Sept. 23, 1969 C. D. O'NEAL 3,468,331

STACKED PORT FLUIDIC AMPLIFIER

Filed July 3, 1967 2 Sheets-Sheet 1

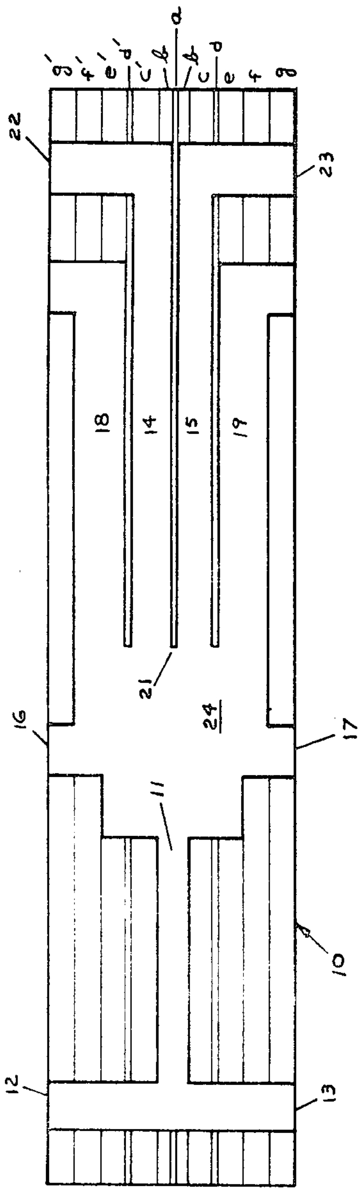

FIG. 1

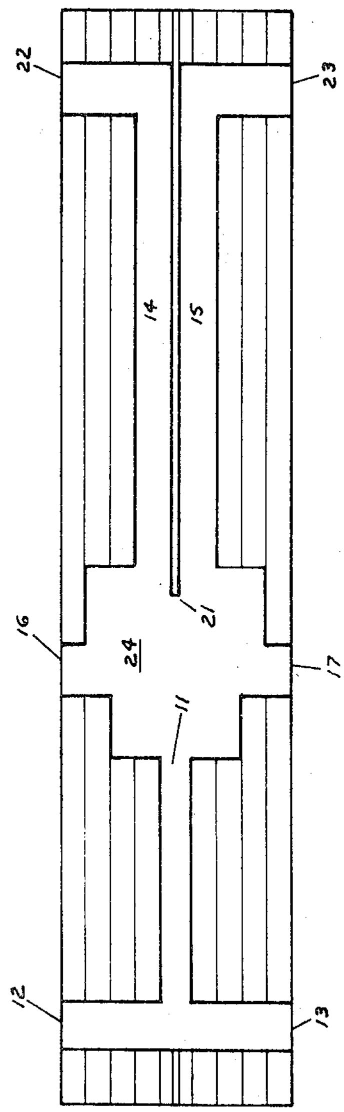

FIG. 2

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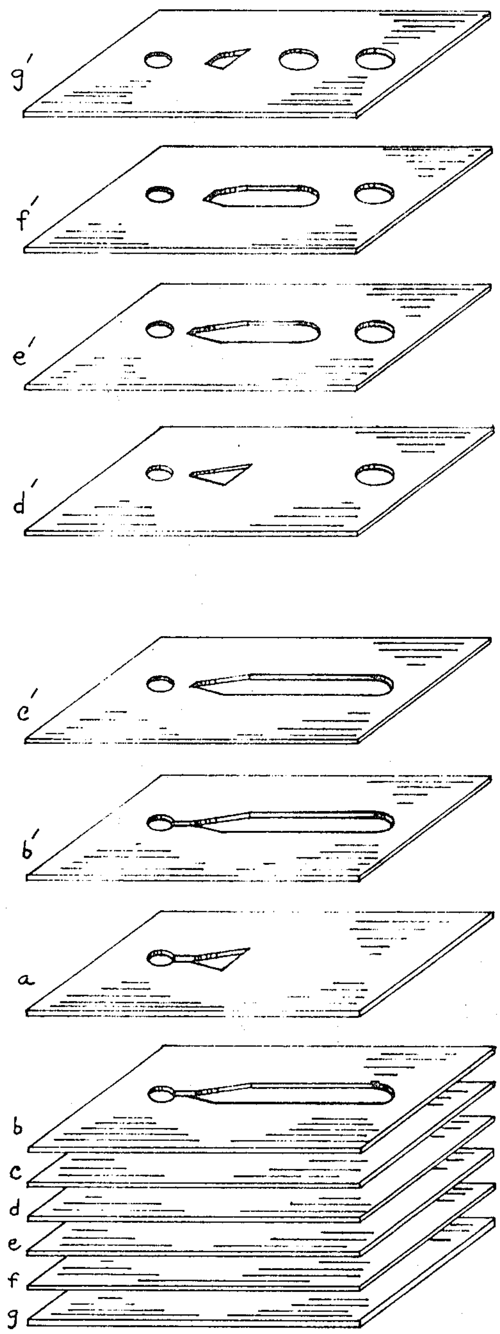

FIG. 3

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U.S. Cl. 137—81.5 6 Claims

ABSTRACT OF THE DISCLOSURE

This invention teaches an improvement in the application of laminate techniques to the construction of fluidic devices, in that it makes possible the use of aligned apertures in a plurality of stacked planes for creating a fluidic device of desired configuration, and significantly enables the creation of a splitter which is not only desirably very thin, but also retains structural integrity by being supported at both ends.

This invention relates to fluidic devices, and more particularly to the construction of such devices such that not only can high volume fabrication techniques can be employed, but also the resulting device as created has very desirable operating characteristics.

In the past, a number of fluidic devices have been proposed, some of which were proportional devices, with others being in the nature of digital devices. When constructing proportional amplifiers, I found it was increasingly difficult to create flow dividing splitters that would function properly with very small nozzle sizes. As element geometry decreased, splitters were required to be smaller and smaller until they became exceedingly hard to fabricate. This was because of the fact a conventional splitter is essentially a long, unsupported tapered piece of metal that is not only hard to dispose in the correct position with respect to the nozzle, but also it tends to generate acoustical noise when the device with which it is associated is in operation.

In accordance with the present invention, I avoid entirely the construction of fluid elements having splitters in the form of long, tapered, unsupported pieces of metal, but rather use instead a splitter plane whose edges are quite satisfactorily supported.

Whereas when one is fabricating fluidic elements from planes or foils, he normally etches the entire interaction area of an element out of a single plane, and then stacks such plane with other planes to create the desired arrangement, in accordance with my concept, the interaction area is constructed by the juxtapositioning of several apertured planes, which are stacked so as to allow the splitter to be defined by a single supported plane, which splitter in effect is disposed 90° to the direction of stacking. In this manner, the need for long, unsupported splitters with their inherent difficulties of fabrication is avoided.

The essence of my invention is the fact that I have provided a splitter in the shape of a long, supported plane rather than a slender, tapered piece of metal to accomplish the divided action employed in a proportional amplifier, for example. It should be noted, however, that by the use of my invention, I may also create bistable elements in which wall attachment principles may be utilized. In addition, my novel construction affords the designer more latitude than he previously had, for he can by the addition or removal of planes from a given geometry, affect the configuration of the interaction area in a desired manner.

In accordance with my invention I may utilize a com-

paratively large number of planes in at least some of which, apertures are created. These apertures are disposed in such a manner that when the planes are stacked together, the apertures form at least one cavity, a nozzle for delivering fluid into the cavity, at least two exit passages from the cavity, and a pair of control ports.

Approximately centrally disposed with respect to the cavity, an apertured plane is employed, an edge of the aperture of which forms a splitter edge. This splitter in effect is represented by a single plane normal to the adjacent planes, above and below which fluid from the nozzle can flow. The flow is thus divided into two portions, with approximately 50% flowing above the splitter plane and 50% below the splitter plane when no differential in control signal is present.

As will be obvious to those skilled in the art, upon a differential in the control signal being created by a change in the pressure level of the one control port with respect to the other, a different amount of flow will thereafter take place above the splitter plane than below it, thus achieving the goal of providing a proportional amplifier without the use of a long tapered, unsupported piece of metal. Although my splitter is quite thin, it is adequately supported at both ends, thus enabling it to be used with extremely small nozzle geometries.

In order to fully utilize the advantages of my invention I have found it necessary to make the planes out of metal foil because only a metal foil will have the requisite amount of strength in thicknesses as small as are involved herein. For example, the splitter plane in accordance with my invention may have a thickness of say one-half thousandth to one-thousandth of an inch without possessing the inherent fragility of the prior art type of splitter. It should be also noted that by the use of my invention, a much higher flow rate can be employed than was possible in prior art devices.

I am not limited to the construction of proportional amplifiers, for as previously mentioned, in accordance with my invention I can make wall attachment devices, this being achieved by virtue of the fact that the layers of metal on either side of the splitter plane can be configured so as to present one or more surfaces adjacent the outlet of the nozzle.

My invention lends itself to the construction of fluidic devices having no vents, this being true because my advantageous form of splitter does not materially disturb the output flow.

It is therefore the principal object of my invention to provide a fluidic device which lends itself to miniaturization while at the same time permitting the use of relatively simple fabrication and techniques.

It is another object of my invention to provide a fluidic device in which the splitter of the device is formed of a plane rather than a single, long unsupported, tapered piece of metal.

Other objects, features and advantages will be more apparent from the study of the enclosed drawings in which:

FIGURE 1 is a cross sectional view of a stacked port fluidic amplifier of vented configuration, this being predominantly a momentum effect device;

FIGURE 2 is a cross sectional view of a fluidic amplifier generally along the lines of FIGURE 1, but in which no vents are used, this being predominantly a pressure effect device; and

FIGURE 3 illustrates in an exploded view a number of the planes that are utilized in the construction of a fluidic amplifier or the like in accordance with my invention, this view being of a vented configuration.

Turning now to FIGURE 1 it will be noted that this vented version of my invention may employ a number of planes or laminates in the construction of a fluidic amplifier **10**, most plane configurations of which may be used twice. Plane *a* in the central portion of the array of planes is the splitter plane which serves to split the flow emanating from the power nozzle **11**, and is generally .0005" to .001" in thickness. Plane *a* is normally used singly, whereas plane *b* through *g* disposed below the splitter plane have a *b'* through *g'* above the splitter.

Plane *b* and its counterpart are typically .002" thick in the preferred embodiment, which therefore means that the nozzle **11** may have a dimension of .005". Plane *c* and its counterpart are for example .004" thick, with these planes each having a large aperture so that channels or receivers **14** and **15** will be defined below and above the splitter **21**, through which channels, fluid entering supply ports **12** and **13** and emanating from power nozzle **11** can flow. It is therefore the flow emanating from nozzle **11** that is divided by splitter **21**, with which the nozzle is substantially aligned. The fluid from nozzle **11** flows across chamber **24** whose upper and lower boundaries are defined by planes *f* and *g* and planes *f'* and *g'*, and whose sides are defined by the edge thicknesses of several planes.

Inasmuch as this embodiment is of the vented type, it utilizes planes *d* and *d'* in order to separate the vent channels **18** and **19** from the output channels **14** and **15**. The planes *d* and *d'* are preferably of the same thin material as the splitter plane *a*, inasmuch as in effect, these planes also perform a splitter function. In other words, the jet emanating from the nozzle **11** contains a turbulent boundary region between it and the ambient fluid medium. This region is thus isolated from the output channels **14** and **15** by plane *d* and its counterpart *d'*.

Approximately 50% of the flow emanating from nozzle **11** normally flows below the splitter **21**, through channel or volume **14** to the outlet **22** that is disposed at the upper right end of the amplifier device **10** as viewed in FIGURE 1, whereas the other 50% normally flows along channel or volume **15** to the outlet **23**, located on the lower right end of the amplifier.

In accordance with this embodiment of my invention, control signals may be impressed upon the flow emanating from nozzle **11**, such signals being directed through control ports **16** and **17** disposed in the upper and lower walls of chamber **24**. As a result of a differential existing between ports **16** and **17**, a larger percentage of the flow than 50% may be caused to flow along one side or surface of the splitter than along the other side, thus enabling this device to achieve a proportioning of the flow in accordance with desired percentages.

In the vented configuration of my device as illustrated in FIGURE 1, the phenomena which predominantly accounts for the operation of the device is the momentum exchange between control signals emanating from control ports **16** and **17** and the power stream emanating from nozzle **11**. This exchange occurs in chamber **24** and serves to deflect the path of the power jet.

Planes *g* and *g'* may define the upper and lower confines of the proportional amplifier **10**, or upper and lower cover plates may be used with the device if such be preferred.

As will be understood, the apertures and chambers of the device **10** may be established by creating appropriate holes or apertures in the planes *a* through *g* (and their counterparts) before the various planes are secured together. For example, holes may be cut or punched initially in planes *g* and *g'* corresponding with the positions of the supply, control and output holes. Planes *f* and *f'* are cut similarly, but differ by having an enlarged hole near the location of the control port, thus to define a portion of the vent channel **18** and **19**. Planes *e* and *e'* have even larger portions cut away, so as to form a portion of chamber **24** and a portion of the vent channel **18** and **19**. Planes *c* and *c'* are of course cut away to form the passages or volumes adjacent the splitter **21**, and the top and bottom of nozzle **11**. nozzle **11**.

The ventless configuration of my device as illustrated in FIGURE 2 is predominantly a pressure effect device and such relies on a differential pressure across the power jet as the mechanism by which the power jet is deflected. In this figure, like reference numerals are used to indicate the same elements or apertures as employed in FIGURE 1. Absent of course from this figure are vent channels **18** and **19** and their outlets.

As in FIGURE 1, the splitter **21** serves to divide the flow emanating from nozzle **11**, with which it is preferably aligned.

Some turbulence may occur in chamber **24** during the operation of this embodiment, but its effect on the operation of the device can be minimized by the judicious arrangement of chamber geometries. By a differential of pressure across the chamber **24** caused by the use of differential control signals at ports **16** and **17**, a desired deflection of the power stream from nozzle **11** can be brought about, resulting in more flow from one outlet than the other.

FIGURE 3 is an exploded view that represents the element planes or foils that may be used in the construction of the vented device shown in FIGURE 1. Reference letters *a* through *g* and their counterparts are of course relatable to the same letters appearing in FIGURE 1. As was noted in FIGURE 1, signal exists as well as vents are provided. The various apertures utilized in these planes can of course be formed in accordance with etching techniques described at greater length in the copending patent application of Richards and Depperman entitled "High Speed Fluidic Devices," Ser. No. 546,935, filed May 2, 1966 and assigned to the assignee of the present invention.

As to the means for securing the element planes together, conventional bonding techniques may be employed if desired.

As should now be apparent, I have provided an effective technique for the creation and manufacture of fluidic devices in which effective proportioning or division of a flow can be brought about, with a splitter being utilized which is effectively supported at both ends, thus avoiding the expense and other undesirable attributes associated with prior art splitters. Also, this technique makes rapid changes of geometry possible in that a chamber or a nozzle can be changed as to their sizes or relationships merely by the addition or subtraction of planes. In other words, whereas prior art devices could be changed as to their volumes by the addition or subtraction of planes, they could not, as is here possible, materially alter the geometric relationships of the interacting fluid streams.

I claim:

1. A fluidic device comprising a stacked array of element planes, at least some of said planes having apertures therein, said apertures being created in said planes so that when said planes are stacked together, the apertures together form at least one cavity, as well as passages for fluid to flow into and out of said cavity, one of said apertured element planes being disposed in a substantially central portion with respect to said cavity, with an edge of the aperture of latter element plane acting as a splitter for flow into said cavity.

2. The fluidic device as defined in claim **1** in which said stacked planes form a ve nted device.

3. The fluidic device as defined in claim **1** in which said said stacked planes form a vented device.

4. A fluidic device comprising a stacked array of element planes, at least some of said planes having apertures therein, said apertures being created in said planes in such a relationship that when said planes are stacked together, the apertures together form at least one cavity, a nozzle for delivering fluid flow into said cavity, at least two exit passages from said cavity, and a pair of control ports, one of said apertured element planes being disposed in a substantially central portion with respect to said cavity, with an edge of the aperture of latter element plane acting as a splitter for flow from said nozzle.

5. The fluidic device as defined in claim **4** in which said stacked planes form a vented device.

6. The fluidic device as defined in claim **4** in which said stacked planes define a ventless device.

References Cited

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251—367

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(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,468,331 Dated September 23, 1969

Inventor(s) Charles D. O'Neal

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 68, Claim 2, "vented" should read --vented--;
line 70, Claim 3, "vented" should read --ventless--.

SIGNED AND
SEALED

DEC 23 1969

(SEAL)
Attest:

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Attesting Officer

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Commissioner of Patents