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[54] **FLUIDIC SURFACE DEVICE AND NOZZLE SYSTEM FOR THE FORMATION OF JETS IN THE DEVICE**

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[52] **U.S. Cl.** **137/803,** 137/825, 137/833

[51] **Int. Cl.** **F15c 1/00**

[58] **Field of Search** 137/81.5, 803, 825, 137/833

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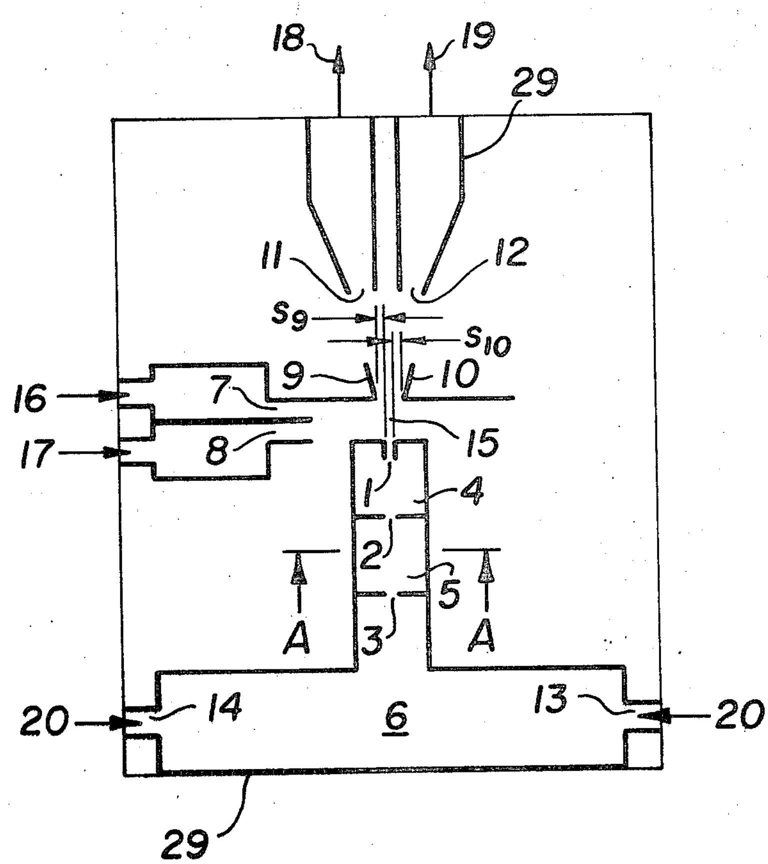
[57] **ABSTRACT**

A fluidic circuit element includes a nozzle assembly in the form of a nozzle supplied from a supply source of fluid by way of one or more throttles separated from each other and from the nozzle by intermediate chambers. The spacing between the throttles and between the last throttle and nozzle are less than the smallest transverse dimensions of the throttles. A symmetrical jet is produced by a single arrangement of this type, or alternatively an asymmetrical jet may be produced by employing a similar series of throttles and outlet nozzle of larger dimensions cooperating with the first system. The nozzle system is shown and disclosed in combination with a wall attachment device.

10 Claims, 3 Drawing Figures



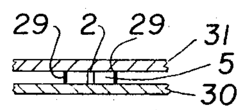


FIG. 2

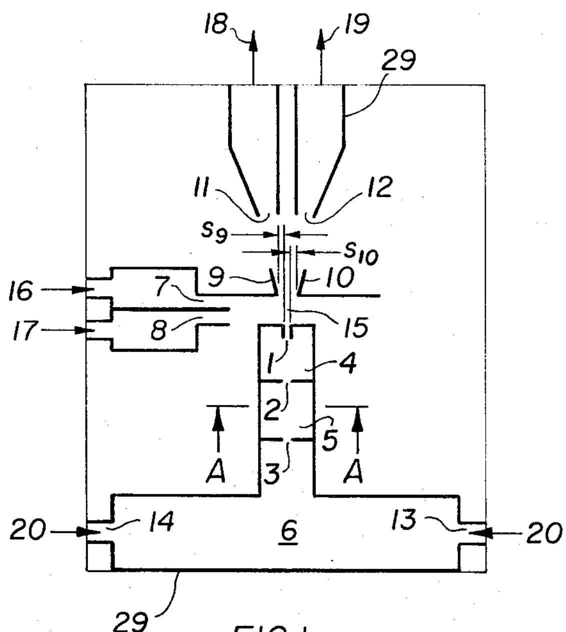


FIG. 1

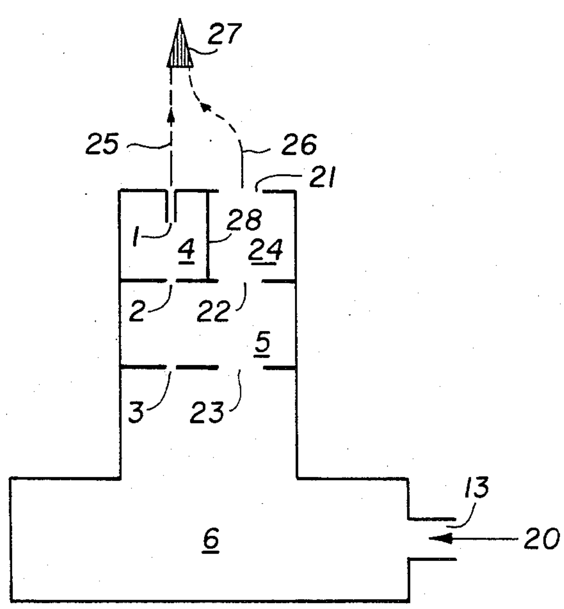


FIG. 3

FLUIDIC SURFACE DEVICE AND NOZZLE SYSTEM FOR THE FORMATION OF JETS IN THE DEVICE

This invention relates generally to fluidic circuits, and is more particularly directed to a nozzle system for the formation of jets in fluidic devices, in which the jet issuing from the nozzle system is substantially independent of the direction of supply of the fluid to the nozzle system.

Previous arrangements for steadying and aligning the current in front of a nozzle (i.e., the side of the nozzle toward the fluid supply source) are well known. For example, flow grids have been employed to align the flow of current of the fluid, the grids distributing the fluid uniformally over the cross sectional area of the feed regardless of the direction they are fed thereto. Similarly, sieves or porous materials have been employed in other arrangements, such devices operating in the same manner as the flow grids. Devices employing long capillary fed zones have also been employed for compensating for asymmetrical profile of the fluid applied to the device.

The form of the jet issuing from the nozzle depends substantially upon the form of the nozzle. For example, nozzles have been suggested in the form of sharp edged diaphrams having flat or rounded faces. In addition, asymmetrical jets have been produced by employing asymmetrical supply chambers in front of the nozzles. Other arrangements have employed interference sources, such as projecting edges, offset corners, or surfaces for guiding or repelling the current, for the production of desired asymmetry of the jet. Symmetry of a jet has also been achieved by focusing techniques by means of additional jets or currents, for example, by means of a ring nozzle surrounding the nozzle to be controlled. Asymmetry of a jet may also be accomplished in the same manner by employing interfering jets. The fluid jet to be aligned may also be preshaped by means of a moving nozzle, the fluid subsequently flowing through a sharp edged diaphram. Other arrangements have employed lateral control jets to effect the preshaping of the fluid jet in front of the main nozzle of the jet element.

The above described arrangements for aligning the current in front of a main nozzle have the disadvantage that accurate alignment of the current, for example, axial symmetrical alignment, is only possible to a limited extent when moving elements are employed, and the formation of the jet is thereby impaired. This is particularly true when the subsequent nozzle is not adapted to the arrangement provided for the alignment of the current flow.

The above described arrangements also have the disadvantage that reproducible accuracy of the arrangements, and thus of the jet formation, requires great effort. Reproducible accuracy is particularly necessary in the formation of miniaturized jet elements.

It is therefore an object of this invention to provide an improved arrangement for forming of jets in fluidic circuit devices, as well as to provide means for simplifying the manufacture of such jet forming elements.

The invention is thus directed to the provision of a nozzle system which can readily be produced, and which is designed so that its characteristics are readily reproducible during manufacture, and in which the direction and flow profile of the jet are substantially independent of the direction and flow profile of the current of the fluid in front of the nozzle system (i.e., the fluid applied to the nozzle system).

According to the invention, the objects of the invention are achieved by providing one or more throttles, arranged in cascade, and aligned with each other in front of one or more outlet nozzles. The spacing between the throttles and also between the last throttle and the outlet nozzle are greater than the smallest throttle dimension. (As hereinafter employed, the term "dimension" as applied to the throttles and nozzles refers to the dimensions thereof transverse to the flow of fluid therethrough.) The formation of the jet can be influenced by different dimensions of the throttles, as well as by the form of the chambers between the throttles and of the chamber between the last throttle and the outlet nozzle.

In accordance with the invention, each throttle may have several openings. When two openings are provided on each throttle, two outlet nozzles are provided cooperating therewith. An asymmetrical jet may be produced in the overall nozzle system by employing different dimensions in the two partial nozzle systems.

The outlet nozzle of the system preferably is in the form of a Borda mouthpiece.

The dimensions of the aligned throttles, as well as the dimensions of the outlet nozzle, can be equal, in the formation of the jet issuing from the nozzle system. It is advantageous, however, to make the dimensions of the throttles smaller than the dimensions of the outlet nozzle aligned therewith. A particularly useful embodiment of the invention is provided by successively decreasing the dimensions of the throttles from the source of fluid toward the outlet nozzle, and in this arrangement the outlet nozzle preferably has greater dimensions than the throttle just preceding the outlet nozzle.

By providing combinations of means for aligning the current flow, and adapting these means as necessary, the present invention provides an advantage that jets of the form necessary for use in jet elements may be formed, and that sharp focusing of the jets may be readily achieved by simple techniques and by employing simple geometric configurations in the device. If the nozzle system is to be employed, for example, in a wall attachment device, the arrangement according to the invention permits the use of short outlets and walls necessary for adhesion and alignment of the jet, as well as meeting the other requirements of high sensitivity with simultaneous operational stability of the wall attachment devices. These objectives may be achieved without sacrificing the miniaturization of the elements. In view of the great reproducibility of the form of the jet provided by the present invention, the distance between the main nozzle and the walls of a wall attachment device, as above noted, can be increased, thereby providing room for the arrangement of several signal input devices between the nozzle and the walls, the input signal devices being adequately separated so that input signals applied thereto are decoupled.

In addition to the above advantages, the jet elements according to the invention can be readily miniaturized by simple techniques, and without impairing the above characteristics.

In order that the invention will be more clearly understood, it will now be described in more detail with reference to the accompanying drawings, in which:

FIG. 1 is a top view with the top plate removed, of a wall attachment device incorporating a nozzle system according to the invention;

FIG. 2 is a modified cross sectional view of a portion of the element of FIG. 1 taken along the lines A—A, and including a portion of the top plate thereon; and

FIG. 3 is a view of a modification of the nozzle system according to the invention, employing several throttles arranged in cascade form.

Referring now to the drawings, and more in particular to FIG. 1, therein is illustrated a wall attachment fluidic circuit element incorporating a nozzle system according to the invention. The contours of the wall attachment device are illustrated by the heavy lines, such as lines 29, which denote the walls of the device. As illustrated in FIG. 2, the device may have a bottom plate 30 and a top plate 31 between which the walls 29, for example in the form of straps or bars, extend, according to the contours illustrated in FIG. 1, to form the device.

The nozzle system in FIG. 1 incorporates an outlet nozzle 1, aligned throttles 2 and 3, a chamber 4 between the outlet nozzle 1 and the throttle 2, a chamber 5 between the throttle 2 and the throttle 3, and a supply chamber 6 of any desired form. The supply chamber is provided with one or more input connections, such as inputs 13 and 14, for the supply of feed fluid therethrough as indicated by the arrows 20. The dimensions of the throttles and nozzle and their relative spacing has been discussed above.

The wall attachment device also includes nozzles 7 and 8 for the application of control signals as indicated by the arrows 16 and 17 respectively, walls 9 and 10 as necessary for the attachment and for the alignment of the jet and mixing nozzles 11 and 12 for the signal outputs as indicated by the arrows 18 and 19 respectively. The feed fluid 20 enters the supply chamber 6, as noted above, by way of connections 13 and 14, and flows through the throttle 3 into the chamber 5, and thence through the throttle 2 into the chamber 4. Alternatively, one of the throttles may be omitted if desired, or additional throttles and intermediate chambers may also be provided if desired. From the chamber 4, the fluid flows through the outlet nozzle 1, aligned with the throttles 2 and 3, and forms the main jet in the interaction region 15 of the device.

The angled walls 9 and 10 of the device are staggered with respect to the outlet nozzle 1, so that the wall 9 is closer to the main jet than the wall 10 (i.e., the dimension s_9 is smaller than the dimension s_{10} as illustrated in FIG. 1). Consequently, the main jet, in the absence of control signals, becomes attached to the wall 9 due to the Coanda effect, and an output signal 18 is received by the mixing nozzle 11. The main jet may be deflected by control jets issuing from either of the nozzles 7 and 8, to be released from the wall 9 and attached to the wall 10, so that the jet is directed to the mixing nozzle 12 for the formation of the output signal 19. The control jets are directed into the interaction region 15, as illustrated in FIG. 1.

In accordance with the invention, as illustrated in FIG. 1, the shape and alignment of the main jet is produced as a result of the dimensions and gradations of the cross sections of the outlet nozzle 1 and of the throttles 2 and 3, as well as of the respective distances between the outlet nozzle 1 and the throttles 2 and 3 and the desired shape of the intermediate chambers 4 and 5. The outlet nozzle 1, as above stated, is preferably in the form of a Borda mouthpiece, i.e., having a reentrant tube in the chamber 4. The jet emanating from the outlet nozzle 1 of the nozzle system is axially symmetrical and is accurately aligned and formed, and can be deflected by jets of small energy emanating from the nozzles 7 or 8. Since the main jet emanating from the nozzle 1 has a high degree of precision with respect to its axial symmetry, slight displacement of the angled walls 9 and 10, as indicated by the displacement s_9 and s_{10} respectively, relative to the outlet nozzle 1, is permissible. These minor displacements make it possible to make the walls 9 and 10 relatively short, while still enabling stable adhesion of the main jet to walls, and this in turn increases the sensitivity of the elements with respect to the control signals 16 and 17. The high degree of axial symmetry of the jet also permits the distance between the outlet nozzle 1 and the walls 9 and 10 to be increased, thereby providing sufficient room adjacent the interaction region 15 for the most favorable and suitable alignment of the control nozzles 7 and 8, while still permitting the nozzles to be decoupled. Thus, as illustrated in FIG. 1, the control nozzles 7 and 8 may be directed to the interaction region on the same side thereof, thereby effecting greater decoupling than in conventional arrangements in which the space limitations of the interaction region require oppositely disposed control nozzles.

The above characteristics of the main jet emanating from the outlet nozzle 1 of the nozzle system are attained even though the supply chamber 6 is directed to the nozzle system from a different direction, thereby providing another advantage of the system in respect to the additional design flexibility of the system.

Referring now to FIG. 3, this figure illustrates a modification of the nozzle system according to the invention, in order to provide an asymmetrical outlet jet. In this arrangement, an additional set of throttles 22 and 23, and an additional nozzle 21 are provided. The throttles 2 and 3, the outlet nozzle 1, and the intermediate chamber 4 are aligned as in the arrangement of FIG. 1. In FIG. 3, however, chamber 5 is enlarged in a direction transverse to the flow of the fluid, and another throttle 23 is provided in the same wall as the throttle 3, the throttle 23 being larger than the throttle 3. The throttle 23 is aligned with a throttle 22 in an extension of the wall in which the throttle 2 extends, the throttle 22 being larger than the throttle 2 and extending into an intermediate chamber 24 separated by wall 28 from the chamber 4. The outlet nozzle 21 is aligned with the throttles 22 and 23, and extends from the chamber 24 into the interaction region.

In the wall attachment device as above described with reference to FIG. 1, unlike other wall attachment devices, in addition to the particularly useful outlet nozzle, the arrangement also employs a particularly useful arrangement for the mixing nozzle which does not employ a separating wedge. The outlet nozzle 1 and the mixing nozzles 11 and 12 are separated from each other by a mixing nozzle chamber in which the free fluid jet can be formed. This permits extensive decoupling between the control inputs and the signal outputs, and insures the "free" wiring of the elements.

Bistable storage elements having signal inputs on each side of the interaction region and monostable elements, in which the OR function is caused by a two inlet jet element, can be distinguished on the basis of their logical properties. Monostability in a monostable element can be achieved by an asymmetrical displacement of the walls, as above discussed. A substantial difference between the two types of elements, i.e., bistable storage elements and monostable storage elements, resides in the manner of ventilation of the interaction region. Thus, in a storage element, the interaction region is ventilated from both sides, i.e., between the control inlet nozzles and the main jet, while in a monostable element the interaction region is ventilated on only one side, i.e., on the side opposite the control inputs. As a result of the greater suction power of the main jet achieved in monostable devices, unnecessary parts of the signal carrier of the control signal are more rapidly eliminated and the switch back time of the main jet is reduced. Consequently, the dynamic properties of the element are improved, and the monostability is enhanced by the different resistance conditions on both sides of the main jet, whereby improved decoupling of the control inputs is insured.

In the arrangement of FIG. 3, fluid from the supply chamber 6 passes through one partial nozzle system, i.e., through throttles 2 and 3, chambers 4 and 5, and outlet nozzle 1 to form the outlet jet indicated by the arrow 25. The fluid from the supply chamber 6 also passes through the other partial nozzle system consisting of throttles 22 and 23, chambers 5 and 24 and outlet nozzle 21, to form the jet indicated by arrow 26. Due to the different dimensions of the partial nozzle systems, the jets 25 and 26 have different energies as they issue from the two outlet nozzles 1 and 21, and consequently a resultant asymmetrical jet, indicated by the arrow 27, is formed due to the mixing of the jet 25 and 26. The formation of the resultant jet 27 is influenced by the arrangement of the throttles 2,3,22 and 23 and outlet nozzles 1 and 21, and also by the shape of the intermediate chambers 4, 5 and 24, as well as by the presence of the separating wall 28.

While the invention has been described with particular reference to several embodiments, it will be understood that modifications may be made therein without departing from the spirit and scope of the invention, and it is intended herein to cover all such variations and modifications of the invention that fall within the true spirit and scope thereof.

What is claimed is:

1. A nozzle system for forming a jet in a fluidic circuit device, said system comprising an outlet nozzle, a source of supply fluid, a throttle between said source and said outlet nozzle, and an intermediate chamber between said throttle and said outlet nozzle, said throttle and outlet nozzle constituting the only openings in said chamber, the spacing between said throttle and said outlet nozzle being greater than the smallest transverse dimension of said throttle, whereby the shape of a jet issuing from said outlet nozzle is a function of the dimensions of said throttle, and the shape and dimension of said intermediate chamber.

2. The nozzle system of claim 1 wherein the outlet nozzle has the shape of a Borda mouthpiece.

3. The nozzle system of claim 1 further comprising a second outlet nozzle, said second outlet nozzle having greater transverse dimensions than said first mentioned nozzle, second throttle means aligned with said second outlet nozzle and having greater transverse dimensions than said first mentioned throttle, and a second intermediate chamber between said second throttle means and second outlet nozzle, and wall means separating said second chamber and said first mentioned chamber.

4. The nozzle system of claim 1 further comprising a second throttle positioned between said supply and said first mentioned throttle, and a second intermediate chamber between said second throttle and said first mentioned throttle, said first mentioned and second throttles constituting the only openings in said intermediate chamber, the distance between said second throttle and said first mentioned throttle being greater than the smallest transverse dimension of said second nozzle, said outlet nozzle, first mentioned throttle and second throttle being aligned.

5. The nozzle system of claim 4 wherein the transverse dimensions of said outlet nozzle and said aligned throttles are equal.

6. The nozzle system of claim 4 wherein the transverse dimensions of said throttles are smaller than the transverse dimensions of said outlet nozzle aligned therewith.

7. The nozzle system of claim 4 wherein the transverse dimensions of said first mentioned throttle are smaller than the transverse dimensions of said second throttle.

8. A nozzle system for forming jets in a fluidic circuit device, said nozzle system comprising a first outlet nozzle, a second outlet nozzle having transverse dimensions greater than said first nozzle, a source of supply fluid, first and second throttles between said source and said first and second nozzles respectively and aligned with said first and second nozzles respectively, and first and second intermediate chambers between said first and second throttles respectively and said first and second outlet nozzles respectively, the distances between said first and second nozzles and said first and second throttles being greater than the smallest transverse dimensions of said first and second throttles respectively.

9. The nozzle system of claim 8 wherein said first nozzle has the form of a Borda mouthpiece.

10. The nozzle system of claim 8 further comprising a third throttle between said source and said first throttle and aligned with said first throttle and said first outlet nozzle, a fourth throttle between said source and said second throttle and aligned with said second throttle and second outlet nozzle, and a common intermediate chamber spacing said third and fourth throttles from said first and second throttles.

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