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[54] FLUID SWITCHING DEVICE

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[52] **U.S. Cl.** **137/81.5**

[51] **Int. Cl.** **F15c 1/04**

[58] **Field of Search** ..... 137/81.5; 235/201 PF

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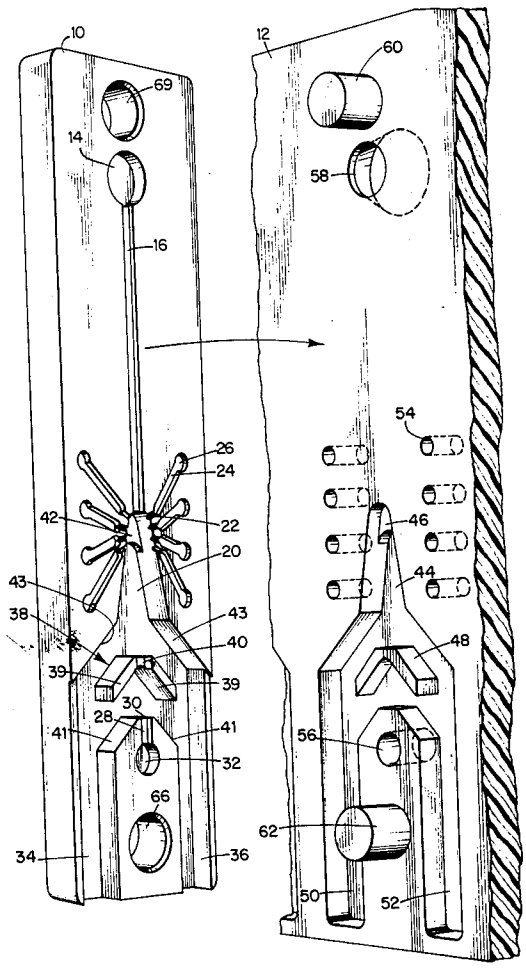
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[57] **ABSTRACT**

A pure fluid device for providing extremely fast switching between two digital states. A laminar input stream is caused to interact with a control stream within an interaction zone which includes an apertured target through which the input stream flows. In the presence of a control stream, the input stream is caused to diffuse and distort into engagement with the target, resulting in a rapid reduction in output pressure. The device features extremely low control flow which permits driving by a single device of a large number of like devices in a logic system.

13 Claims, 6 Drawing Figures



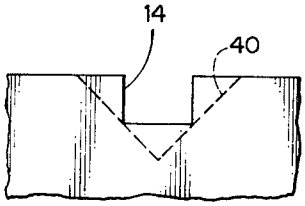


Fig. 2.

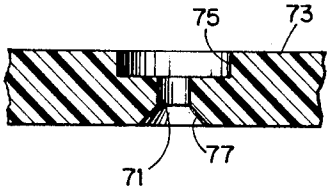


Fig. 4.

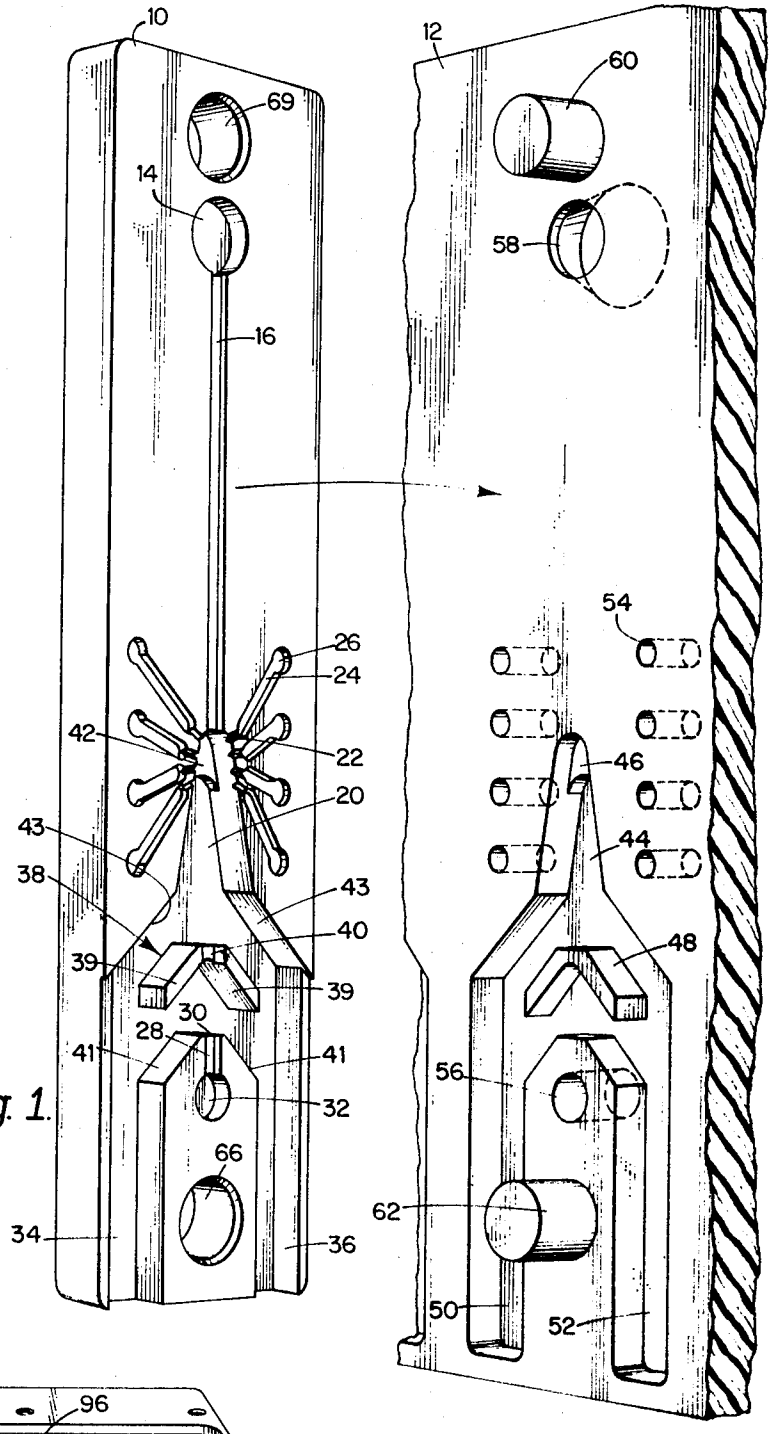


Fig. 1.

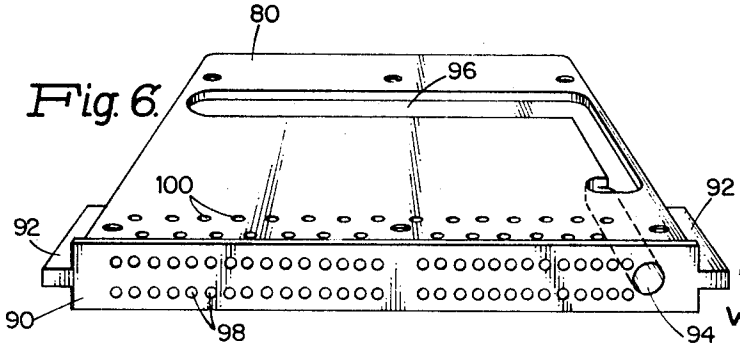


Fig. 6.

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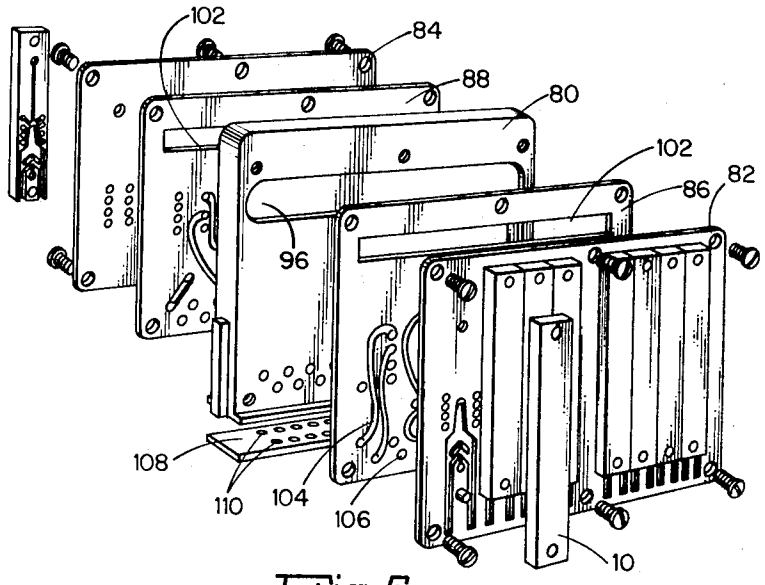


Fig. 5.

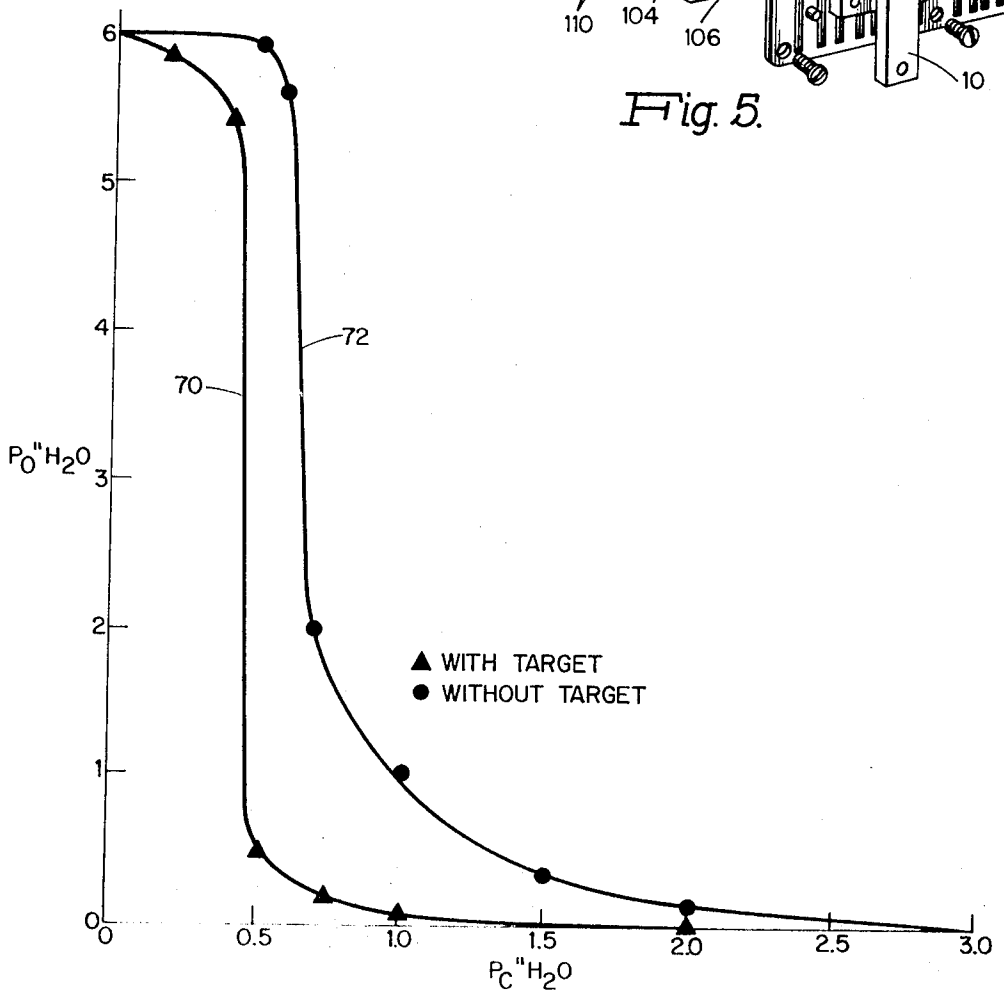


Fig. 3.

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FLUID SWITCHING DEVICE

FIELD OF THE INVENTION

This invention relates to fluidic devices and more particularly to pure fluid devices operative in a switching mode.

BACKGROUND OF THE INVENTION

Pure fluid devices are known for providing control and logic functions and employ the controlled interaction of a fluid control stream and a laminar input stream to provide requisite fluidic operation. In a known type of fluid amplifier, described for example in U.S. Pat. Nos. 1,628,723, 2,408,603, and 3,234,955, an input stream generally in laminar flow is directed from the orifice of a supply tube through an unconfined space toward the orifice of a collector tube, with a control tube arranged and adapted to direct a control stream into interaction with the input stream. In the absence of a control stream, the input stream reaches the collector tube in a laminar condition, giving rise to a relatively high output pressure which represents a first output state. When, however, the control stream is applied with predetermined flow to the input stream, the power stream undergoes a change from a laminar to turbulent state, with the result that pressure in the collector tube is reduced from that existing under laminar flow conditions, this pressure change signifying a different output state. The difference in pressure sensed at the collector tube can be employed to represent binary states for digital control purposes. A major deficiency of such known devices is that the switching speed is limited by the time required for the transition of the input stream from laminar to turbulent condition. Moreover, known devices require a relatively high control pressure which limits the number of like logical elements which can be driven by a single device, and which in turn limits the complexity of logic configurations achievable with such devices.

SUMMARY OF THE INVENTION

In accordance with the present invention, a pure fluid device is provided utilizing low pressure control flow in which extremely rapid switching between digital device states is achieved. The invention comprises an enclosed or shielded interaction zone through which a laminar input stream is caused to flow. A collector passage is arranged coaxially with the input stream to receive the laminar stream in the absence of control flow. One or more control passages communicate with the interaction zone and are each operative to direct a low pressure control stream into engagement with the laminar input stream. A target element is provided within the interaction zone and includes an aperture aligned with the output passage and through which the laminar input stream flows. In the absence of a control stream, the input stream flows through the aperture of the target and through the interaction zone to the collector, giving rise to a relatively high output pressure therein. In the presence of a control stream provided from one or more of the control passages, the input stream becomes enlarged and distorted but not turbulent. When the input stream engages the stream rapidly becomes diffused resulting in a predetermined decrease in output pressure in the collector passage.

DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawing, in which:

FIG. 1 is an exploded pictorial view of a fluid switching device according to the invention;

FIG. 2 is a cutaway view illustrating the relative position of a target aperture employed in the invention;

FIG. 3 is a plot of output pressure versus control pressure useful in comparing digital operation of the invention and operation of a prior art turbulence amplifier;

FIG. 4 is a cutaway view of a target element employed in the invention;

FIG. 5 is an exploded pictorial view of a logic circuit module embodying the invention; and

FIG. 6 is a pictorial view of the mounting plate of the module of FIG. 5.

DETAILED DESCRIPTION OF THE INVENTION

The novel switching device according to the invention is illustrated in FIG. 1 as embodied in a circuit element strip **10** and which is cooperative with a related circuit pattern formed in a confronting board **12** to provide a complete switching device. A plurality of circuit strips **10** can be arrayed along the length of the board **12** to provide a multiple element circuit card, the individual devices of which can be selectively interconnected to provide intended logical circuit functions.

The novel device includes an input port **14** which communicates with an elongated input passage **16** of square cross section and which terminates at an orifice **18** confronting an interaction region **20** which is of outwardly flaring configuration, as illustrated. A plurality of control passages **22** are provided in strip **10** with one end communicating with the interaction region **20**, with the other end of each passage communicating with a control fluid supply passage **24** which terminates in a supply port **26**. In the illustrated embodiment, passages **22** are of triangular cross section, and associated supply passages **24** are of rectangular cross section. An output passage **28** of square cross section is provided in axial alignment with input passage **16** and having an orifice **30** confronting the interaction region **20** and an opposite orifice terminating in an output port **32**.

The interaction region **20** flares outwardly as illustrated and joins first and second vent channels **34** and **36**, each of which communicates with the working atmosphere. A generally V-shaped target element **38** is disposed within the more widely flared portion of region **20** and includes an aperture **40** of V-shaped cross section positioned in alignment with input passage **16** and output passage **28**, as depicted in FIG. **2**. The interaction region is of a shape and size to permit laminar flow, proper switching levels and noise description. In addition, the interaction region is configured to cause flow away from the output orifice **30** when the input stream becomes diffused in the presence of a control stream. Referring to FIG. **1**, it is seen that target element **38** includes sides **39** which flare outwardly away from orifice **30**. Similarly, flared walls **41** and **43** are provided, as illustrated, generally parallel to sides **39**, to permit flow of the diffused stream to vent channels **34** and **36** and away from output orifice **30**.

The portion of region **20** adjacent control passages **22** includes a surface **42** which is raised or stepped from the surface of region **20**. The input stream tends to be more stable by reason of this stepped portion, which, in effect, acts as an extension of the input passage **16**. Moreover, the stepped portion acts to confine or focus the control streams from passages **22** to thereby achieve more precise control of the respective control streams. The control streams are by virtue of the invention, independent one from the other. Each control passage is effectively decoupled from the others and from the input passage. Actuation of one control stream does not affect the pressure of the other control passages, nor does change in the state of the input stream affect the control states.

The board **12** includes a pattern which is cooperative with the pattern formed in strip **10** to complete the device structure. An interaction region **44** is provided in board **12** of identical configuration with interaction region **20**. A raised portion **46** is also provided in the input end of interaction region **44** similar to the raised portion **42** provided in region **20**. An element **48** of like configuration as element **38** is provided within interaction region **44** in a position in alignment with element **38** when circuit strip **10** is mounted on board **12**. Outwardly extending channels **50** and **52** cooperate with respective channels **34** and **36** and extend beyond the end of element strip **10** to provide vent openings. A plurality of control ports **54** are provided through board **12**, the inner orifice of each being in alignment with a respective control port **26**. Similarly,

an output port **56** is provided through board **12** and is adapted for alignment with output port **32**. An input port **58** is also provided through board **12** and arranged for communication with input port **14**.

In assembled form, element strip **10** is placed with the surface containing the novel device in engagement with the confronting surface of board **12**, with the patterns on respective surfaces being maintained in precise alignment by means of mounting pins **60** and **62** provided on respective opposite ends of board **12** and associated mounting holes **64** and **66** provided in respective ends of strip **10**. The input passage **16**, output passage **28**, and aperture **40**, formed as open-sided channels in strip **10**, confront the mounting surfaces of board **12** when assembled to provide closed fluid passages. The formation of the fluid passages in a single substrate eliminates alignment problems which may be experienced when passages are formed in a pair of confronting plates. Typically, the confronting surfaces of strip **10** and board **12** are intimately secured one to the other by means of a suitable adhesive such as an epoxy cement. An input air stream from a suitable source is applied to input port **58**, while one or more control streams from a source are applied to control ports **54**. An output stream is coupled from the output port **56** and can be applied to other fluidic devices or to utilization apparatus, as desired.

In operation, a low pressure input stream of air or other suitable operating fluid is applied via ports **58** and **14** to input passage **16** which is of a shape and length to maintain the stream in laminar flow. The laminar input stream flows out of orifice **18** as a free jet through interaction region **20** and aperture **40**, and in the absence of a control stream is received by output orifice **30**. Thus, in the absence of control flow, the laminar stream flows linearly through the interaction region and aperture **40** disposed therein, the receipt of this laminar stream by output or collector passage **28** giving rise to a relatively high output pressure at output port **56**.

The control passages **22** are each disposed and operative to direct a low pressure control stream into interaction with the laminar input stream flowing through region **20**. With one or more control streams provided to control ports **54**, interaction between the input and control streams causes distortion and diffusion of the laminar input stream, in turn causing the input stream to engage the edge surfaces of target **38** which results in the stream rapidly becoming diffuse and turbulent. The turbulent flow now present within interaction region **20** is vented to the atmosphere via channels **34** and **36** and cooperating channels **50** and **52**. In this state of turbulence, a markedly reduced amount of flow is received by output passage **28**, with the result that the output pressure sensed at output port **56** is greatly reduced from that present under laminar flow conditions. The novel device thus exhibits a binary operating characteristic in that a relatively high output pressure is provided in the absence of control flow, while a relatively low output pressure is provided in the presence of control flow. These digital device states are utilized in a well known manner to provide logical networks and circuits to suit system requirements.

The invention offers markedly improved switching characteristics over devices of known construction and achieves such enhanced switching performance with extremely low control flow. The switching performance of the invention as compared with the switching characteristics of a conventional device is depicted in FIG. **3**. Curve **70** illustrates the variation in output pressure as a function of control pressure for a device according to the invention, while curve **72** depicts output pressure variation for a turbulence amplifier such as described in the aforesaid U.S. Pat. No. 3,234,955. The illustrated characteristic curve **70** of the invention was derived from a novel device employing a target configuration shown in FIG. **4**. A circular aperture **71** formed in target element **73** is dimensioned to accommodate flow of the input stream therethrough in the absence of control flow. The end of aperture **71** which confronts the input stream is formed in a recess **75** and which aids in diffusion of the input stream upon application of a control stream. A tapered portion **77** serves to also aid such diffusion.

Referring to curve **70** of FIG. **3**, it is evident that the output pressure rapidly decreases upon application of a control stream. With no control stream present, the output pressure in the illustrated curve is about 6 inches of water. The output pressure rapidly reduces to approximately 0.5 inch of water with a control pressure of 0.5 inch of water and continues to reduce to an output pressure of approximately 0.2 inch of water with a control pressure of 1.0 inch of water applied to a control passage. The transition from a higher pressure to a lower pressure output state is easily accomplished in less than 1 millisecond, the switching performance of the novel fluid device being therefore comparable with the switching speeds of many electronic elements.

In contrast to the switching performance provided by the invention, curve **72** depicts the typical response of a turbulence amplifier of conventional construction. It is evident from inspection of this curve that there is a relatively gradual variation in output pressure with relatively large changes in control pressure, as a result of which such conventional devices exhibit poor cutoff characteristics and a generally higher minimum output pressure. This conventional device for a given control flow and pressure is not turned off, whereas the novel device of the present invention is turned off.

A device constructed in accordance with the invention exhibits an extremely low output pressure in the presence of control flow, typically 0.2 inch of water. Moreover, the novel device device is operative with an extremely low rate of control flow, in contrast to devices of known construction. As a result, the invention exhibits a higher fan-out than usually available in fluidic devices, which permits the driving of a greater number of switching devices by a single device and the consequent capability of providing more complex and sophisticated fluid logic circuitry. A fluid device constructed according to the invention can drive at least 20 like devices. The extremely low control flow also permits higher fan-in, eight control ports being employed in the illustrated embodiment.

As described above, the novel switching device can be embodied in a mounting strip, a plurality of which can be arranged in side by side relationship on a mating surface of a mounting board. The mounting board can, in turn, be packaged in a modular unit which is adapted for coupling to a fluid logic system. Such a modular construction is illustrated in FIG. **5** and includes a mounting plate **80**, also shown in FIG. **6**, for containing a fluid circuit board **82** mounted on one surface thereof and a like circuit board **84** mounted on the opposite surface thereof. A gasket **86** is interposed between circuit board **84** and plate **80**. In the illustrated embodiment, eight switching devices each formed on a respective strip **10**, are provided on each circuit board and thus each module includes **16** active elements which are selectively combinable to provide an intended logical function.

As seen most clearly in FIG. **6**, the mounting plate **80** is adapted for mounting on a surface **90** and is usually maintained in mounted configuration by means of flanges **92** which cooperate with associated channels in mounting hardware. Air or other working fluid is supplied to an input port **94** disposed in surface **90** and which communicates with generally L-shaped channels **96** disposed on respective opposite surfaces of plate **80**. A plurality of openings **98** are provided in a regular array on the mounting surface **90**, each opening **98** communicating with a respective opening **100** disposed in the sides of plate **80**, as illustrated. Each gasket **86** and **88** includes an opening **102** disposed for alignment with the upper portion of channel **96**, and the input port **58** of each circuit card **82** and **84** also is in communication with opening **102** and channel **96**.

Air from a suitable source applied to input port **94** is thus caused to flow to the input passages **16** of all active elements on the circuit cards. The output ports **56** of each switching device are selectively coupled to control ports of other switching devices by means of fluid paths **104** provided in gaskets **86** and **88**. Selected ones of the output ports **56** are

also coupled to associated openings **98** of plate **80** for coupling to utilization apparatus or other modules via openings **106** provided through respective gaskets **86** and **88** and which are in alignment with respective openings **100** in plate **80** and output ports **56** of each element.

It will be appreciated that the several switching devices can be selectively interconnected to provide intended logical functions by suitably configured fluid paths provided in the gaskets associated with each circuit board. The assembled module is coupled to other modules or to utilization apparatus by means of a gasket **108** associated with mounting surface **90**, and which includes a plurality of openings **110** in alignment with respective openings **98**. In any particular logical configuration, all of the openings **98** will usually not be employed and it is necessary only to communicate with those openings **98** which are so employed. For versatility of system design, it is advantageous to be able to programmably couple any of openings **98** to other modules and apparatus by means of an interconnecting matrix or other coupling means. Such a matrix is connectable to all of openings **98** but a specific interconnection is provided by a coded fluid transmission means which permits fluid flow only to and from selected openings **98**. As seen in FIG. **5**, coding is provided by selected openings in gasket **108**. Coding can also be provided by pins inserted in certain ones of openings **98** or the associated fluid matrix to selectively occlude flow therein, or by valves which can be disposed within openings **98** or the associated fluid matrix. A modular and programmable fluid system utilizing the present invention is described in copending application of Hans-Dieter Kinner, Paul M. Blaiklock and Richard S. Yahrmarkt, entitled Fluidic Control System, Ser. No. 77,254, filed of even date herewith and now abandoned and assigned to the assignee of this invention.

The invention is not to be limited by what has been particularly shown and described except as indicated in the appended claims.

What is claimed is:

1. A pure fluid switching device comprising:
- a shielded interaction region vented to the working atmosphere;
- an input passage having an orifice communicating with one end of said interaction region and adapted to establish and maintain an input fluid stream in laminar flow through said region;
- an output passage having an orifice disposed at an end of said interaction region opposite said input passage orifice and in alignment therewith;
- one or more control passages each having an orifice communicating with said region and operative to introduce a low pressure control stream into said region in engagement with said input fluid stream; and
- a target element disposed in said region and having an aperture in alignment with said input passage and through which said input fluid stream flows in the absence of a control stream;
- said device being operative in the presence of a control stream to cause distortion of said input stream into engagement with said target element whereby the pressure in said output passage rapidly decreases to a value substantially less than the pressure in said output passage in the absence of a control stream.

2. A device according to claim **1** wherein said input and output passages are each of substantially square cross section.

3. A device according to claim **1** wherein said input and output passages are each of substantially square cross section, and said one or more control passages are each of V-shaped cross section.

4. A device according to claim **1** wherein said target element includes an aperture having edges which closely confront said input fluid stream in the absence of a control stream and which engage said input fluid stream in the presence of a control stream.

5. A device according to claim **1** including a mounting strip in which said device is formed and a circuit board having a surface adapted to intimately engage a surface of said mounting strip in which said device is formed and having a pattern cooperative with portions of said device formed in said mounting strip to define said interaction region.

6. A device according to claim **1** wherein said interaction region includes:
- a relatively narrow portion with which said input passage and said one or more control passages communicate;
- a portion contiguous with said narrow portion and outwardly flaring therefrom; and
- at least one vent channel communicating between the working atmosphere and said outwardly flaring portion.

7. A device according to claim **6** wherein the relatively narrow portion of said interaction region includes a stepped portion confronting said input passage and said one or more control passages.

8. A fluidic logic module comprising:
- a mounting plate having a mounting surface containing an input port and a plurality of first fluid ports, and having opposite side surfaces each containing a plurality of second fluid ports in fluid coupling relationship with respective ones of said first fluid ports, and a fluid input passage disposed in each side surface of said plate and each being in fluid communication with said input port;
- a pair of gaskets each disposed on and substantially coextensive with a respective side surface of said mounting plate and each having a plurality of openings in fluid communication with said plurality of second fluid ports; and
- a pair of logic cards each disposed on and substantially coextensive with a respective one of said gaskets and each having a plurality of fluid devices formed therein adapted for selective interconnection to provide an intended logical function;
- each of said gaskets having a plurality of fluid paths formed therein and operative to selectively interconnect said fluidic devices on respective logic cards thereby to provide an intended logical function;
- said fluid devices each including:
- a shielded interaction region vented to the working atmosphere;
- an input passage having an orifice communicating with one end of said interaction region and adapted to establish and maintain an input fluid stream in laminar flow through said region;
- an output passage having an orifice disposed at an end of said interaction region opposite said input passage orifice and in alignment therewith;
- one or more control passages each having an orifice communicating with said region and operative to introduce a low pressure control stream into said region in engagement with said input fluid stream; and
- a target element disposed in said region and having an aperture in alignment with said input passage and through which said input fluid stream flows in the absence of a control stream;
- said device being operative in the presence of a control stream to cause distortion of said input stream into engagement with said target element whereby the pressure in said output passage decreases to a value substantially less than the pressure in said output passage in the absence of a control stream.

9. A fluid switching device comprising:
- a mounting strip having formed therein
- a shielded interaction region vented to the working atmosphere;
- an input passage having an orifice communicating with one end of said interaction region and adapted to establish and maintain an input fluid stream in laminar flow through said region;
- an output passage having an orifice disposed at an end of said interaction region opposite said input passage orifice and in alignment therewith;

one or more control passages each having an orifice communicating with said region and operative to introduce a low pressure control stream into said region in engagement with said input fluid stream; and

a target element disposed in said region and having an aperture in alignment with said input passage and through which said input fluid stream flows in the absence of a control stream; and

a mounting board confronting said mounting strip and having a pattern cooperative therewith to define said interaction region and said target element;

said device being operative in the presence of a control stream to cause distortion of said input stream into engagement with said target element whereby the pressure in said output passage rapidly decreases to a value substantially less than the pressure in said output passage in the absence of a control stream.

10. A device according to claim **9** wherein said input and output passages are each of substantially square cross section, and said target element aperture is of triangular cross section.

11. A device according to claim **9**, wherein said mounting strip and mounting board include elements cooperative to accurately align said device formed therein.

12. A device according to claim **9** wherein said passages are formed as open sided channels in said mounting strip and wherein said mounting board is cooperative therewith to define closed passages

13. A device according to claim **12** wherein said mounting board includes fluid ports each coupled to a respective one of said passages.

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