Feb. 4, 1969 L. W. LANGLEY 3,425,432

BISTABLE FLUID AMPLIFIER

Filed April 29, 1965

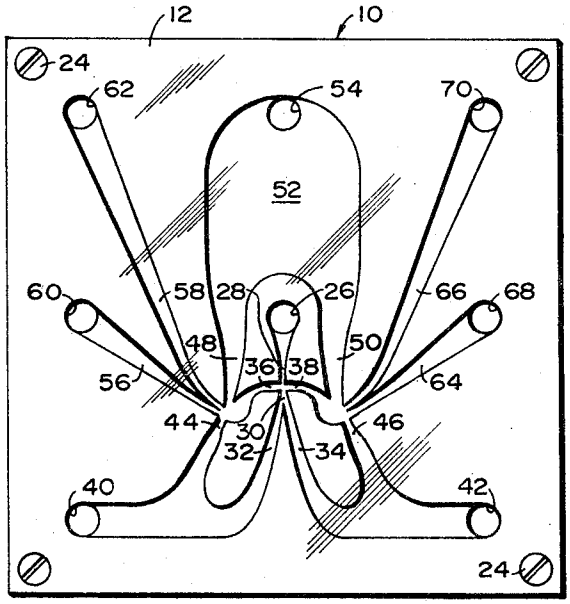



FIG. 2

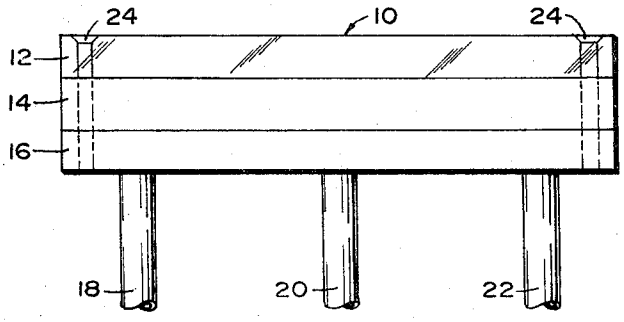



FIG. 1

INVENTOR.
Lawrence W. Langley

BY Walter F. Zaboroski

ATTORNEY

United States Patent Office 3,425,432
Patented Feb. 4, 1969



3,425,432

# BISTABLE FLUID AMPLIFIER

Lawrence W. Langley, Corning, N.Y., assignor to Corning Glass Works, Corning, N.Y., a corporation of New York

Filed Apr. 29, 1965, Ser. No. 451,943
U.S. Cl. 137—81.5 14 Claims
Int. Cl. F15c 1/00

## ABSTRACT OF THE DISCLOSURE

A bistable fluid amplifier is disclosed which utlizes a portion of its output fluid as its own control fluid. A portion of the output fluid, which is directed toward an exhaust chamber in the absence of an input control signal, is directed by a control signal to a control orifice and thereby deflects a power stream from one stable condition to another.

Generally, in a fluid amplifier, a high energy fluid stream, hereinafter referred to as the power stream, issues into an interaction chamber from a nozzle or orifice constructed such that the power stream is well defined in the space, which stream is directed towards a receiving aperture by the pressure distribution in the power stream boundary layer region. This pressure distribution is controlled by the wall configuration of the interaction chamber, the power stream energy level, the fluid transport characteristics, the backloading of the amplifier outlet passages, and the flow of control fluid to the boundary layer region.

In accordance with Bernoulli's theorem, the high velocity power stream issuing from the power stream orifice creates regions of low pressure adjacent the interaction chamber wall and this together with the configuration of the interaction chamber in part cause the power stream to "lock-on" to one side wall and remain in the "locked-on" condition without any control fluid flow. Control fluid flow is brought about by control fluid orifices which issue a control stream directed toward the power stream in a direction generally perpendicular thereto. The power stream can be deflected to the opposite wall of the interaction chamber by the control stream and be caused to "lock-on" thereto as heretofore described and remain there even after the control stream has been terminated.

The apparatus is provided with two outlets or fluid recovery apertures or passages facing the power stream, which outlet passages are arranged such that when the power stream is "locked-on" to one wall, substantially all of the fluid of the power stream is directed to one of the outlet passages, and when it is "locked-on" to the other wall substantially all of the fluid of the power stream is directed to the other of the outlet passages. The fluid so directed to either or both of the passages may be delivered to utilization devices as desired.

A low energy stream can deflect a well defined high energy power stream to the extent required to cause a substantial portion of the power stream to be delivered to one of the outlet passages, while the integrity or the well defined character of the power stream is retained sufficiently after interaction of the two streams so that the total energy or change in total energy delivered to such outlet passage can be greater than the energy or change in energy required to accomplish this deflection. Therefore, since the changes in energy at the utilization device produced by deflection of the stream are greater than the changes in energy required to produce the deflection, the apparatus is said to be capable of amplification and can produce a power gain in the form of a pressure gain or a flow gain or both. The gain achievable with a particular system will vary and be to a degree dependent upon various characteristics and parameters of the stream and apparatus. In prior art fluid amplifiers it has been difficult to obtain a high gain particularly in devices where the power stream is controlled by signals from a plurality of sources.



After the power stream enters one of the passages and the down stream flow resistance or pressure increases for any reason, such as by functioning of the utilization device, the upstream flow decreases. In addition, any flow, for any reason, toward the power stream orifice in the other of the passages, herein called feedback, may also change the power stream flow characteristics. Clearly such flow resistance and pressure changes, or feedback are undesirable since the power stream flow characteristics are affected by sources over which little or no control can be exercised.

It is an object of this invention to provide a fluid amplifier wherein the hereinabove noted disadvantages are overcome.

Another object of this invention is to provide a bistable fluid amplifier wherein the power stream is substantially independent of downstream flow or load changes.

A further object is to obtain optimum design parameters from circuitry embodying a fluid amplifier.

Another object is to provide an economic fluid operated system embodying a fluid amplifier which provides a high gain, and means for control by signal from a plurality of sources.

A still further object is to provide a bistable fluid amplifier having high gain and low power dissipation.

Still another object is to provide a fluid operated system which operates predictably and provides greater versatility in that it can be controlled by signals from a plurality of sources while having a low control power level.

Broadly, according to the instant invention a bistable fluid operated system is provided having means for issuing a well defined, high energy fluid power stream; a pair of outlet passages positioned in an intercepting relationship to the power stream; control means positioned to deflect the power stream from one of the outlet passages to the other of the outlet passages; fluid exhaust means, means disposed intermediate the outlet passages and the exhaust means for issuing a second fluid stream, the exhaust means being positioned in an intercepting relationship to the second fluid stream; and means responsive to at least one source of fluid signals for deflecting the second fluid stream from the exhaust means to the control means, whereby the second stream deflects the power stream from one of the outlet passages to the other of the outlet passages.

Additional objects, features, and advantages of the present invention will become apparent to those skilled in the art from the following detailed description and the drawing on which, by way of example, only the preferred embodiment of this invention is illustrated.

FIGURE 1 is a side elevation of a fluid operated device embodying this invention.

FIGURE 2 is a plan view of a fluid operated device embodying this invention.

The bistable fluid amplifier of this invention may be utilized as a memory element, counter, logic element, storage element, or the like. The stream fluid may be compressible such as air, nitrogen, or other gases, or incompressible such as water or other liquids. Both the compressible or incompressible fluids may contain solid material. This invention is not limited to any particular fluid.

Referring to FIGURE 1, a fluid amplifer **10** is illustrated comprising plates **12**, **14**, and **16**. Fluid stream passages or apertures are formed in plate **14**. Such a device may also be formed with only two plates wherein

the passages or apertures are formed in one of the plates to a depth less than its thickness while the other plate is a cover. Tubes **18**, **20**, and **22** provide suitable connections to the various passages, while srrews **24** maintain the assembly together. For ease of description and illustration plate **12** is shown 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.

Referring to FIGURE 2, a suitable source of high pressure fluid, not shown, is connected to aperture **26** from which it flows through power stream orifice **28** and emerges therefrom as a well defined high energy power stream which enters interaction chamber **30** and passes to either of two amplifier outlet passages **32** and **34**. Control fluid orifices **36** and **38** are provided at the interaction chamber. The walls of the interaction chamber of a bistable fluid amplifier are formed, in a manner well known to one familiar with the art, so that the power stream is caused to "lock-on" to one side wall and remain in the "locked-on" condition without any control fluid flow. The power stream can be deflected to the opposite wall of the interaction chamber by a control fluid flow and remain "locked-on" even after the control fluid flow has been stopped. These orifices alternately permit an entrainment flow for the power stream in a manner well known to one familiar with the art.

Outlet passages **32** and **34** are connected through outlet apertures **40** and **42** to suitable utilization devices such as digital logic circuit elements, analog circuit elements, visual indicators, transducers, diaphragms, pistons, or the like.

Auxiliary control fluid orifice **44** is connected intermediate outlet passage **32** and power stream control fluid orifice **36**, while auxiliary control fluid orifice **46** is connected intermediate outlet passage **34** and power stream control fluid orifice **38**. Exhaust passages **48** and **50** of exhaust chamber **52** are formed in a stream intercepting relationship with auxiliary control fluid orifices **44** and **46** respectively. Exhaust chamber **52** is connected to exhaust port **54**. One end of each of signal transmitting passages **56** and **58** is connected to a suitable source or sources of fluid control signals, not shown, through apertures **60** and **62** respectively, while the other ends of passages **56** and **58**, which ends form orifices for the control signal fluid, are connected intermediate auxiliary control fluid orifice **44** and exhaust passage **48**. Similarly, one end of each of signal transmitting passages **64** and **66** is connected to a suitable source or sources of fluid control signals, not shown, through apertures **68** and **70** respectively while the other ends of passages **64** and **66**, which ends also form orifices for the control signal fluid, are connected intermediate auxiliary control fluid orifice **46** and exhaust passage **50**. Suitable sources of control signals are transducers, other fluid amplifiers, output gating devices, logic devices such as AND and NOR devices, valves, or the like.

The operation of the bistable fluid amplifier of this invention is as follows. When a source of pressurized fluid, such as compressed air for example, is connected to fluid amplifier aperture **26**, a well defined high energy power stream issues from orifice **28** and "locks-on" to either of the outer walls of the inverted "V" formed by outlet passages **32** and **34**, specifically the left wall of outlet passage **32** or the right wall of outlet passage **34**. For the purposes of this description it is assumed that the power stream will "lock-on" the left wall of outlet passage **32** and flow towards outlet aperture **40**. A portion of this power stream will flow through outlet aperture **40** to a utilization device while the remainder thereof will flow through auxiliary control fluid orifice **44** and emerge as an auxiliary or second fluid stream which passes through exhaust passage **48** to exhaust port **54**. Aperture **60** is connected to one source of fluid signals while aperture **62** is connected to another source of fluid signals. A signal transmitted to either aperture **60** or aperture **62** will be equivalent in effect. For example, when a fluid signal is received at aperture **60** from a suitable fluid signal source, such as a transducer, the fluid thereof is transmitted through passage **56** and caused to impinge on the stream issuing from orifice **44** causing it to be deflected from exhaust passage **48** to power stream control fluid orifice **36**. This second stream then issues from control fluid orifice **36** and impinges on the power stream causing it to be deflected from the left wall of outlet passage **32** and "lock-on" to the right wall of outlet passage **34**. It is readily understood that the power stream would have been similarly deflected from outlet passage **32** to outlet passage **34** had a signal been received at aperture **62** and transmitted through passage **58**. When the power stream is deflected to flow through passage **34**, no flow is available through outlet aperture **40** and the second fluid stream ceases issuing from orifice **44**. It is also seen that any signals transmitted through passages **56** and **58** will have a negligible effect on the power stream while it is flowing through outlet passage **34** since there is no fluid stream issuing from orifice **44** on which such signals may act.

Similarly, as the power stream passes through passage **34**, a portion thereof will pass through outlet aperture **42** to a suitable utilization device while the remainder will issue from auxiliary control fluid orifice **46** as an auxiliary or second fluid stream which thereafter passes through exhaust passage **50** to exhaust port **54**. Aperture **68** is connected to a source of fluid signals, such as a transducer, as is also aperture **70**. When a signal is transmitted from such a suitable source of fluid signals through aperture **68** and passage **64**, the fluid thereof is caused to impinge on the fluid stream issuing from auxiliary control fluid orifice **46** causing such stream to be deflected from exhaust passage **50** to power stream control fluid orifice **38**. A fluid signal transmitted through aperture **70** and passage **66** would similarly impinge upon and deflect the fluid stream issuing from auxiliary control fluid orifice **46**. It is seen, therefore, that fluid signals which may be received at apertures **68** and **70** are equivalent in effect. When the fluid stream issuing from orifice **46** is deflected to orifice **38**, it impinges on the power stream issuing from orifice **28** causing it in turn to be deflected to passage **32**. When the power stream is so deflected, flow through aperture **42** to a utilization device will cease, as will the flow through orifice **46**. A signal transmitted through apertures **68** and **70** will have a negligible effect on the power stream while it is flowing through passage **32**.

With the bistable fluid amplifier of the present invention, only one source of pressurized fluid is required. A portion of the power stream itself is used as the control fluid. It is readily seen, therefore, that only a small signal from a suitable signal source is required to deflect the relatively small second fluid stream which in turn deflects the main power stream. Consequently, both a high pressure gain and a high flow gain is achieved. If the flow resistance or pressure increases, or the flow is completely stopped for any reason downstream of apertures **40** and **42**, such as by the functioning of a utilization device, the power stream characteristics upstream will be substantially unaffected since it will merely pass through either of the auxiliary control fluid orifices and be exhausted through port **54**. Likewise, any feedback will also be exhausted in the same manner.

It is further seen that although the present invention has been described with two individual signal sources connected to each side of the amplifier, it is contemplated that one or any larger number of independent signal sources may be similarly connected. Where signal cross feeding may be otherwise eliminated or tolerated, a plural-

ity of signal sources may be connected to one of the signal inlet apertures.

One familiar with the art will readily understand that the final design parameters of specific fluid amplifiers will at least be dependent upon the fluid density, temperature, and pressure, as well as the characteristics required of the power stream at the point of utilization.

Although the present invention has been described with respect to specific details of certain embodiments thereof, it is not intended that such details be limitations upon the scope of the invention except insofar as set forth in the following claims.

I claim:

1. An integral bistable fluid operated system comprising
- first means for issuing a well defined high energy fluid power stream,
- second means defining a pair of outlet passages positioned in an intercepting relationship to said power stream,
- control means positioned to deflect said power stream from one of said outlet passages to the other of said outlet passages,
- fluid exhaust means,
- third means disposed intermediate one of said outlet passages and said exhaust means for issuing a second fluid stream, said exhaust means being positioned in an intercepting relationship to said second fluid stream,
- at least one source of fluid signals, fluid from at least one of said sources of fluid signals flowing into said control means during the presence and absence of said second fluid stream, and
- fourth means defining an orifice for issuing the fluid from one of said sources of fluid signals to deflect said second fluid stream from said exhaust means to said control means whereby said second fluid stream deflects said power stream from one of said outlet passages to the other of said outlet passages.

2. The system of claim 1 wherein said control means comprise two control fluid orifices positioned downstream from said first means on opposite sides of and substantially perpendicular to said power stream, fluid from at least one of said sources of fluid signals flowing into one of said control fluid orifices during the presence and absence of said second fluid stream.

3. The system of claim 1 wherein said third means comprise a pair of orifices.

4. An integral bistable fluid operated system comprising
- an orifice for issuing a well defined high energy fluid power stream,
- first means defining a pair of outlet passages positioned in a stream intercepting relationship to said power stream,
- a pair of fluid passages each terminating in an orifice adapted to issue a control fluid directed against opposite sides of said power stream to deflect said power stream from one of said outlet passages to the other of said outlet passages, each of said pair of fluid passages having an inlet end at the end opposite said orifice,
- fluid exhaust means,
- second means disposed intermediate one of said outlet passages and said exhaust means for issuing a second fluid stream, said exhaust means being positioned in an intercepting relationship to said second fluid stream, and
- third means issuing a third fluid stream in response to a signal for deflecting said second fluid stream from said exhaust means to the inlet end of one of said pair of fluid passages whereby the deflected second fluid stream issues from one of said orifices as said control fluid, said third fluid stream flowing into said inlet end of one of said pair of fluid passages in the absence of said second fluid stream.

5. The system of claim 4 wherein said second means comprise a pair of orifices.

6. The apparatus of claim 4 wherein said fluid power stream is air.

7. A bistable fluid operated system comprising
- an orifice for issuing a well defined high energy fluid power stream,
- means defining a pair of outlet passages positioned in a stream intercepting relationship to said power stream,
- a pair of power stream control orifices adapted for issuing a first control fluid directed against substantially opposite sides of said power stream to controllably deflect said power stream from one of said outlet passages to the other of said outlet passages,
- fluid exhaust means,
- a pair of auxiliary orifices, one of said auxiliary orifices disposed intermediate one of said outlet passages and said exhaust means and the other of said auxiliary orifices disposed intermediate the other of said outlet passages and said exhaust means, said auxiliary orifices being adapted for alternately issuing at least a portion of said power stream as a second fluid stream, said exhaust means being positioned in a stream intercepting relationship to said second fluid stream, and
- a second fluid stream control orifice adapted for issuing a second control fluid in response to a signal for deflecting said second fluid stream from said exhaust means to one of said power stream control orifices whereby the deflected second fluid stream issues from said one of said power stream control orifices as said first control fluid, said second control fluid flowing into one of said power stream control orifices in the absence of said second fluid stream.

8. An integral bistable fluid operated system comprising
- means for issuing a well defined high energy fluid power stream,
- means defining a pair of outlet passages positioned in a stream intercepting relationship to said power stream,
- control means adapted for issuing a first control fluid directed against substantially opposite sides of said power stream to controllably deflect said power stream from one of said outlet passages to the other of said outlet passages,
- fluid exhaust means,
- means disposed intermediate one of said outlet passages and said exhaust means for issuing a second fluid stream, said exhaust means being positioned in an intercepting relationship to said second fluid stream, and
- means for issuing a second control fluid to controllably deflect said second fluid stream from said fluid exhaust means to said control means whereby the deflected second fluid stream is issued by said control means as said first control fluid, said second control fluid flowing into said control means in the absence of said second fluid stream.

9. A bistable fluid operated system comprising
- an orifice for issuing a well defined high energy fluid power stream,
- first means defining a pair of outlet passages positioned in a stream intercepting relationship to said power stream,
- a pair of power stream control orifices adapted for issuing a first control fluid to controllably deflect said power stream from one of said outlet passages to the other of said outlet passages,
- fluid exhaust means,
- a pair of auxiliary orifices, one of said auxiliary orifices disposed intermediate one of said outlet passages and

said exhaust means and the other of said auxiliary orifices disposed intermediate the other of said outlet passages and said exhaust means adapted for issuing at least a portion of said power stream as a second fluid stream, said exhaust means being positioned in a stream intercepting relationship to said second fluid stream, and

first and second orifices adapted for independently issuing a second control fluid in response to a signal, said first orifice being positioned to controllably deflect said second fluid stream from said fluid exhaust means to one of said power stream control orifices, and said second orifice being positioned to deflect said second fluid stream from said fluid exhaust means to the other of said power stream control orifices whereby the deflected second fluid stream issues from said power stream control orifices as said first control fluid, said second control fluid flowing into said power stream control orifices in the absence of said second fluid stream.

**10.** The system of claim **9** further comprising utilization means disposed to receive at least a portion of the fluid intercepted by at least one of said outlet passages.

**11.** The system of claim **10** wherein said fluid power stream is air.

**12.** A bistable fluid operated system comprising

an orifice for issuing a well defined, high energy fluid power stream,

means defining a pair of outlet passages positioned in a stream intercepting relationship to said power stream,

a pair of power stream control orifices adapted for issuing a first control fluid to controllably deflect said power stream from one of said outlet passages to the other of said outlet passages,

fluid exhaust means,

a pair of auxiliary orifices, one of said auxiliary orifices disposed intermediate one of said outlet passages and said exhaust means and the other of said auxiliary orifices disposed intermediate the other of said outlet passages and said exhaust means adapted for alternately issuing at least a portion of said power stream as a second fluid stream, said exhaust means being positioned in a stream intercepting relationship to said second fluid stream,

a first plurality of second fluid stream control orifices adapted for independently issuing a second control fluid and positioned to controllably deflect said second fluid stream from said fluid exhaust means to one of said power stream control orifices whereby the deflected second fluid stream issues from said one of said power stream control orifice as said first control fluid, and

a second plurality of second fluid stream control orifices adapted for independently issuing a second control fluid and positioned to controllably deflect said second fluid stream from said fluid exhaust means to the other of said power stream control orifices whereby the deflected second fluid stream issues from said other of said power stream control orifices as said first control fluid,

said second control fluid flowing into said power power stream control fluid orifices in absence of said second fluid stream.

**13.** The system of claim **12** further comprising utilization means responsive to at least a portion of the fluid intercepted by at least one of said outlet passages.

**14.** The system of claim **12** wherein said fluid power stream is air.


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