May 16, 1967 T. D. READER 3,319,656

BISTABLE DEVICE

Filed Nov. 8, 1963

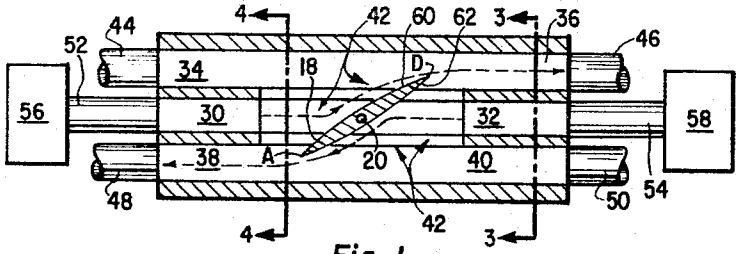


Fig. 1

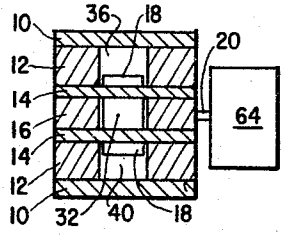


Fig. 3

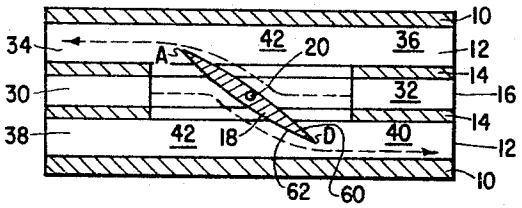


Fig. 2

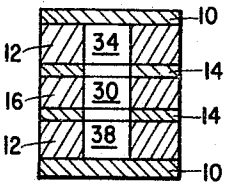


Fig. 4

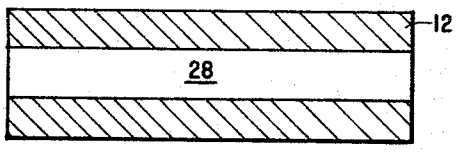


Fig. 7

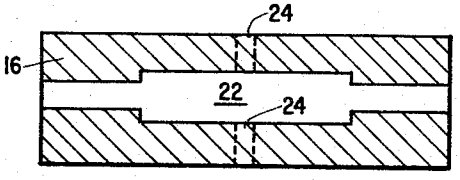


Fig. 5

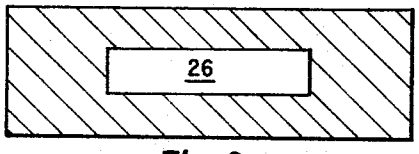


Fig. 6

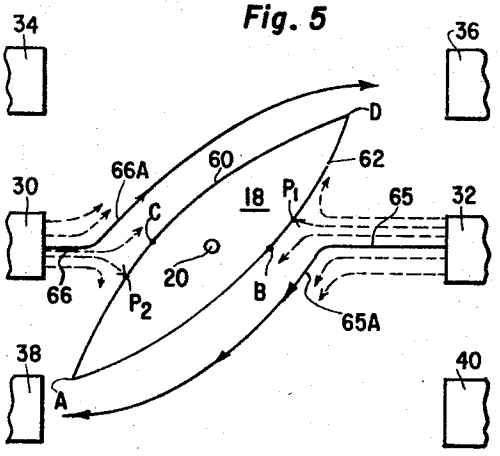


Fig. 8

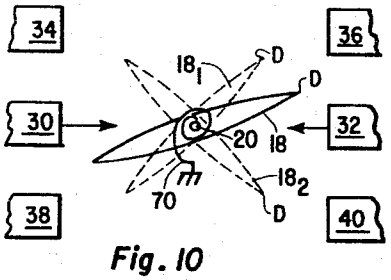


Fig. 10

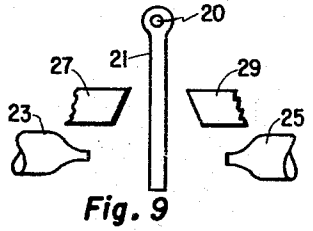


Fig. 9

INVENTOR

TREVOR D. READER

BY *Griffin and Stokes*

ATTORNEYS

United States Patent Office 3,319,656
Patented May 16, 1967

3,319,656

BISTABLE DEVICE

Trevor D. Reader, King of Prussia, Pa., assignor to Sperry Rand Corporation, New York, N.Y., a corporation of Delaware

Filed Nov. 8, 1963, Ser. No. 322,409
7 Claims. (Cl. 137—625.44)

The present invention relates to fluid operated switches and more particularly to bistable fluid switches employing a movable blade as the bistable element. The invention provides a simple and inexpensive switch for selectively controlling the fluid pressure at a plurality of outlets by selectively positioning a movable blade in either one of two stable states.

An object of the present invention is to provide a bistable fluid switch for selectively varying the pressures at a plurality of outlets.

An object of the present invention is to provide a bistable fluid switch employing a movable blade for selectively switching one or more input streams toward one or more outlets.

Another object of the invention is to provide a bistable fluid switch for selectively directing a fluid stream, said switch employing a movable blade which is held in either one of its two stable states by the action of the fluid stream in flowing over its surface.

Still another object of the present invention is to provide a fluid switch having a central chamber, first and second inlet means for injecting fluid streams into the chamber in opposite directions, first, second, third, and fourth outlet means, and a movable blade for selectively directing one of said fluid streams toward said first outlet and the other of said fluid streams toward said third outlet or alternatively directing one of said fluid streams toward said second outlet and the other of said fluid streams toward said fourth outlet.

A further feature of the invention present in one embodiment is the provision of a binary counter comprising a rotatable blade having a torsion spring attached thereto, said blade being disposed in the path of an intermittently generated fluid stream. The arrangement is such that the blade oscillates between two positions as the fluid stream is intermittently directed against the blade surface.

Other objects of the invention and its mode of operation will become apparent upon consideration of the following description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a front view, partly in section, showing one stable position of the switch;

FIGURE 2 is a front sectional view showing a second stable position of the switch;

FIGURE 3 is a sectional view taken along the line 3—3 of FIGURE 1;

FIGURE 4 is a sectional view taken along the line 4—4 of FIGURE 1;

FIGURES 5, 6, and 7 show wafer configurations for an exemplary embodiment of the invention;

FIGURE 8 is a diagram for illustrating the principle of operation of the invention;

FIGURE 9 shows a suitable control means for use in one embodiment of the invention; and

FIGURE 10 is a schematic diagram illustrating the mode of operation of a second embodiment of the invention.

Referring now to the drawing, a preferred embodiment of the invention comprises a plurality of flat plates or wafers **10**, **12**, **14**, and **16** of various configurations and a movable element or blade **18** mounted for rotational movement on a shaft **20**.

The configuration of wafer **16** is shown in FIGURE 5. The wafer comprises two strips of wafer material separated by an open channel **22** the depth of the wafer and extending the entire length of the wafer. A hole **24** extends through the wafer for the purpose of supporting the shaft **20**.

The configuration of wafer **14** is shown in FIGURE 6. There are two wafers **14** and each wafer has a centrally located rectangular hole **26**.

The configuration of wafer **12** is shown in FIGURE 7. There are two wafers **12** and each comprises two strips of wafer material separated by an open channel **28** the depth of the wafer and extending the entire length of the wafer. There are two wafers **10** which are substantially solid and serve as the top and bottom covers for the switch.

The wafers are stacked one on top of the other as shown in FIGURES 1–4 and are fastened together by screws or other conventional fastening means so that fluid cannot escape from the switch between the surfaces of adjacent wafers.

When the wafers are stacked as described above they form a substantially solid body having first and second inlets or input channels **30** and **32** and four outlets or output channels **34**, **36**, **38**, and **40**. All input and output channels connect at one end with a central chamber **42**. Each of the input and output channels is threaded at the other end to receive a pipe or other fluid conducting means.

Output channels **34**, **36**, and **38** and **40** are connected to pipes **44**, **46**, **48**, and **50**, respectively. These pipes may be connected to one or more output devices (not shown). Input channels **30** and **32** are connected to pipes **52** and **54**, respectively, and these pipes are connected to fluid sources **56** and **58** respectively. Sources **56** and **58** may be pumps or compressors and preferably include conventional pressure regulating means to insure that fluid is supplied to input channels **30** and **32** at a substantially constant pressure.

Shaft **20** is carried in holes **24** (FIGURE 5) and extends through chamber **42**. The shaft intersects and is positioned perpendicular to the axis of fluid streams entering the chamber from channels **30** and **32**.

Blade **18** is symmetrically mounted on shaft **20** and rotates with the shaft. The blade is an elongated body having curved and symmetrically shaped upper and lower surfaces **60** and **62**. The blade is made slightly less than the width of chamber **42** so that it does not bind against the side walls of the chamber.

The shaft **20** extends through one wall of the switch (FIGURE 3) to a control means **64**. The control means may be any suitable device for rotating the shaft **20** in either direction to thereby move blade **18** between the position shown in FIGURE 1 and the position shown in FIGURE 2. It may, for example, take the form of a vane **21** connected at one end to shaft **20** and positioned between two opposing fluid jets **23** and **25** as shown in FIGURE 9. In this case the vane is alternately rotated to a first or a second position as force is exerted against it alternately by first one and then the other of the jets issued by nozzles **23** and **25**. Alternatively, the control means may take the form of a manually rotatable control knob. Preferably, the control means also includes stops or rotation-limiting means **27** and **29** for limiting the movement of vane **21** so that blade **18** cannot be rotated in a counterclockwise direction any further than the position shown in FIGURE 1 and cannot be rotated in a clockwise direction any further than the position shown in FIGURE 2.

Assuming that fluid sources **56** and **58** are supplying fluid to input channels **30** and **32** and assuming further that a jet stream from nozzle **25** has acted against vane **21** and thus moved blade **18** to the position shown in FIGURE 1, the switch operates as follows.

The high velocity fluid stream entering chamber 42 from channel 32 strikes blade 18 and is deflected downwardly so that it flows around the blade and into channel 38. This causes an increase in pressure in channel 38 which may be transmitted by way of pipe 48 to an output device.

The high velocity fluid stream flowing from channel 32 to channel 38 tends to entrain molecules of fluid from the region where channel 40 connects with chamber 42. As molecules of fluid are removed from this region the pressure in channel 40 is decreased and this signal may be transmitted over pipe 50 to an output device.

The high velocity fluid stream entering chamber 42 from channel 30 strikes blade 18 and is deflected upwardly so that it flows around the blade and into channel 36. This causes an increase in pressure in channel 36 which may be transmitted by way of pipe 46 to an output device.

The high velocity fluid stream flowing from channel 30 toward channel 36 entrains molecules of fluid from the region where channel 34 connects with chamber 42. This causes a reduction in pressure in channel 34 and this signal may be transmitted over pipe 44 to an external device.

In summary, when blade 18 is in the position shown in FIGURE 1 pressure conditions are such as to tend to draw fluid into the switch through channels 34 and 40 and expel fluid from the switch through channels 36 and 38.

On the other hand, when blade 18 is in the position shown in FIGURE 2 pressure conditions are such as to tend to draw fluid into the switch through channels 36 and 38 and expel fluid from the switch through channels 34 and 40. In this case the fluid stream entering the chamber through channel 30 flows out through channel 40 and in doing so withdraws molecules of fluid from the region where channel 38 connects with the chamber. At the same time, the fluid stream entering the chamber through channel 32 flows out through channel 34 and in doing so withdraws molecules of fluid from the region where channel 36 connects with the chamber.

The blade 18 is bistable. That is, once moved to one of the positions shown in FIGURES 1 and 2 as a result of a jet stream isuing from one of the nozzles 23 or 25 the blade remains in this position even though nozzle 23 or 25 may no longer exert a force on vane 21. FIGURE 8 is a diagram illustrating the principles which make the blade stable after it is moved to the position shown in FIGURE 1 by a jet stream issuing from nozzle 25 against vane 21.

Vector 65 represents in a general manner the path of flow of the high velocity fluid stream flowing from channel 32 toward channel 38. The momentum of the fluid carries it in a straight line path until it strikes the surface 62 of the blade. Because of the curvature of the blade surface and its angular position with respect to the center line of the fluid stream the force is not evenly exerted over the surface area struck by the stream. There is a stagnation point P_1 representing the point of highest pressure exerted normal to the surface 62. The pressure exerted against surface 62 in the region of point P_1 is greater than the pressure exerted at any other point on the surface as long as fluid issues from channel 32. This force tends to rotate the blade in a counterclockwise direction thus moving vane 21 (FIGURE 9) against stop 29.

Upon striking surface 62 the fluid stream issuing from channel 32 is deflected away from the surface and tends to assume a straight line path indicated generally at 65_a. However, the fluid stream travelling path 65_a moves at high velocity and in doing so tends to draw molecules of fluid into the stream from the regions surrounding the path. This reduces the pressure in the region between the fluid stream and that portion of surface 62 lying between points A and B. This makes the pressure on surface 62 between points A and B less than the pressure on surface 60 between points A and C. The resulting

difference in forces tends to rotate the blade counterclockwise so that vane 21 pushes against stop 29.

A similar presure distribution exists along surface 60 as a result of the fluid stream issuing from channel 30. That is, the region of low pressure exists along surface 60 between points C and D. These pressures also tend to rotate the blade in a counterclockwise direction.

When a jet stream from nozzle 25 strikes vane 21 and thus rotates blade 18 to the position shown in FIGURE 2, the fluid streams entering the chamber from channels 30 and 32 create low presure regions adjacent surfaces 62 and 60, respectively, thus tending to rotate the blade in a clockwise direction. The reason for this is believed obvious from the discussion of FIGURE 8. The stop mechanism prevents clockwise rotation from the position shown in FIGURE 2 so that the fluid forces acting against the blade hold it against the stop 27.

Although the invention has been described as having stops for limiting the movement of blade 18, such stops are not absolutely necessary. Assume that no stops are provided and the control means has rotated the blade to the position shown in FIGURE 8. The different pressures acting on blade surfaces 60 and 62 tend to rotate the blade counterclockwise. However, as the blade rotates counterclockwise surface 62 near point A is moved into the path of the fluid stream flowing toward channel 38 and surface 60 near point D is moved into the path of the fluid stream flowing toward channel 36. Particles of fluid in the streams impinge on surfaces 60 and 62 thus exerting a force on the blade which tends to rotate it in a clockwise direction. Theoretically, there is a position at which the force of the impinging fluid particles exactly balances the rotational forces created by the low pressure regions. In actual practice however, there may be a slight oscillation about this position if there is any variation in either of the fluid streams. In oscillating, the points A and D may dip into the fluid stream thus causing variations in the signals developed in the output channels. For this reason it is preferable to employ positive stops which prevent the points A and D from rotating into the paths of the fluid streams.

The present invention may be modified to function as a binary counter wherein the blade 18 alternately switches between two states in response to fluid streams periodically directed against the blade from either channel 30 or 32 or both channels simultaneously. This modification is diagrammatically illustrated in FIGURE 10 where means such as a simple torsion spring 70 is attached to shaft 20 and replaces the control means 64 of the embodiment previously described.

The spring 70 is adjusted such that blade 18 asumes as a normal rest position the position shown in solid outline in FIGURE 10. When a signal in the form of a fluid stream issues from channels 30 and 32 the blade rotates counterclockwise through a small angle and assumes the position indicated in phantom outline by reference numeral 18_1. The forces which cause the blade to assume position 18_1 are the same as those forces which hold blade 18 of the prior embodiment in a stable position as described with reference to FIGURE 8.

While blade 18 is in position 18_1 the input stream from channel 30 flows into output channel 36 and the input stream from channel 32 flows into output channel 38. Thus, output signals manifested by high pressure are produced in channels 36 and 38 while output signals manifested by low pressure are produced in channels 34 and 40.

The blade maintains the position 18_1 only as long as fluid streams issue from channels 30 and 32. Energy was stored in the torsion spring when the blade 18 was rotated from its rest position to position 18_1. Upon termination of the fluid streams this energy is expended in rotating the blade from position 18_1 toward the rest position. However, the spring causes the blade to overshoot the rest position and swing toward position 18_2.

If channels **30** and **32** issue fluid streams at this time the forces acting against blade **18** cause it to assume position 18_2. While the blade is in position 18_2 the input stream from channel **30** flows into output channel **40** and the input stream from channel **32** flows into output chanel **34**.

The blade maintains position 18_2 only as long as input streams issue from channels **30** and **32**. Upon termination of the input streams the blade begins to rotate in a counterclockwise direction in response to the force exerted by the spring. Again, the blade overshoots the rest position so that it moves once more toward position 18_1. If channels **30** and **32** again issue fluid streams the blade is driven to position 18_1 so that high pressure signals are manifested in output channels **36** and **38** and low pressure signals are manifested in output channels **34** and **40**. This completes one cycle of operation of the device.

In summary, each fluid stream pulse issued by channels **30** and **32** causes the blade to alternately assume a first or a second state. Considering a particular output, an output signal is produced for every two input signals applied to the device. This mode of operation corresponds to that of a binary or modulo-2 counter.

There is a restriction on the interval of time which must elapse between input signals applied to channels **30** and **32**. A period of time approximately equal to a half cycle of the natural frequency of the blade and its shaft must elapse between the termination of one input signal and the initiation of the next.

While preferred embodiments of the invention have been shown and described herein, various substitutions, additions and omissions are readily apparent. For example, in an embodiment having a separate input control means **64** one of the input channels, say channel **32**, may be omitted and fluid injected into the chamber only from channel **30**. Also, if only input channel **30** is provided then either one or both of output channels **34** and **38** may be eliminated. In some instances it may be desirable to connect a pointer or visual indicator to shaft **20** to provide a visual indication of the state of the switch. Constructions other than the wafer construction may be employed without departing from the spirit and scope of the invention as defined in the subjoined claims.

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

1. A fluid switch comprising: first means for producing a first high velocity fluid stream, a movable element mounted for rotating movement in the path of said fluid stream about an axis extending substantially perpendicular to the axis of said stream, said movable element having first and second surfaces shaped such that said fluid stream tends to rotate said movable element to a first position when it strikes said first surface and rotates said movable element to a second position when it strikes said second surface, a torsion spring connected to said movable element for normally biasing said movable element at an angular position intermediate said first and second positions, means included within said first means for intermittently terminating said first stream for a period of time equal to approximately one-half cycle of a natural frequency of said spring and movable element, means for selectively rotating said movable element so that said fluid stream selectively strikes said first and second surfaces.

2. A fluid switch as claimed in claim **1** and further comprising a second means for producing a second high velocity fluid stream substantially coaxial with but opposing said first stream, said movable element being disposed between said streams, said second means including means for intermittently terminating said second stream for a period of time equal to approximately one-half cycle of the natural frequency of said spring and movable element.

3. A fluid switch as claimed in claim **2** and further comprising first receiving means for receiving said first stream after it strikes a surface of said movable element and second receiving means for receiving said second stream after it strikes a surface of said movable element.

4. A fluid switch as claimed in claim **3** and further comprising means defining a chamber, said movable element being disposed in said chamber, said first and second receiving means comprising fluid channels terminating at openings in said chamber.

5. A fluid switch comprising: a body having a chamber formed therein; a movable element mounted in said chamber for rotational movement between first and second positions and having first and second curved surfaces; torsion spring means for normally holding said movable element in a position intermediate said first and second positions; means intermittently injecting a fluid stream into said chamber against said movable element whereby said stream may strike said first or said second surface depending upon the rotational position of said movable element; said stream acting against said first surface to rotate said element to said first position and store energy in said spring means or acting against said second surface to rotate said element to said second position and store energy in said spring means, the energy so stored being sufficient to rotate said movable element from one of said first and second positions to the other during the periods between successive injections of said fluid stream; and outlet means connected to said chamber for producing from said fluid stream fluid signals indicating whether said movable element is in said first or said second position.

6. A fluid switch comprising: means defining a fluid chamber; means for injecting into said chamber in opposing directions first and second high velocity fluid streams; a movable element mounted in said chamber for rotating movement in the paths of said fluid streams about an axis extending through the axes of said streams; means for selectively rotating said movable element to a first or a second position; and a plurality of output channels connected to said chamber for selectively receiving said fluid streams after they are diverted by said movable element, said movable element having two curved surfaces for diverting said fluid streams, said surfaces being shaped such that said fluid streams exert forces thereon tending to hold said movable element in said first or said second position after it has been rotated thereto.

7. A fluid switch comprising: means defining a fluid chamber, means for injecting fluid into said chamber, at least first and second channel means terminating first and second openings in said chamber, a movable element pivotally mounted about an axis substantially perpendicular to and in the path of said injected fluid for selectively directing said injected fluid across said first opening and into said second opening to thereby increase the pressure at said second opening and decrease the pressure at said first opening, said movable element having a surface aerodynamically shaped so that said injected fluid tends to hold said element in a predetermined position as it flows over said surface, means for selectively pivoting said movable element about said axis to said predetermined position, third channel means terminating at a third opening in said chamber, means for selectively pivoting said movable element about said axis to a second predetermined position whereby said injected fluid flows over a second surface of said element and towards said third opening, said second surface being aerodynamically shaped so that said injected fluid tends to hold said element in said second predetermined position as it flows over said second surface.

References Cited by the Examiner

UNITED STATES PATENTS

787,565	4/1905	Coryell	137—625
1,905,733	4/1933	Moore	137—81
2,777,251	1/1957	Bailey	46—179
3,102,389	9/1963	Pedersen	137—81
3,223,103	12/1965	Trinkler	137—81

M. CARY NELSON, *Primary Examiner.*

W. R. CLINE, *Assistant Examiner.*