July 29, 1969 R. A. KANTOLA 3,457,935

FLUID AMPLIFIERS

Filed Nov. 28, 1966

Fig 1

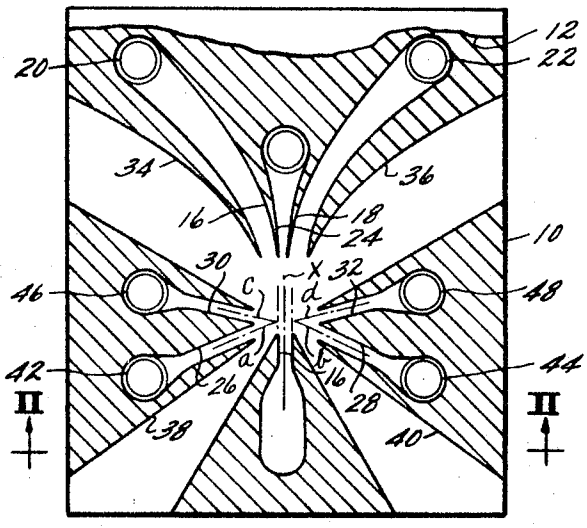


Fig 2

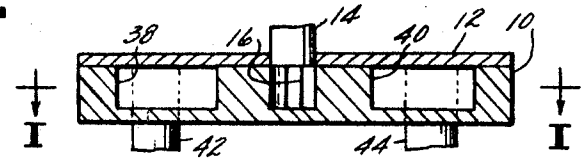
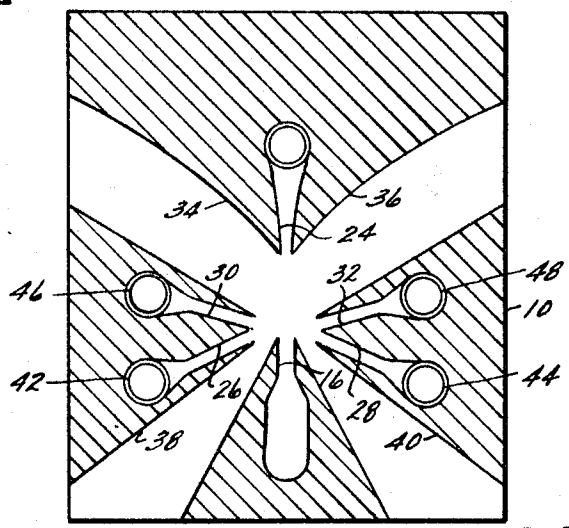


Fig 3



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FLUID AMPLIFIERS

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ABSTRACT OF THE DISCLOSURE

A proportional fluidic device having two or more pairs of control ports is disclosed wherein venting passageways are provided between the power nozzle and the control ports, and the axes of the control ports on a given side of the power nozzle intersect at points which are approximately at the adjacent outer bounds of the power streams.

The present invention relates to improvements in fluidic devices and more particularly to proportional fluidic devices commonly known as fluid amplifiers.

Fluidic devices utilize fluid pressures to perform many sensing, logic, and control functions. This technology is relatively new and has expanded at a rapid rate due to the inherent advantages of such devices, which, in general, have no moving parts and are potentially very economical and reliable. Further, particularly where air or other gases are employed as the motivating fluid, adverse environments, such as extreme temperatures, may be tolerated with little or no effect on their accuracy or reliability.

One important class of fluidic devices is based on the control of a relatively high pressure fluid stream by relatively low pressure input signals. The high pressure stream is deflected by the input signals to provide an output pressure signal which may be directly or inversely proportionate to the input signal, depending upon the disposition of receiver ports relative to the high pressure fluid stream. The maximum value of the output signal is usually greater than that of the input signals, hence, the reference to such devices as fluid amplifiers.

Deflection of the high pressure or power stream may be controlled by the provision of a pair of control ports on opposite sides thereof. Generally these ports are substantially perpendicular to the normal axis of the power stream and opposed to each other. Passageways leading to these control ports are connected to signal-generating devices having a pressure output, the magnitude, or variation in magnitude, of which reflects a given condition, such as temperature, speed of a rotating part, or some other parameter.

The fluid input signals involve flow of fluid through the control ports, which flow represents the output impedance to such signal-generating devices. Previous conventional fluid amplifier designs have had the serious disadvantage of a signal (pressure) change in one control port causing pressure variations in the other control port or ports. This reaction pressure change in the other control ports adversely affects the operation of the signal-generating means connected thereto.

Accordingly, one object of the invention is to minimize, if not eliminate, the effect of changes in one signal input to a fluid amplifier on the operation of other signal-generating devices connected to other inputs of the fluid amplifier and thereby obtain greater accuracy.

The interaction between control port pressures above referred to has a further undesirable effect on fluid amplifier operation in that the output of the fluid amplifiers is not proportional to the input signals, or if linearity is obtained, it is only over a relatively narrow range of input signal pressures. Accordingly, another object of the invention is to significantly increase the range of input signal pressures which provide a linearly proportionate output of a fluid amplifier.

The above objects are obtained by minimizing, if not eliminating, the effect of pressure variations in one control port on the pressure in another control port or ports.

More specifically these ends are attained through the provision of venting passageways between the power stream nozzle and the control ports, in addition to the usual venting passageways provided between the control ports and the output signal receiver means.

Preferably and in order to provide more accurate summation of input signals, two pairs of control ports are provided with their flow axes intersecting approximately at the adjacent outer bounds of the power stream. Additionally it is preferred that the venting passageways, the control ports, and the power nozzle be formed by convergent surfaces, which terminate in relatively sharp points, defining the exits of the control ports and the power nozzle. Further it is preferred that the axes of the control ports be disposed at a relatively low angle to a line normal to the nominal axis of the power stream. Further is is preferred that the control port outlet openings be equally spaced from the nominal axis of the power stream and spaced apart a distance between three to five times the width of the power stream nozzle.

The above and other related objects and features of the invention will be apparent from a reading of the following description of the disclosure found in the accompanying drawing and the novelty thereof pointed out in the appended claims.

In the drawing:

FIGURE 1 is a plan view, partly in section, on line I—I in FIGURE 2, illustrating a fluidic device embodying the present invention;

FIGURE 2 is a section taken on line II—II in FIGURE 1; and

FIGURE 3 is a view similar to FIGURE 1 illustrating the present invention embodied in a different type of proportional amplifier.

Fluid amplifiers may be conveniently fabricated, as illustrated in FIGURES 1 and 2, by etching or otherwise forming channels in a base member **10** and then securing to the base member an overlying cover plate **12** to provide closed passageways of a desired configuration, all of which lie essentially in the same plane. Fluid pressure inputs and outputs to these passageways may be provided by way of conduits extending either through the base member **10** or the cover plate **12**, as indicated in FIGURE 2.

Motivating fluid for the present fluidic device may be supplied through a conduit **14** for discharge through a power nozzle **16** to provide a power stream having a nominal axis indicated at *x*. The power stream maintains its integrity with a width approximating that of the outlet of nozzle **16**. The power stream, when maintained on this nominal axis, creates equal pressure in receiver ports **16** and **18** downstream thereof. The recovered pressures in ports **16** and **18** provide the output signal or signals (one receiver port only may be used) which may be transmitted by way of conduits **20** and **22** respectively to whatever device is to be controlled by this fluid amplifier. Greater accuracy of the output signal is obtained through the provision of a vented opening or cusp **24** intermediate the ports **16** and **18**, in accordance with known practice.

A first pair of control ports **26** and **28** are provided respectively on opposite sides of the power stream discharged from the nozzle **16**. A second pair of control ports **30** and **32** are provided downstream of the first pair of ports and are likewise disposed on opposite sides of the power stream. Venting passageways **34**, **36** are provided between the outlets of the control ports **30** and **32**

and the inlets of the receivers **16**, **18** respectively. Further, and in accordance with the present invention, venting passageways **38** and **40** are provided between the outlets of the control ports **26** and **28** and the outlet of the nozzle **16**.

Each of the control ports **26**, **28**, **30**, and **32** is connected to separate signal generators (not shown) through conduits **42**, **44**, **46** and **48** respectively. The pressure signals thus fed to the control ports cause control streams to be directed along axes *a*, *b*, *c*, and *d*, towards the power stream with the axes on each side of the power stream intersecting each other at points spaced apart a distance equal to the width of the power stream nozzle **16** and aligned therewith, that is, the points of intersection are approximately at the adjacent outer bounds of the power stream.

Deflection of the power stream results from a pressure differential between the signal inputs to the first pair of control ports **26**, **28** or a pressure differential between the second pair of control ports **30**, **32**. As was indicated above, each of these control ports is connected to a pressure signal generator so that a control stream is discharged therefrom against the power stream. Assuming an increase in the pressure in control port **26**, there will be a resultant deflection of the power stream and a decrease in the recovered pressure of the receiver **16** and an increase in the pressure in receiver **18**, thereby providing output signals through conduits **20** and **22**. Similarly, an increase in the pressure of any of the other control ports will result in a deflection of the power stream in a direction dependent upon the side of the power stream which has the larger effective pressure exerted thereon by the control streams.

With the described arrangement and particularly by reason of the provision of the venting passageways **38** and **40**, a variation in the pressure in any one of the control ports has the minimal effect, if any, on the pressures in the remaining control ports.

It has further been found that by spacing the control port outlets apart a distance approximately 3–5 times the width of the power nozzle results in a further minimization of pressure changes in one control port causing pressure variations in other control ports. The accuracy of the entire system in which the present fluid amplifier would be incorporated is thereby greatly enhanced, since the resistance to fluid flow at the control port outlets is essentially constant and thus there is no substantial variation from the fluid amplifier itself to the flow of fluid through the signal-generating means which provide inputs to the fluid amplifier.

Further advantages of the present invention are found from the fact that since the pressure in one control port is unaffected by the pressure in another, both have an effective action in deflecting the power stream which is a direct function of the pressure signal inputs thereto. This results in increased linearity, over a wider range of pressures, between the input signal strength and the output signal strength reflected by the pressures in the receivers **16** and **18**.

Another advantage of the described arrangement is found in the described relationship of the control stream axes *a*, *b*, *c*, and *d*. Since these axes are effective, on opposite sides of the power stream, at essentially the same points, the deflection of the power stream caused by a given pressure differential between the first pair of control ports **26** and **28** will approximate, if not be identical with, the deflection caused by the same pressure differential across the second pair of control ports **30** and **32**. If the pressure differential between control ports **26** and **28** is 1 p.s.i. and greater at control port **26** and the same pressure differential exists between control ports **30** and **32** with a greater pressure at **32**, the signal inputs to the first and second pairs of ports are equal in magnitude and different in direction. This condition is sensed by equal pressure signals in the receivers **16** and **18**.

It will further be noted that it is preferred that the surfaces defining the control port outlets, the venting passageways, and the power nozzle outlet **16** be defined by converging surfaces which terminate in relatively sharp points.

FIGURE 3 illustrates an alternate type of receiver means for a fluid amplifier embodying the present invention. The several control ports are effective on the power stream discharged from the nozzle **16** in the same manner as previously described. However, a single receiver **50** is provided in aligned relation with the nominal axis of the power stream. Thus, when there is a pressure differential effective on the power stream, it is deflected from the receiver **50** and the resultant output signal through conduit **52** is reduced, and when the effective pressures on the power stream are equal, it remains on its nominal axis with a maximum output signal through conduit **52**.

It will be apparent to those skilled in the art that the present invention is applicable to a single pair of control ports as well as to a plurality of control ports, as illustrated herein. Further, the motivating fluid may be either a gas or a liquid.

Having thus described the invention, what is claimed as novel and desired to be secured by Letters Patent of the United States is:

1. A proportional fluidic device comprising,

a nozzle for directing a power stream therefrom,

opposed control port means on opposite sides of said nozzle and closely adjacent the discharge thereof, said control port means comprising at least two pairs of oppositely disposed control ports, the axes of the control ports on each side of said power stream intersecting at approximately the adjacent outer bounds of said power stream on a common line which is perpendicular to the axis of said power stream,

receiver means downstream of said control port means having a recovered pressure varying with the deflection of said power stream, and

vent means on opposite sides of said nozzle, between said control port means and said nozzle, and also between said control port means and said receiver means,

whereby a change in pressure in one control port will have a minimal effect on the pressure in the other control ports on the same side as well as a minimal effect on the pressures in the control ports on the opposite side of the power stream.

2. A fluidic device as in claim **1** wherein said control port means comprises two pairs of oppositely disposed control ports lying in the same plane.

3. A fluidic device as in claim **2** wherein the control ports, the nozzle, and the venting passageways between the control ports and nozzle are formed by converging surfaces terminating in relatively sharp points at the outlets to said ports and nozzle.

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