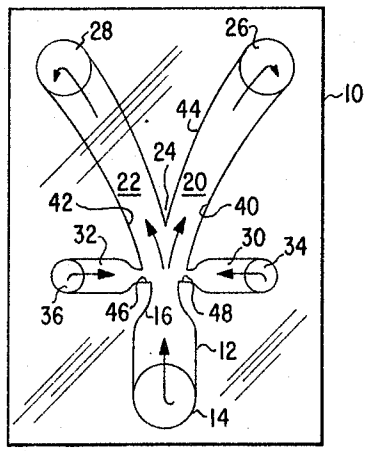
Aug. 16, 1966 J. M. TURICK 3,266,512

FLUID AMPLIFIER CONTROL VALVE

Filed Oct. 16, 1963

FIG. 1—PRIOR ART



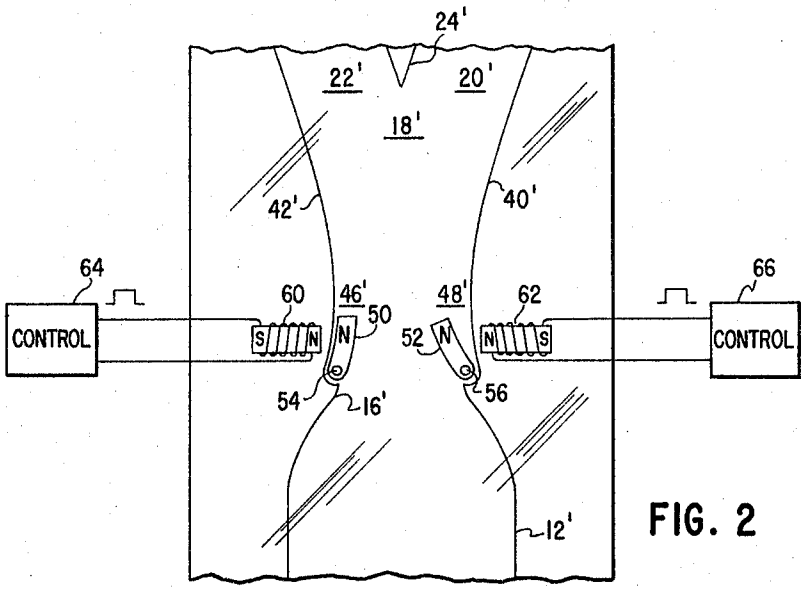




FIG. 2

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# FLUID AMPLIFIER CONTROL VALVE

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This invention relates to multistable fluid amplifiers of the boundary layer lock-on type wherein mechanical means is provided for directing the power stream from one to another of its stable output paths.

Fluid multistable amplifiers as presently known in the prior art operate to switch the power stream by a pure fluid control stream. The input control fluid signal may or may not have had its genesis from a purely fluid source such as external fluid logic circuitry. Often an intermediate transducer is required to convert a non-fluid signal, generally from an electrical or an electronic generating source, to the fluid control stream used in switching the power stream. The instant invention eliminates such an intermediate transducing component. It contemplates modification of a fluid tmplifier with boundary layer lock-on such that the power stream nozzle section includes a mechanical disrupter element which can be selectively moved into the power stream in order to destroy an existing downstream boundary layer. The disrupter element in turn can move in response to a variety of signals such as a pulse of electrical energy.

One object of the present invention is to therefore provide a stable fluid amplifier whose power stream can be switched without use of a fluid control stream.

Another object of the present invention is to provide a boundary layer fluid amplifier wherein the boundary layer existing in an output channel thereof may be destroyed by selective operation of a mechanical element upstream therefrom.

Still another object of the present invention is to provide a stable fluid amplifier directly responsive to an e'ectrical signal for changing state.

These and other objects of the present invention will become apparent during the course of the following description, which is to be read in view of the drawings, in which:

FIGURE 1 shows a typical prior art boundary layer multistable fluid amplifier; and

FIGURE 2 shows how said prior art amplifier may be modified according to the principles of the present invention so as to eliminate need for a control fluid stream.

In order to better understand the present invention, reference is first made to FIGURE 1 which shows a typical prior art bistable fluid amplifier of the boundary layer lock-on type whose power stream is switched between two output channels by means of fluid control streams. A plurality of interconnected fluid channels are cut or otherwise formed in a body of fluid impervious material **10**. In practice, a center section of the material has the channels cut therein which extend in depth between the two major surfaces of said section. The center section thereafter is sandwiched between two cover plates which form the top and bottom walls of the channels. Consequently, the channels have a rectangular cross-section. In the drawings the center section and cover plates are assumed to be made of transparent plastic. A power stream input channel **12** has fluid continuously supplied thereto via port **14** from a pump or other source (not shown). Port **14** is connected to an external channel (not shown) leading from said source and which enters body **10** at a right angle to its major surfaces. The walls of channel **12** terminate in a nozzle section **16** which communicates with a fluid interaction chamber **18**. Nozzle **16** produces a power fluid jet which emerges into this chamber. Branching from said chamber **18** are two power stream output channels **20** and **22**, either of which can receive the entire power stream. These channels **20** and **22** converge together at a divider edge **24**. Channel **20** exits at a right angle from body **10** via a port **26**, while channel **22** does likewise via a port **28**. Ports **26** and **28** in turn are connected to external utilization devices not shown in the figure.



Also entering chamber **18** are two opposed control stream channels **30** and **32** each of which is selectively fed with control stream fluid pulses via ports **34** and **36**, respectively. Ports **34** and **36** are supplied with fluid pulses from external sources, not shown, but which are individually actuated whenever it is desired to switch the power stream flow from one output channel to the other.

In operation of FIGURE 1 the fluid power stream issues from nozzle **16** in interaction chamber **18**. Assume that it flows, for one reason or another, slightly closer to side wall **40** of that chamber which is also the extended outermost side wall of output channel **20**. Fluid is entrained by the power stream so that the pressure near wall **40** will be slightly lower than the pressure near the opposite wall **42** of output channel **22**. This difference in pressure causes the power stream flow axis to move even more toward wall **40** which in turn causes a further reduction in pressure between it and said wall. The power stream continues to bend until it finally locks on to wall **40** and follows its curvature. Thus, the power stream exits through output channel **20** and port **26** by virtue of the "boundary layer" region existing between it and wall **40**. This boundary layer can be destroyed by now issuing a relatively low energy fluid control stream pulse from channel **30** into chamber **18**. Enough control fluid is supplied from control channel **30** to the boundary layer to raise the pressure therein until the differential pressure across the power stream is no longer sufficient to hold the power stream locked onto wall **40**. Consequently, the power stream swings back towards the center of chamber **18**, and in so doing, entrains fluid between it and the opposite wall **42**. This operation reverses the polarity of the pressure differential across the power stream. Eventually, the power stream of its own accord switches to flow through output channel **22** because of boundary layer lock-on between it and wall **42** of said channel. Power stream flow in either channel **22** or **20** is stable since there need be no continuous application of fluid from either control channel **30** or control channel **32**. These control channels merely need supply enough fluid into the boundary layer region to destroy it and thus cause the power stream to move towards the opposite wall where a similar boundary layer effect can commence. The boundary layer effect may be enhanced by slightly offsetting walls **40** and **42** with respect to the side walls of nozzle **16**. These offset regions are designated **46** and **48**.

Turning now to FIGURE 2, the present invention contemplates modification of a typical prior art boundary layer fluid amplifier by replacing the control fluid channels **30** and **32** with mechanical elements situated upstream from the boundary layer region. That structure in FIGURE 2 which corresponds to the structure of FIGURE 1 is identified by primed FIGURE 1 numerals. An input power stream channel **12'** is defined by walls which terminate in a nozzle section **16'**. At said nozzle section **16'** on either side of the channel are located mechanical elements **50** and **52** each in the shape of a curved flapper valve. Each element **50** and **52** is mounted at its upstream end about vertical pivots **54** and **56**, respectively, so that each element is adapted to swing about its said pivot such that it can project into the nozzle in a manner shown, for example, by the position of element **52**.

Chamber 18' is provided from which leads two output channels 20' and 22' joined together at the divider edge 24'. In practice, the two side walls 40' and 42', which are also side walls of channels 20' and 22', respectively, may be undercut in the region of nozzle 16'. The free ends of elements 50 and 52 cooperate with these side walls to form offset regions 46' and 48' when the elements are in their unextended position. As mentioned above, such offset regions may enhance the boundary layer lock-on effect. The flow surfaces of elements 50 and 52 for this structure can therefore be considered as part of the nozzle 16' terminus.

Normally, the force exerted by the power stream as it passes through nozzle 16' is sufficient to maintain elements 50 and 52 in their undeviated position, i.e., that position assumed by element 50 in FIGURE 2. For this case the nozzle terminus is symmetrical on either side of the flow axis so that a basic boundary layer type fluid amplifier configuration is displayed which is quite similar to that shown in FIGURE 1 except that there are no control stream input channels. The power stream flow is stable in either output channnel 20' or 22'. Assume now that the power stream flows through output channel 20' with both elements 50 and 52 being undeviated. By moving element 52 about its pivot 56 in a counterclockwise direction, its free end extends into the power stream flowing through nozzle 16'. This causes a disruption in the laminar flow of the power stream through nozzle 16' which in turn disturbs or destroys the boundary layer along wall 40'. The power stream thereupon begins to swing back to the center of chamber 18 and in so doing sets up and creates a boundary layer along wall 42'. The reverse pressure differential across the power stream now completes the switching of power stream flow into output channel 22' where it will be stable even after element 52 is returned to its undeviated position. By next swinging element 50 clockwise about its pivot 54, a disturbance occurs of the wall 42' boundary layer which will cause the power stream to return to output channel 20'.

Although valve elements 50 and 52 may be swung from their undeviated positions by many different means, a preferred structure shown in FIGURE 2 comprises the use of electromagnets 60 and 62. Each electromagnet is comprised of a magnetic material core around which is wrapped a coil whose terminals are connected to external control means 64 and 66, respectively. These electromagnets may be embedded in the impervious plastic body 10 under the assumption that said body material cannot completely shield elements 50 and 52 from the magnetic field set up around the electromagnets. By applying selectively current to either electromagnets 60 and 62 from their respective control circuits, a magnetic field is produced which has a polarity depending upon the polarity of current in the coil. It is here assumed that each magnet, upon receipt of a control pulse, is energized such that its end closest to the valve element becomes the north pole, whereas the magnet other end becomes the south pole. Elements 50 and 52 are also made of magnetic material and are permanently polarized so that the free swinging end of each becomes a permanent north pole. By disposing the north pole end of an electromagnet adjacent to the north pole end of an element, it is seen that the repulsion existing therebetween forces the element free end out into the nozzle flow area. Conversely, repulsion also exists between south poles. The particular advantage of magnetic deflection is that (1) there need be no mechanical actuating linkage connected to the elements, and (2) when a valve element is in its undeviated position, i.e., when a minimum gap exists between its free end and the end of its respective actuating magnet, maximum force is present at the start of the control action. In other words, the amount of force between two poles varies inversely according to their separation one from the other. Maximum force applied to an element at the time when it first begins to swing is highly beneficial, since it is at this time that maximum energy is required to overcome the downstream boundary layer. As the element swings further, however, less force is required to maintain it in its deviated position and in the disclosed structure said reduction of force is automatically accomplished by virtue of the increased separation between the like poles. Therefore, the magnetic actuation of the elements is quite efficient since there is no wasted energy. A similar case can be made for electrostatic deflection.

As can be seen from above, the fluid amplifier of the present invention is highly stable yet sensitive to signals which do not first require transformation into fluid streams. It might be added that any subsequent uncontrolled vibration or "bouncing" of an actuated valve will not affect the power stream switching action which begins by the initial movement of the valve. Therefore, damping of said valve is not required.

Although a preferred embodiment of the present invention has been shown and/or described, it is apparent that modifications may be made thereto by persons skilled in the art without departure from the novel principles defined in the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A fluid amplifier system comprising:
   (a) a fluid amplifier configuration including a fluid power stream input nozzle from which branch a plurality of power stream output channels, wherein power stream flow is stable in at least one of said output channels by virtue of boundary layer attachment to its wall downstream from said nozzle;
   (b) at least one mechanical element comprising an elongated magnetic member having upstream and downstream ends, said magnetic member being located upstream from said output channels and having a power stream flow surface and which is pivotally mounted about its upstream end in the wall of said nozzle about an axis which in turn extends both parallel to said element flow surface and at a right angle to the direction of power stream flow, said element being movable between a first position whereat its said flow surface is substantially coplanar with the wall flow surface, and a second position whereat at least a portion of its said flow surface extends into the nozzle flow volume transversely to power stream flow whereby said power stream strikes said flow surface and is deflected so as to disrupt said downstream boundary layer so as to create power stream flow instability in said one output channel and cause said power stream to flow into another power stream output channel;
   (c) electromagnetic means selectively operable for for moving said element to said second position; and
   (d) wherein said elongated element has a magnetic pole located in its downstream end, and said electromagnetic means is operable to create a like magnetic pole adjacent the magnetic pole in the downstream end of said elongated member so that the repulsive force between said poles moves said element to its second position.

2. A fluid amplifier system comprising:
   (a) a bistable fluid amplifier configuration including a fluid power stream input nozzle from which branch first and second power stream output channels, wherein power stream flow is stable in any one of said output channels by virtue of boundary layer attachment to a wall thereof downstream from said nozzle;
   (b) first and second mechanical flapper valve elements each of which comprises an elongated magnetic member having upstream and downstream ends, each of said magnetic members being located upstream from said output channels and each having a power stream flow surface, said magnetic members

being located in the wall of said nozzle on opposite sides thereof such that their downstream ends form part of the nozzle orifice, each said valve element further being pivotally mounted about an individual axis which in turn extends both parallel to said element flow surface and at a right angle to the direction of power stream flow such that the element is individually movable between a first position whereat its said flow surface is substantially coplanar with the wall flow surface, and a second position whereat its downstream end extends into the nozzle flow volume whereby said power strikes said flow surface and is deflected so as to disrupt boundary layer attachment in one of said output channels so as to create power stream flow instability in said output channel and cause said power stream to flow in the other output channel;

(c) first and second electromagnetic means each selectively operable for individually moving said first and second valve elements, respectively, to their second positions; and

(d) wherein each of said elongated magnetic members has a magnetic pole located in its downstream end,



and each of said electromagnetic means is operable to create a like magnetic pole adjacent to the downstream end of its associated valve member so that the repulsive force between said poles moves said associated valve element to its said second position.


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