Nov. 25, 1969 T. W. BERMEL 3,480,030

FLUIDIC DIODE

Filed March 18, 1968

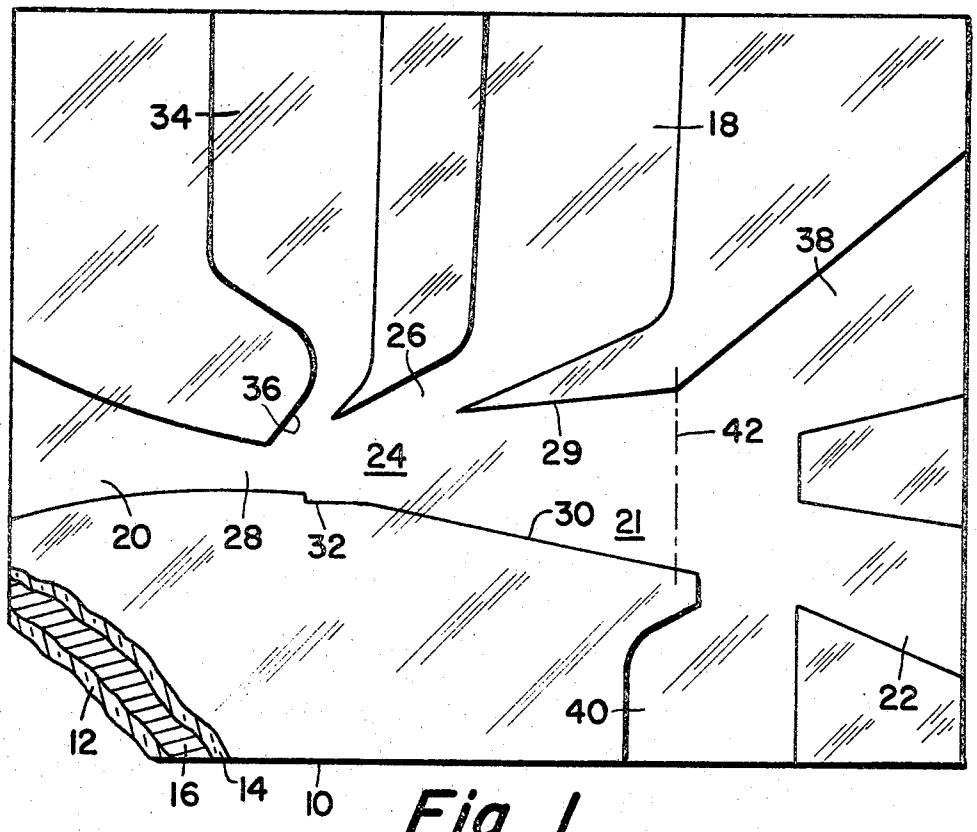



Fig. 1

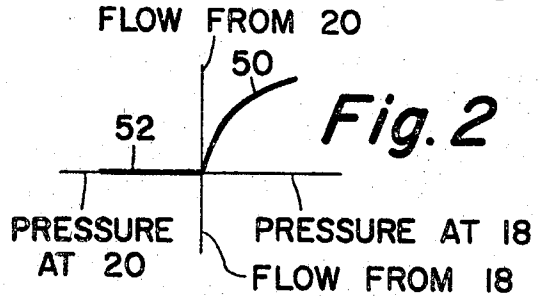



Fig. 2

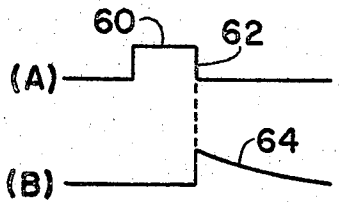



Fig. 4

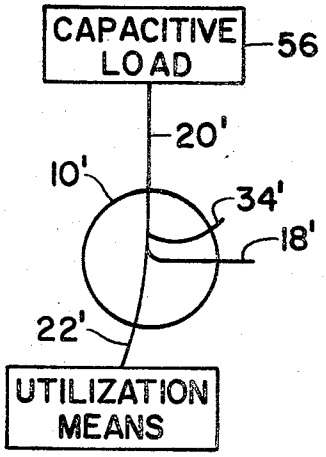



Fig. 3

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# FLUIDIC DIODE

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U.S. Cl. 137—81.5 8 Claims

## ABSTRACT OF THE DISCLOSURE

A flow-type fluidic diode having first and second primary passages and at least one auxiliary passage which may consist of a vent. Fluid introduced into the first primary passage will, due to the wall attachment effect, issue from the the auxiliary passage. However, fluid introduced into the second primary passage will issue from the first primary passage.

## BACKGROUND OF THE INVENTION

### Field of the invention

A fluidic diode is a device having at least two passages, which are referred to herein as primary passages, the flow of fluid between these two passages in one direction being substantially different than the flow therebetween in the opposite direction.

Basically, fluidic diodes can be classified according to two types, pressure diodes and flow diodes, this invention relating to the latter type. In both pressure-type and flow-type fluidic diodes, fluid flow between the two primary passages in the forward direction is substantially unimpeded, although the pressure-flow relationship may not be linear. However, flow between the two primary passages in the reverse direction depends upon the particular type of fluidic diode. Reverse flow in a pressure diode is substantially impeded; however, there may be some fluid flow in the reverse direction. In a flow-type fluidic diode, there is substantially no flow between the two primary passages in the reverse direction, the fluid introduced in one of these passages being vented or issuing from the diode by way of a secondary passage.

Generally in a fluidic device, a fluid stream issues into an interaction chamber from a nozzle or orifice which is constructed so that the stream is well defined in space. The stream is directed toward a receiving aperture by the pressure distribution in the stream boundary layer region. This pressure distribution is controlled by the wall configuration of the chamber, the energy level of the stream, the fluid transport characteristics, back loading of the outlet passage or passages, and the flow of control fluid which may be introduced into the boundary layer region.

A high velocity stream issuing from an orifice creates regions of low pressure adjacent the interaction chamber wall and this, together with the configuration of the interaction chamber, may cause the high velocity stream to "lock-on" to one sidewall and remain in the "locked-on" condition unless some disturbance ends this condition. The diode of this invention incorporates the "wall-attachment" principle to control the flow of fluid in the reverse direction of flow, thereby insuring that substantially no fluid flows between the two primary passages of the diode during the reverse flow condition.



### Description of the prior art

One known type of pressure diode, the Tesla diode, offers some resistance to the flow of fluid in the reverse direction, but some fluid does flow in the reverse direction. Fluid flowing in the reverse direction is divided into two paths, a first of which experiences a change in direction of more than 90° and is then directed against the flow of fluid in the second path, the result of such flow opposition being to impede the flow of fluid in the reverse direction. Due to the angles at which the first path intersects the second path, fluid flow in the forward direction traverses only the second of the above defined paths and meets only negligible resistance. Such a diode is not effective at low pressures, and even at high pressures when its effectiveness increases, some fluid flows in the reverse direction.

Another pressure-type diode is disclosed in U.S. Patent No. 3,362,633 issued to P. A. Freeman. This diode uses a disk-like pill which is slidable in an elongated slot to control the flow of fluid through the diode. The ends of the elongated slot contain first and second ports, respectively, and a port located centrally within the slot is externally connected to the second port. Fluid pressure at either of the end ports causes the pill to move to a position at the opposite end of the slot, thereby blocking the passage of fluid through the port at that end. However, fluid flowing into the first port exits via the side port and is externally coupled to the second port. Although this pill-type fluidic diode exhibits a high resistance to flow in the reverse direction, it has a relatively low operating speed due to the inertia of the pill.

A well-known flow-type fluidic diode, which operates on the vortex principle, consists of a vortex chamber having first and second orifices which are tangentially connected to the cylindrical wall of the chamber and a vent axially located at the end wall of the vortex chamber. Fluid entering the first orifice passes substantially unimpeded through the chamber through the second orifice. However, fluid entering the second orifice creates a recirculating vortex and most of the fluid is vented from the axial orifice. This diode is not effective in venting all of the fluid which enters the second orifice, some passing through the first orifice.

## SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide an improved flow-type fluidic diode. A further object of this invention is to provide a fluidic diode which employs the wall attachment effect to prevent the flow of fluid between the two primary orifices during the reverse flow condition.

Briefly, the fluidic diode in accordance with this invention comprises an interaction chamber defined by first and second spaced sidewalls. An orifice is located at one end of the chamber for issuing fluid to and receiving fluid from this chamber. A second orifice communicates with the second sidewall, the axis thereof making an obtuse angle with the axis of the first orifice, the second orifice being so disposed that fluid flowing therefrom is directed into the first orifice. A passage is disposed in the chamber at the end thereof opposite the first orifice. Means are provided for assisting the attachment of fluid issuing from the first orifice onto the first sidewall so that it flows through the passage.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a plan view, partially in section, of the preferred embodiment of the fluidic diode of this invention.

FIGURE 2 is a graph illustrating a typical pressure-flow diagram for the diode of FIGURE 1.

FIGURE 3 is schematic diagram of a fluidic pulse generator incorporating the diode of this invention.

FIGURE 4 is an idealized waveform diagram representing the instantaneous pressures which exist at various points in FIGURE 3.

## DETAILED DESCRIPTION

The improved fluidic diode of the present invention as shown in FIGURE 1 consists of a laminate structure, in conventional fashion, having outer sheets or plates **12** and **14** acting to sandwich a configured intermediate sheet or plate **16**. For ease of description and illustration, the sheet **14** is shown as being formed of transparent material. Plates **12**, **14** and **16** may be formed of any suitable material such as metal, glass, ceramic, plastic, or the like, and may be secured, sealed or bonded together by any suitable method well known to one familiar with the art, such as fusion of the plates, securing the plates with screws, and the like. The plate **16** may be machined, etched or otherwise grooved to provide openings or channels through which the fluid streams pass. The fluid streams are confined between the top and the bottom plates **12** and **14** so as to flow through passages provided in the center plate **16**.

A fluidic diode is a passive element which provides a substantially unilateral flow between the two points to which its two primary passages are connected. The diode **10** consists of two primary passages **18** and **20** and an auxiliary passage or vent **22**. The passages **18** and **20** are connected to a centrally located interaction chamber by nozzles or orifices **26** and **28**, respectively. The chamber **24** is bounded on two sides by a pair of sidewalls **29** and **30**. Due to the angle at which the orifice **26** communicates with the chamber **24**, fluid flowing from an external source into the passage **18** is directed by the orifice **26** to the orifice **28** so that it flows out of the passage **20**.

The fluidic diode of this invention utilizes wall attachment effects which in part depend upon the configuration of the sidewalls of the device. Fluid flowing into the passage **20** from an external source is directed by the orifice **28** into the region **24**. The wall attachment effects of this device are dominant and are sufficient to maintain the stream issuing from the orifice **28** in a flow pattern adjacent the wall **30** and thereafter through the auxiliary passage **22**. The creation of the wall attachment effect is enhanced by providing an offset region **32** in the upstream portion of the wall **30**. The wall attachment effect is further enhanced by providing the chamber **24** with a vent **34** which communicates with the chamber **24** by way of an orifice **36** which is located in opposing relationship with the offset region **32**. The vent **34** also provides the chamber **24** with venting when a fluid is applied to the passage **18** from an external source and the passage **20** is loaded to an extent that the fluid cannot flow therefrom.

When the passage **22** is to be used as an output, the vents **38** and **40** are provided to keep the diode load insensitive.

If the fluid issuing from the orifice **28** is to be vented rather than being applied to an external load, the passage **21**, which is the downstream portion of the chamber **24**, may terminate and may be vented along the broken line **42**, provided that the length of the wall **30** is maintained long enough to insure that fluid issuing from the orifice **28** locks thereon.

A typical pressure-flow diagram for the diode of FIGURE 1 is shown in FIGURE 2. When a positive pressure from an external source is applied to the passage **18**, the resulting flow from the passage **20** is in accordance with the curve **50**. However, a positive pressure applied to the passage **20** results in no flow from the passage **18** as indicated by the line **52**, all of this fluid being vented from the passage **22**.



The diode of this invention can be used for any application requiring a device having the pressure-flow characteris ics illustrated in FIGURE 2. Another application of this diode, which is illustrated in FIGURE 3, utilizes the output passage **22**. Elements in this figure which are similar to those in FIGURE 1 are indicated by primed reference numerals. The device shown in FIGURE 3 is connected so that it generates a pulse at the auxiliary or output passage **22'** upon the cessation of a positive pressure at the input passage **18'**.

The operation of this pulse generator will be described in conjunction with the waveforms shown in FIGURE 4. A capacitive load **56** is connected to the passage **20'**. An input pressure illustrated by the line **60** in FIGURE 4(A) is applied to the passage **18'** and flows from the passage **20'** to the capacitive load **56**. Should the back pressure on the passage **20'** reach a point such that no further fluid flows from the passage **20'**, fluid flowing into the passage **18'** will be vented by the vent **34'**. Upon cessation of the positive pressure at the passage **18'**, as indicated by the line **62** of FIGURE 4(A), the capacitive load will discharge into the passage **20'** and will flow from the output passage **22'**. The output pressure existing at the passage **22'** is illustrated by a curve **64** in FIGURE 4(B) as being a pressure pulse which increases to a peak value as the positive pressure at the passage **18'** ceases and which thereafter decreases to zero as the capacitive load discharges.

I claim:

**1.** A flow-type fluidic diode comprising

an interaction chamber defined by first and second spaced sidewalls,

first orifice means at one and of said chamber for issuing fluid to and receiving fluid from said chamber,

second orifice means communicating with said second sidewall, the axis thereof making an obtuse angle with the axis of said first orifice means, said second orifice means being so disposed that fluid flowing therefrom is directed into said first orifice means,

a passage oppositely disposed in said chamber from said first orifice means, and

means for assisting the attachment of fluid issuing from said first orifice means onto said first sidewall so that it flows through said passage.

**2.** A fluidic diode in accordance with claim **1** wherein said means for assisting the attachment of fluid comprises an offset region in said first wall.

**3.** A fluidic diode in accordance with claim **2** wherein said means for assisting the attachment of fluid further comprises a vent oppositely disposed in said chamber from said offset.

**4.** A fluidic diode in accordance with claim **1** wherein said first and second sidewalls are disposed on non-parallel surfaces, said sidewalls converging toward said first orifice means.

**5.** A fluidic diode in accordance with claim **1** wherein the portion of said chamber opposite said first orifice means functions as a vent to ambient pressure.

**6.** A fluidic diode in accordance with claim **1** which further includes an outlet passage communicating with the end of said chamber opposite said first orifice means, said diode further including means for venting said outlet passage to maintain load insensitivity.

**7.** A fluidic diode in accordance with claim **1** wherein said first and second sidewalls are disposed on non-parallel surfaces, said sidewalls converging toward said first orifice means, and

said means for assisting the attachment of fluid comprises an offset region in said first wall and a vent

oppositely disposed in said chamber from said offset, said diode further comprising an outlet passage communicating with the end of said chamber opposite said first orifice means, and

means for venting said outlet passage to maintain load insensitivity.

**8.** A fluidic diode in accordance with claim **1** which further comprises

a capacitive load connected to said first orifice means,

a source of fluid pressure signals connected to said second orifice means, and

utilization means connected to said passage.



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