jet nozzle in order to produce a constant flow. To do this, each succeeding control nozzle should present a constant load regardless of whether the succeeding power jet is flowing across the control nozzle or not.

If outputs are placed in the system other than at the extreme outputs, they would have to be adjusted in accordance with the pressure drop to allow sufficient flow and pressure to escape to permit operation but not to the extent that there is insufficient flow to control the next unit. This can readily be done in simple systems. In complex systems where the pressure pattern is not necessarily repeatable, but is somewhat sporadic as a result of the operation of various elements of the system, it can be seen that simple pressure bleeds are inadequate to impedance match a complex system. Since a pressure differential is required to hold the power jet against the wall and as this pressure differential changes as the unit is switched, a pressure release can remove energy needed to control succeeding units.

It is, therefore, an object of this invention to provide fluid logic elements which are capable of being impedance matched with other fluid elements.

Another object of this invention is to provide fluid logic elements in which all input power and control jets are the same size.

Still another object of this invention is to provide a fluid logic system in which all the power jets are supplied with the same fluid pressure.

A further object of this invention is to provide fluid elements for a fluid logic system in which all of the elements in the system have sufficient pressure drop to cause fluid flows necessary for operation .

A still further object of this invention is to provide fluid logic elements for a fluid logic system in which each succeeding control nozzle presents a constant load regardless of whether the succeeding power jet is flowing across the control nozzle or not.

Another object of this invention is to provide for control of reflected sonic waves and fluid pulses.

The specific nature of the invention, as well as other objects, uses and advantages thereof, will clearly appear from the following description and from the accompanying drawing, in which:

FIG. 1 is a plan view of an AND fluid logic element;

FIG. 2 is a plan view of a first embodiment of an OR fluid logic element;

FIG. 3 is a second embodiment of an OR fluid logic element;

FIG. 4 is an embodiment of a bistable fluid element including multiple inputs and multiple outputs; and

FIG. 5 is a plan view of another embodiment of a bistable fluid element incorporating multiple inputs and multiple outputs.

Turning now to FIG. 1 in which is shown an AND fluid logic circuit, the circuit element is typically made up of a laminate of plastic material, such as Lucite, or of metal or any other desired material. The top lamina is a cover plate through which the various inputs to the logic element are applied. A layer is machined, drilled, or etched or otherwise grooved to present the opening therein which enables the fluid streams to exit through a selected passage depending upon the presence of an input stream through either or both of said input nozzles. The lower surface has no openings therein so as to seal the units. The fluid streams are confined between the top and bottom surfaces so as to flow through the passages provided in the central section between such top and bottom surfaces.

The logic element illustrated in FIG. 1 is an AND circuit **10** having a pair of input nozzles **11** and **12** which are substantially perpendicular to each other. These nozzles are connected to input signals through opening **13** to a source of "A" signals and through opening **14** to a source of "B" signals, respectively.

The input nozzles **11** and **12** are directed into an interaction chamber **15**. Also opening into the interaction chamber **15** are the three receivers **18**, **23** and **26** as well as the channels **32** and **33** which maintain the interaction chamber **15** at the ambient condition. The first receiver **18** is positioned so as to receive the fluid flow through nozzle **12** with its "B" logic information in the absence of "A" logic information. The central receiver **26** is positioned so as to receive the fluid flows through nozzles **11** and **12** when both the "A" and "B" sources enable fluid flow. The third receiver **23** is positioned so as to receive fluid flow through nozzle **11** in the presence of "A" fluid flows during the absence of "B" fluid flows.

The first receiver **18** is bounded on one side by a lock-on

wall **16** which extends to the egress of nozzle **11** to provide a boundary for interaction chamber **15**. Receiver **18** is bounded on its opposite side by a wall **17** which is a side of the first divider **19** the sides of which converge at a point **35**. The second receiver **26** is bounded by a second and third divider **27** and **28** respectfully. The side walls of divider **27** converge at a point **29** in the interaction chamber **15**. A first bleeder channel **32** is defined by the sides of dividers **19** and **27** which face each other. Channel **32** is opened into the interaction chamber **15** between points **35** and **29**. Second receiver **26** opens into interaction chamber **15** between point **29** and a point **31** which is the point of convergence of divider **28**. The third receiver **23** is defined by a lock-on wall **21**. Wall **22** comes to a point of a divider **20** which separates the third receiver from the second channel **33** which connects the interaction chamber **15** to the ambient condition.

The letter W represents a nozzle width such as the width of nozzle **11** or **12** and the remainder of the openings into the interaction chamber are designated as **2W** to indicate that an optimum size for such openings is twice the nozzle width.

The bleeds in the AND unit are positioned to prevent simultaneous signals in the A.B and A.$\overline{B}$ or B.$\overline{A}$ channels when the A and B signals are not equal or may be only a fraction of each other.

FIG. 2 shows an OR fluid logic circuit incorporating the principles of this invention. The OR logic element **85** is provided with a plurality of inputs **86, 87, 88** and **89** which provide A, B, C, or D logic information respectfully. The sources of such logic information are not shown but can be connected through the top layer of the laminated body **85**. The four input channels are directed toward interaction chamber **91**. It is obvious that any number of a plurality of input channels may be used to accomplish OR logic functions. In receiving position of any signal applied through any of the input channels is a receiver **92** which is defined by the dividers **95** and **96**. These dividers enter into the interaction chamber **91** to further define a first passage **93** on the side of divider **95** which is opposite to the receiver **92** and a second channel **94** which is on the opposite side of divider **96** from receiver **92**. These channels **93** and **94** provide an opening from the interaction chamber **91** to the ambient condition. A pair of cusps **97** and **98** are provided at the terminus of the extreme input channels to reinforce the bleeding off of excessive fluid which would otherwise be directed into the receiver **92**. The points of convergence of dividers **95** and **96** are located in the interaction chamber **91** and form with the points of the cusps **97** and **98** and the points defining the downstream end of the input channels, the interaction chamber **91**. The relationship of the sizes of the openings into the interaction chamber **15** is not critical. However, a very good relationship of sizes would be that the width of the receivers be approximately twice the width of the input channels.

The OR circuit shown in FIG. 3 differs from the OR shown in FIG. 2 in that the channel **107** which connects the interaction chamber **105** to the ambient condition is located between the input channels **101, 102, 103** and **104**. The four illustrated inputs represent A, B, C, and D logic information. The extreme sides of the input channels **101** and **104** taper toward the interaction chamber **105** to become parallel and form the receiver **106**. The presence of the signal in receiver **106** gives the logic information that a signal is present in input channel A or B or C or D. As in FIG. 2, the number of input channels is limited only by the space available within the structure **100**.

The bistable fluid amplifier **109** in FIG. 4 has a pair of OR circuits used as the controls therefore, and a plurality of output passages are provided for each of the two receivers. A power stream is introduced through channel **110** through the tubing **111** connected thereto from a power source not shown. The tubings **111** are representative of the tubing employed for the power stream, the control fluid and the outputs. The power stream enters through nozzle **112** into the interaction chamber **113** into which are also directed left control nozzle **114** and a right control nozzle **115**. Opening to the ambient condition through the upper surface are holes **116, 117** and **118** which are positioned at the confluence of the plurality of control inputs and at the divider **127** where the left receiver **128** and the right receiver **129** are in communication with the interaction chamber **113**. There are three right control inputs **121, 122** and **123** which introduce control information into the right control nozzle **115**. Also shown are three left control inputs **124, 125** and **126** which introduce logic information into the left control nozzle **114**. The left receiver **128** is divided into three output channels **131, 132** and **133** so that a plurality of further logic elements or loads can be connected thereto. Also, since these elements are tailored to the specific needs of the system in which they are utilized, some of the outputs can be connected to the ambient condition if such is needed for impedance matching. Likewise, right receiver **129** is divided into three outputs **134** and **135** and **136** for the same reason as the left receiver **128**.

In the cut away sections top layer **137** and center layer **139** with securing means **138** for tubing **111** provided within the body of the element **109** for each of the several tubings **111**. The securing means **138** is basically a stepped opening within the body, usually within the center layer **139**, shaped to conform with the outside dimension of the tubing **111** and being of a dimension that is slightly smaller in circumference in the tubing **111** so that once the tubing is inserted within the securing means **138**, it cannot be withdrawn accidently nor in the normal use of the logic element. The smallest dimension of the stepped opening which contacts the tubing **111** is substantially the same for all of the steps. The center bore of the tubing **111** is the same size and shape as the channels which form the power stream, the control inputs and the receiver outputs so that minimum impedance to fluid flow is offered at the junction thereof.

With the power stream introduced to the interaction chamber **113** through power nozzle **112**, signals into any of the OR inputs **121, 122** or **123** will produce a control pulse to switch the power stream into receiver **128**. Likewise, a single input or a plurality of inputs into control lines **124**, or **126** will produce a control signal to switch the fluid power stream into receiver **129**. As illustrated, the two receivers have each three output channels connected thereto so as to provide simultaneous signals to a plurality of load devices connected thereto. The bleeder holes **116, 117** and **118** which are perpendicular to the fluid flow in the channels thereunder, provide for an equalization of pressure throughout the system whereby this logic element **109** can be impedance matched to any output device connected thereto. The special configuration of the side walls of the input channels and the receiver channels enhances the smooth operation of this device.

FIG. 5 shows a second bistable fluid amplifier which differs from the amplifier in FIG. 4 by an alternate method of providing the ambient condition in the interaction chamber thereof. In the fan-in fan-out fluid logic element **140** is found a power nozzle **141** directed into an interaction chamber **142** which also has directed thereinto a left control nozzle **143** and a right control nozzle **144**. Through the top lamina of a laminated package such as in the other species of this invention, are bleeder holes **145** for the left control means and a right bleeder hole **146** for the right control means. A plurality of input channels are provided as channels **147, 148** and **149** which join in an OR configuration to supply left control nozzle **143** with control signals. The right control means is likewise provided with a plurality of input channels **151,**

152 and 153, for example, which are joined in an OR circuit to provide input signals to the right control nozzle 144. The interaction chamber 142 is maintained at the ambient condition by left bleeder channel 154 and right bleeder channel 155. The divider which is symmetric about the center line of the power nozzle 141 is shaped so as to present a concave surface 156 toward fluid power nozzle 141. Also symmetric about the center line of power nozzle 141 are receivers 157 and 158 which are separated by the divider and begin in the interaction chamber 142. At their other ends, the receivers are branched into a plurality of output channels 161, 162 and 163 for left receiver 157 and channels 164, 165 and 166 for right receiver 158. It is seen that connectors for the tubings 111 are the same as the connectors 138 in FIG. 4.

The sidewalls of the input channels converge so as to prevent reflection of waves flowing therethrough and to sharpen the wave front of such wave. Otherwise, entrainment would render the wave ineffective as an active signal. The receiving channels and bleed channels diverge to prevent reflections and to match the outputs.

The walls of receiver 128 and 129 as in FIG. 4, diverge at such a rate that the flow will not separate from the wall, thus providing a uniform wave front. Essentially equal flow is obtained in each output by making the outer channels wider to compensate for the reduced flow in the boundary layer adjacent to the diverging walls. By this means, the output flows can be divided into any proportions desired.

Thus, it is seen that I have provided a related group of logic elements which can be combined to perform complex logic operations in computer applications. For example, the AND circuit of FIG. 1 can have for its inputs the outputs of the OR circuits shown in FIG. 2 and the flip-flop in FIG. 4 the like to produce a system which is capable of functioning as an adder and the like.

It is further seen that by having bleed openings at right angles to the velocity vector, the velocity will carry the flow (kinetic energy) past the bleed while the pressure (potential energy) which is now nondirectional will cause flow out of the bleed. Thus, if the right angle bleed is in a high velocity region it is possible to regulate the pressure while providing sufficient flow to control the succeeding element.

When an element is switched from one output passage to another initially there is very little resistance to flow, velocity is high and static pressure is low. When the high velocity flow encounters the resistance load of the next control nozzle, the flow which cannot pass through the nozzle at the instantaneous pressure ratio converts to an additional pressure raising the pressure ratio and giving a high flow through the control nozzle, thus switching the unit.

The pressure also proceeds upstream in the subsonic flow and would change the pressure ratio over the previous power jet or cause flow out the wrong inlet. The openings at essentially right angles to the flow permit the static pressure to release to ambient with an ensuing flow. This loss of flow and energy is not deleterious at this time as the desired objective of controlling the succeeding element has been achieved, and it serves the useful purpose of maintaining the desired pressure ratio and flows at the nozzles. The fluid logic element becomes self-adaptive.

So, any existing logic system consisting of flip-flop, AND and OR elements can be assembled from fluid logic elements with the same size nozzles supplied from the same pressure source and operated without further impedance matching.

The bleed channels in the AND circuit of FIG. 1 and the OR circuit of FIGS. 2 and 3 accomplish the same purpose by the discreet selection of opening into the interaction chamber and the flaring of the bleed channel in the direction away from the interaction chamber.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement with the scope of the invention as defined in the appended claims.

I claim as my invention:

1. In a fluid bistable amplifier:
(a) fluid power source for producing a fluid stream,
(b) a power nozzle connected to said power source,
(c) a plurality of input channels,
(d) an equal plurality of sources of fluid signals connected one to each of said input channels,
(e) some of said plurality of input channels converging to a first control nozzle,
(f) the remainder of said input channels converging to a second control nozzle,
(g) an interaction chamber,
(h) said control nozzles being axially aligned and oppositely directed into said interaction chamber,
(i) said power nozzle being perpendicular to said control nozzles and directed into said interaction chamber,
(j) a pair of receiver means,
(k) each of said receiver means diverging into a plurality of output means,
(l) individual ones of said plurality of output means being dimensioned to receive a predetermined proportion of said power stream,
(m) and bleeder means perpendicular to the fluid flow at the confluence of the input channels and of the receiver means.

2. The fluid amplifier according to claim 1, wherein:
(a) the sidewalls of said input channels converge toward said interaction chamber by the amount necessary to prevent reflection of waves flowing therethrough, and
(b) the walls of said receiver means diverge in the downstream direction at the rate necessary to prevent flow separation from said walls to provide a uniform wave front thereby enabling the output flows to be divided into any proportions desired.

3. In a fluid bistable amplifier:
(a) fluid power source for producing a fluid stream,
(b) a power nozzle connected to said power source,
(c) a plurality of input channels,
(d) an equal plurality of sources of fluid signals connected one to each of said input channels,
(e) some of said plurality of input channels converging to a first control nozzle,
(f) the remainder of said input channels converging to a second control nozzle,
(g) an interaction chamber,
(h) said control nozzles being axially aligned and oppositely directed into said interaction chamber,
(i) said power nozzle being perpendicular to said control nozzles and directed into said interaction chamber,
(j) a pair of receiver means,
(k) each of said receiver means diverging into a plurality of output means,
(l) individual ones of said plurality of output means being dimensioned to receive a predetermined proportion of said power stream,
(m) a bleeder means perpendicular to the fluid flow at the confluence of each of the input channels,
(n) a concave surfaced divider between said receiver means aligned axially of said power nozzle,
(o) and a pair of bleeder channels connected to opposite sides of said interaction chamber aligned with said concave surface.

4. The fluid amplifier according to claim 3 wherein:
(a) the sidewalls of said input channels converge toward said interaction chamber by the amount necessary to prevent reflection of waves flowing therethrough, and

(b) the walls of said receiver means diverge in the down stream direction at the rate necessary to prevent flow separation from said walls to provide a uniform wave front thereby enabling the output flows to be divided into any proportions desired.

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