March 17, 1970 R. H. BELLMAN ETAL 3,500,845

PNEUMATIC TRIGGER

Filed July 27, 1966 2 Sheets-Sheet 1

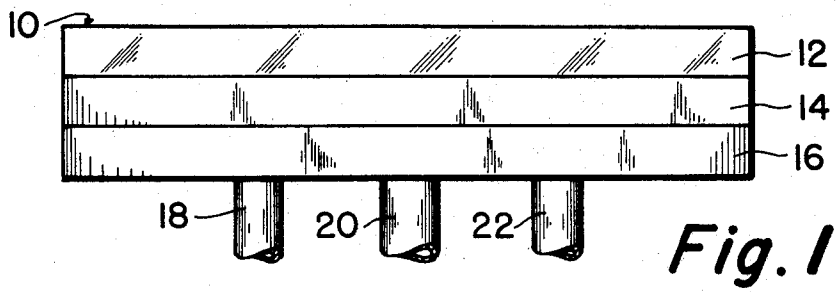


Fig. 1

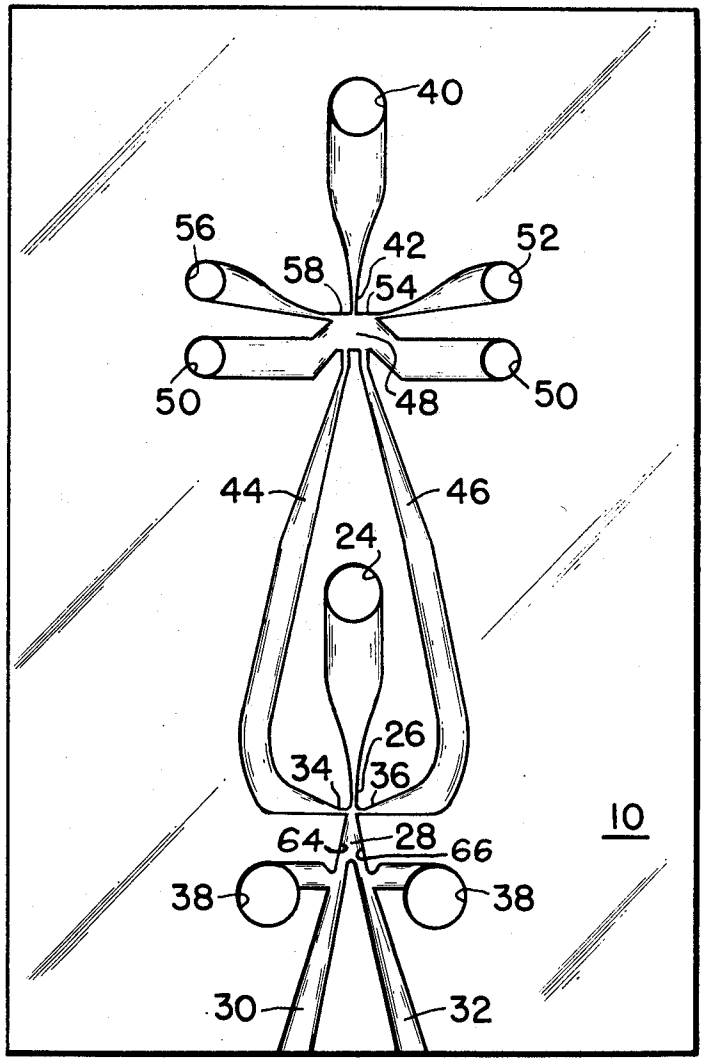


Fig. 2

INVENTORS.
Robert H. Bellman
Thomas W. Bermel
BY Walter S. Zebrowski
ATTORNEY

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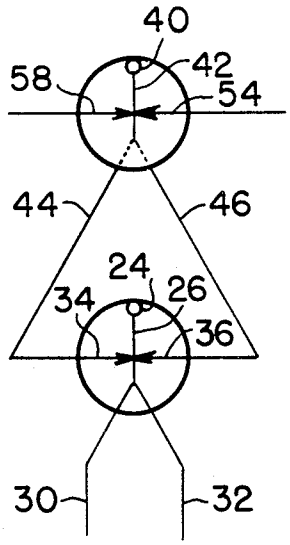


Fig. 3

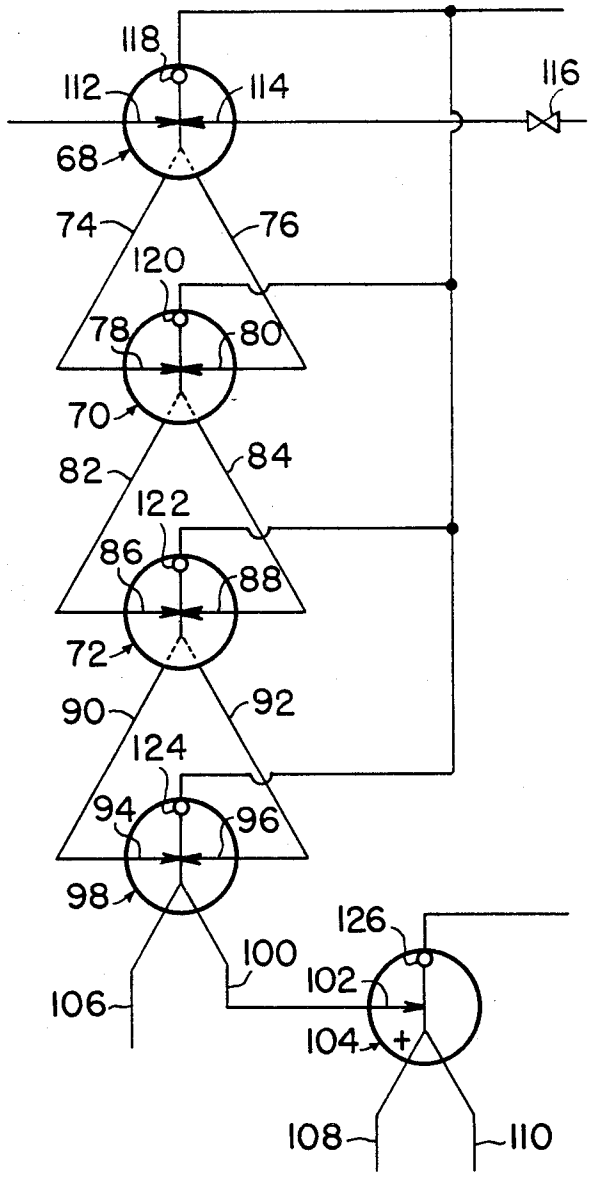


Fig. 4

INVENTORS.
Robert H. Bellman
BY Thomas W. Bermel
Walter S. Zebrowski
ATTORNEY

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PNEUMATIC TRIGGER

Robert H. Bellman and Thomas W. Bermel, Corning, N.Y., assignors to Corning Glass Works, Corning, N.Y., a corporation of New York

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U.S. Cl. 137—81.5 5 Claims

ABSTRACT OF THE DISCLOSURE

A fluid operated device for producing an output fluid stream in response to a fluid control signal which has attained a predetermined minimum threshold level. The device consists of at least one proportional amplifier, the two outlet passages of which are connected to the control passages of a bistable fluid amplifier. A source of biasing fluid is connected to one of the control orifices of the proportional fluid amplifier. The fluid control signal is connected to the opposing control orifice and causes the bistable fluid amplifier to switch when the control signal overcomes the bias.

This invention relates to fluid operated devices and more particularly to an adjustable pneumatic switch or pneumatic trigger, but is not limited to such applications.

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 space, which stream is directed toward 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 back loading 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 sidewall 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. In a bistable fluid amplifier, 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. In a monostable fluid amplifier, the power stream can "lock-on" to one wall only. It can be deflected to the opposite wall but only for such time as there is a control stream and when the control stream has been terminated the power stream will automatically return and "lock-on" to the first wall.

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 in either a bistable or monostable device, substantially all the fluid of the power stream is directed to one of the outlet passages and when it is "locked-on" or deflected to the other wall, as in bistable and monostable devices respectively, substantially all 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 the well defined high energy power stream to the extent required to cause a substantial portion of the 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.

In an ordinary monostable fluid amplifier, where the power stream is stable when flowing through one outlet passage but must be continuously deflected to flow in the other outlet passage, the duration of the flow in the power stream outlet passage toward which it must be deflected, that is in which condition it is unstable, is directly proportional to the duration of the control fluid flow.

It is an object of this invention to provide a fluid device which can produce a digital output from an analog input.

Another object of this invention is to provide an economic pneumatic switch having low hysteresis, high frequency, and adjustable trigger point where the input signal is independent of the output loading.

A further object of this invention is to provide an adjustable pneumatic switch which operates predictably.

Broadly, according to the present invention a fluid device is provided having a bistable fluid amplifier of the type having interconnected fluid passages whereby a well defined power stream may flow from a means for issuing said power stream to one of two outlet passages, and a control means for alternately switching the power stream from one of the outlet passages to the other of the outlet passages. The device also has a means for issuing a second stream of fluid under pressure and has a pair of control passages one end of each of which is connected to the control means of the bistable fluid amplifier while the other ends of the control passages are positioned in a spaced and stream intercepting relationship with the means for issuing the second stream. Also provided is a means for controlling the amount of fluid of the second stream flowing in each of the control passages such that the bistable fluid amplifier power stream can be caused to switch from one of the outlet passages to the other. The invention also embodies means for amplifying the second stream of fluid as well as the output from the bistable fluid amplifier.

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

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

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

FIGURE 3 is a pneumatic schematic diagram of the device of FIGURE 2.

FIGURE 4 is a pneumatic schematic diagram of another embodiment of the present invention.

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 operated device is illustrated comprising plates **12**, **14**, and **16** within which suitable passages or apertures are formed. The passages and internal apertures in plates **12** and **16** must be formed to a depth less than the plate thickness since these plates are also covers for the device. For example, the device may be formed partly in one of the plates while the bal-

ance of it being formed in another of the plates with the plates thereafter being assembled in such a manner as to permit proper interconnection of the passages. Tubes **18**, **20**, and **22** provide suitable connection to the various passages. Plates **12**, **14**, and **16** are shown bonded together by fusion. For ease of description and illustration, plate **12** is 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 together, securing the plates with screws, and the like.

Referring to FIGURES 2 and 3, a suitable source of high pressure fluid, not shown, is connected to aperture **24** from which the fluid flows through power stream orifice **26** and emerges therefrom as a well defined high energy power stream which enters interaction chamber **28** and passes to either of two outlet passages **30** and **32**. Control fluid orifices **34** and **36** 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 sidewall 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 control fluid flow and remain "locked-on" even after the control fluid flow has been stopped. Vent orifices **38** permit entrainment flow for the power stream in a manner well known to one familiar with the art. Outlet passages **30** and **32** may be connected to suitable utilization devices, not shown, such as that hereinafter described.

A second suitable source of high pressure fluid, also not shown, is connected to aperture **40** from which the fluid flows through stream orifice **42** and emerges therefrom as a well defined stream. A pair of control passages **44** and **46**, one end of which passages is connected to control fluid orifices **34** and **36** respectively, have the other ends thereof positioned in a spaced and stream intercepting relationship with orifice **42**. Chamber **48** separates orifice **42** and the inlet to control passages **44** and **46**, which chamber is constructed such that no sidewalls are present onto which the stream issuing from orifice **42** can "lock-on." Chamber **48** is directly connected to vents **50**.

A suitable source of bias fluid is connected to aperture **52** from which it flows through orifice **54** into chamber **48**. A suitable source of fluid control signals is connected to aperture **56** from which they flow through aperture **58** into chamber **48**.

The method of operation of such a pneumatic switch is as follows. When a source of high pressure fluid is connected to aperture **24**, the well defined high energy power stream emerging from orifice **26** initially "locks-on" to either wall **64** of outlet passage **30** or wall **66** of outlet passage **32**. For this description, it is assumed that the power stream will initially lock on to wall **64** causing the power stream to flow through outlet passage **30**. Another source of fluid under pressure is connected to aperture **40** with a stream emerging from orifice **42**. Since there are no sidewalls onto which stream **42** may "lock-on," it will enter control passages **44** and **46** in proportion to the bias and control signal fluid flows as hereinafter described. A source of bias fluid at a predetermined pressure is connected to aperture **52** and emerges from orifice **54** to impinge upon the stream emitting from orifice **42**. The pressure and flow of the biasing fluid is predetermined and controlled, as for example by a valve, such that the stream emerging from orifice **42** will be deflected into passage **44**. A source of fluid control signals is connected to aperture **56** and a control signal fluid flow will emerge from orifice **58** and also impinge on the stream emerging from orifice **42**. Ordinarily orifices **54** and **58** are formed to the same size, whereupon, the stream emitting from orifice **42** will tend to enter control passages **44** and **46** in proportion to the pressure of the fluid emerging from orifices **54** and **58**. For example, when there is no flow through orifice **58** the stream emerging from orifice **42** will be deflected by the bias fluid and will enter passage **44**. As fluid flows through orifice **58** and impinges on the stream emerging from orifice **42** it will tend to deflect it toward passage **46** and the stream will be divided between passages **44** and **46**. When the flow through orifice **58** has increased to a point such that it completely overcomes the bias flow from orifice **54**, the stream emerging from orifice **42** will be completely deflected into passage **46**. It is seen that depending on the fluid flowing through orifices **54** and **58**, the stream emerging from orifice **42** may be proportioned between passages **44** and **46** and such a device is termed a proportional fluid amplifier. A proportional fluid amplifier may also be constructed with a vent passage disposed intermediate control passages **44** and **46** so that the stream emitting from orifice **42** may be exhausted when the control signals and bias fluid are about equal.

When a bias fluid flows through orifice **54** sufficient to deflect a substantial portion of the stream emerging from orifice **42** into passage **44** most of it will emerge from control orifice **34** causing the power stream which has been "locked-on" to wall **64** to be deflected to outlet passage **32** whereupon it will become "locked-on" to wall **66**. When a fluid signal is applied to aperture **56** sufficient to overcome the flow from orifice **54** and to further deflect the stream emerging from orifice **42** into control passage **46**, most of the stream will be emitted through control orifice **36** and cause the power stream emitting from orifice **26** to be deflected from outlet passage **32** to outlet passage **30** and become "locked-on" to wall **64**.

It is, therefore, seen that depending on the flow of control signal fluid and the setting of the bias pressure and flow, an output may be alternately received from passages **30** and **32**. The outlet of passage **30** or **32** may be connected to an alarm, counter, indicating device, or the like. The source of signals connected to aperture **56** may be a liquid level control, or a indicator producing a signal when a machine tool traverses a predetermined distance, or the like. If, for example, aperture **56** were connected to a source of fluid signals emanating from a liquid level controller sensing a liquid level in a tank, and outlet passage **30** were connected to a means for introducing liquid into the tank, the pneumatic switch could be employed to maintain the level within the tank by energizing the means for filling the tank each time the liquid level dropped below a predetermined point.

Since the amount of biasing fluid may be regulated and controlled, the triggering point at which the power stream emerging from orifice **26** may be deflected can be controlled.

Referring now to FIGURE 4, another embodiment of the present invention is shown. Three proportional fluid amplifiers **68**, **70**, and **72** are connected in series such that the output of each amplifier is connected so as to become the control fluid for the next succeeding amplifier. Accordingly, the output of amplifier **68** passes through control passages **74** and **76** and is emitted from control orifices **78** and **80** of amplifier **70** and becomes the control fluid for amplifier **70**. Similarly the output from amplifier **70** passes through control passages **82** and **84** and is emitted from control orifices **86** and **88** of amplifier **72** and becomes the control fluid for this amplifier. The output of amplifier **72** passes through control passages **90** and **92** and is emitted from control orifices **94** and **96** of bistable fluid amplifier **98** thereby becoming the control fluid for amplifier **98**. Outlet passage **100** of bistable fluid amplifier **98** is connected to control orifice **102** of OR–NOR gate **104**. The other output passage **106** of amplifier **98** is vented to ambient. OR–NOR gate **104** is a monostable device which is stable when the output is flowing through outlet passage **108** thereof. The output of gate

104 can be deflected to outlet passage 110 only by providing a fluid flow through control orifice 102.

Control orifice 112 of amplifier 68 is connected to a suitable source of fluid control signals, while control orifice 114 is connected to a source of biasing fluid which is regulated and controlled by some means, such as valve 116, before emitting from control orifice 114. Inlet apertures 118, 120, 122, and 124 of amplifier 68, 70, 72, and 98 respectively are shown connected in common, to which common connection a suitable source of high pressure fluid, not shown, is connected. These inlet apertures could be connected to individual sources of high pressure fluid if such is desired. Inlet aperture 126 of gate 104 is shown provided with a separate connection to a suitable source of high pressure fluid.

The advantages of the embodiment shown in FIGURE 4 are that a small differential between the bias fluid and the control signal can be used to deflect the output from outlet passage 106 to outlet passage 100 of amplifier 98 by amplifying this difference through a plurality of stages such as for example amplifiers 68, 70, and 72. Thus a minute difference may be amplified to be sufficient to operate amplifier 98. The advantage of employing gate 104 is that the output from this gate will flow in one outlet passage only unless and until the control signal emitting from control orifice 112 is of sufficient magnitude so as to overcome the bias fluid by a predetermined amount at which time the output from gate 104 will be caused to be emitted from outlet passage 110. As soon as the control signal falls below the predetermined level, the output from gate 104 will return and flow through outlet passage 108. Another advantage of employing gate 104 is that the output signal therefrom may have a higher pressure by connecting a separate source of high pressure fluid to inlet aperture 126.

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

Although the present invention is 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.

We claim:

1. A phenumatic switch comprising
a bistable fluid amplifier of the type having interconnected fluid passages whereby a well defined substantially continuous power stream may flow from a means for issuing said power stream to one of two outlet passages,
control means for alternately switching said power stream from one of said outlet passages to the other of said outlet passages,
utilization means connected to said outlet passages,
an orifice for issuing a stream of fluid under pressure,
a pair of control passages having one end each connected to said control means and the other ends thereof being positioned in a spaced and stream intercepting relationship with said orifice for issuing a stream,
a chamber intermediate said orifice for issuing a stream and said control passages having a configuration such that said stream of fluid will not "lock-on" to either sidewall,
a pair of control orifices communicating with said chamber,
a source of fluid signals connected to one of said control orifices only,
a source of biasing fluid connected to the other of said control orifices, and
means for regulating the pressure of said biasing fluid,
said stream of fluid being apportioned between said control passages in response to said fluid signals and said biasing fluid, the portion of said stream of fluid entering each of said control passages being substantially wholly transmitted to said control means.

2. A pneumatic switch comprising
a proportional fluid amplifier of the type having interconnected fluid passages whereby a stream of fluid may flow from a means for issuing such a stream to a plurality of outlet passages, first orifice means for directing a stream of biasing fluid against said stream of fluid, and second orifice means opposed to said first orifice means for directing a stream of fluid signals against said stream of fluid, thereby controlling the amount of said stream of fluid flowing in each of said outlet passages,
said proportional fluid amplifier having a chamber intermediate said means for issuing said stream of fluid and said outlet passages having a configuration such that said stream of fluid will not "lock-on" to either sidewall,
means for controlling the pressure of said biasing fluid,
a bistable fluid amplifier of the type having interconnected fluid passages whereby a well defined power stream may flow from a means for issuing said power stream to one of two outlet passages,
utilization means connected to said bistable fluid amplifier outlet passages,
control means for alternately switching said power stream from one of said outlet passages of said bistable fluid amplifier to the other of said outlet passages, and
a pair of control passages communicating between said outlet passages of said proportional fluid amplifier and the control means of said bistable fluid amplifier, the portion of said stream of fluid entering each of said control passages being substantially wholly transmitted to said control means.

3. The pneumatic switch of claim 2 further comprising an OR–NOR gate having a pair of outlet passages, the control orifice of which is connected to one of said outlet passages of said bistable fluid amplifier, said utilization device being connected to the outlet passages of said OR–NOR gate.

4. A pneumatic switch comprising
a plurality of proportional fluid amplifiers of the type having interconnected fluid passages whereby a stream of fluid may flow from a means for issuing such a stream to a plurality of outlet passages in response to means for controlling the amount of said stream of fluid flowing in each of said outlet passages,
said proportional amplifiers being connected such that the flow through the outlet passages of each amplifier being the control fluid for said means for controlling of the next successive amplifier, the means for controlling of the first of said proportional amplifiers being a pair of opposing control orifices one of which is connected to a source of fluid signals while the other is connected to a source of biasing fluid,
a bistable fluid amplifier of the type having interconnected fluid passages whereby a well defined power stream may flow from a means for issuing said power stream to one of two outlet passages,
control means for alternately switching said power stream from one of said outlet passages of said bistable fluid amplifier to the other of said outlet passages,
a pair of control passages communicating between the outlet passages of the last of said proportional amplifiers and the control means of said bistable fluid amplifier, and
a monostable fluid amplifier, the control orifice of which is connected to one of said outlet passages of said bistable fluid amplifier.

5. The pneumatic switch of claim 4 further comprising a means for controlling the pressure of said biasing fluid.

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SAMUEL SCOTT, Primary Examiner

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