

[54] **FLUIDIC CONTROL DEVICE**
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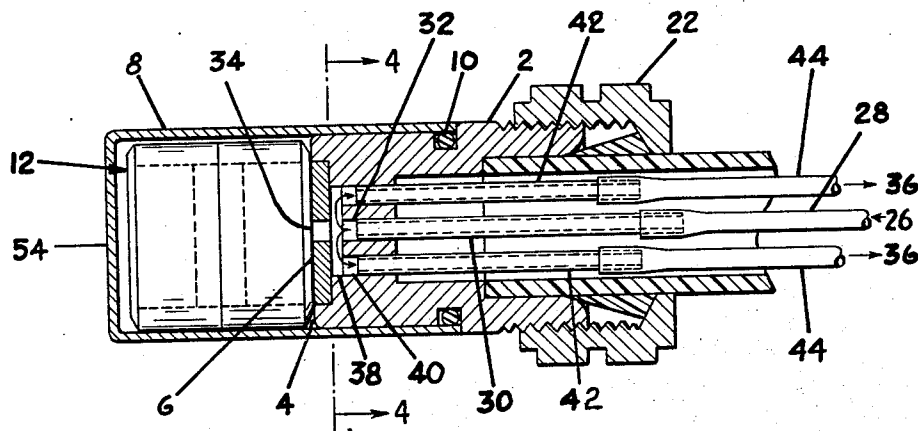
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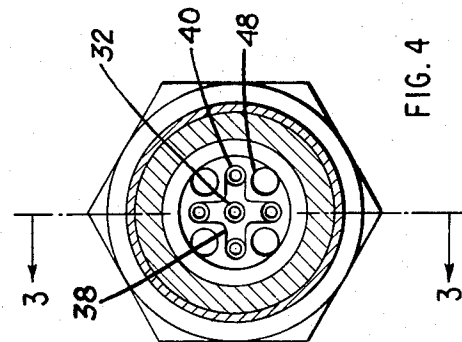
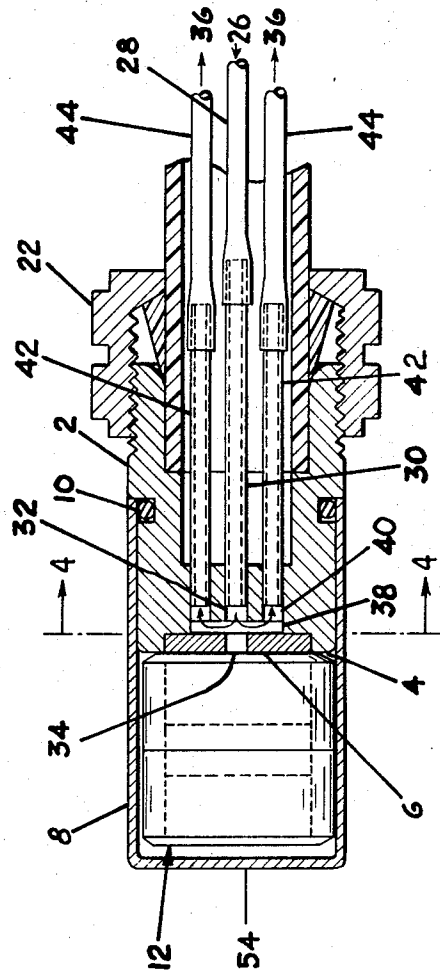
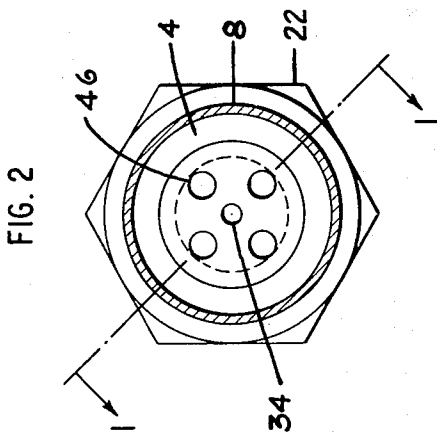
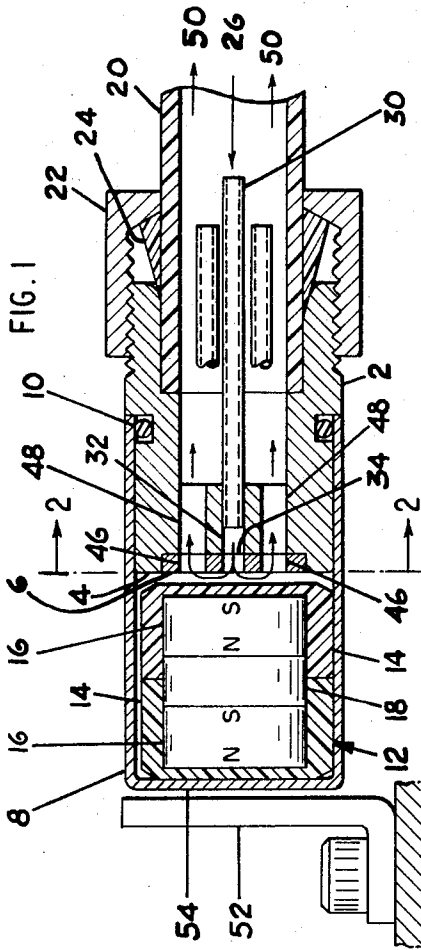
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[57] **ABSTRACT**

A fluidic-magnetic proximity sensor which is able to be totally enclosed and therefore used in contaminated environments due to the use of a magnetic latching means interposed between the element to be sensed and the fluidic element. In operation the enclosed magnet moves in response to proximity of the element to be sensed and closes or opens fluidic paths to actuate a fluidic element such as a back pressure sensor, proximity sensor or flip-flop switch in a fluidic circuit. The apparatus is capable of several modes of operation by interchanging various parts.

5 Claims, 4 Drawing Figures





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FLUIDIC CONTROL DEVICE

BACKGROUND OF THE INVENTION

This invention relates to fluidic controls and circuitry. In particular, it relates to fluidic sensors of the type where the physical presence or proximity of a body is to be sensed. Such sensors are variously described as being back pressure sensors or proximity sensors and as operating as digital, analogue or proportional devices. However, they all have the feature of a fluid supply source, usually air, producing a jet or similar external flow, e.g., a vortex or swirl. The object to be sensed will have the jet impinged upon it, or it may completely close the jet source. As a result, the fluid flow will in part or wholly be redirected to an output or signal channel, producing a signal to a fluidic circuit. The signal channel communicates with the supply channel and can be said to be at a higher resistance than the jet producing channel with respect to the source so that fluid will normally produce the jet. As the jet is blocked partially or wholly its resistance is increased until the flow is diverted to the signal channel. Explanations and descriptions of such devices are shown in the following publications, the contents of which are incorporated by reference herein:

Fluidic Inputs and Interfaces, Automation, November, 1969, p. 71

Fluidic Noncontact Sensors, Automation, August, 1969, p. 95

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention as mentioned above relates to a sensing device for use in fluidic and pneumatic circuits. In the embodiment now to be described, it normally provides a maintained positive pressure signal available for use in fluidic or pneumatic logic devices, that is, it is normally open when considered not actuated, and closed when actuated. It is actuated by being in proximity to an actuating member made of ferromagnetic material. This member may be a simple member attached to or a part of a machine or mechanism, or any ferromagnetic parts being fed through or made by the machine. By means of this actuation, the positive pressure signal is reduced to zero, by being vented to atmosphere. When the actuating member is removed, the device is again pressurized restoring the signal. One feature of the device is that it has only one moving part, a specially polarized magnetic spool that controls the pressure signal and venting. In a sense, the moving part rendering the invention not a pure fluidic device, might be taken to be disadvantageous since one of the features of fluidic devices is the absence of moving parts. However, this one moving part is a freely contained member with a very small movement allowing for long trouble-free operation. As will be seen from the following description, the advantages gained and the inherent reliability of the device for outweigh the fact of its having a moving part. In particular, the invention provides for sensing in a contaminated environment without danger of contaminating the device itself or the fluidic circuit. Another feature of the invention is that it may be used in a situation where fluidic control is desirable but where the fluid itself may be considered a contaminant such as in a sterile environment. The structure of the device is very flexible being adaptable to a variety

of modes including for example, flip-flop operation to be described further below. The various modes can be achieved by simple interchange of parts on a single basic unit of the apparatus. In the description, air is presumed to be the fluid medium as is the usual case in fluidic technology. However, it should be understood that other media could be used.

Referring initially to FIGS. 1 and 3, the apparatus comprises a body portion 2 which has a generally cylindrical shape and in this particular embodiment, is made of a non-magnetic material. In the forward or sensing face 4 of the body 2 there is secured a latching member 6 of ferromagnetic material such as steel in the form of a disc as shown. This latching disc 6 is seated flush in a recess in the face 4. A non-magnetic cover tube 8, e.g., stainless steel is sealably attached to the body 2 by means of the ring 10 and extends forwardly of the body to define a sealed spaced for freely receiving a specially polarized magnetic spool actuator assembly 12; the sealed space permitting oscillatory movement of the actuator assembly 12 toward and away from the body 2 preferably to a maximum of one thirty-second inch. The magnetic spool actuator assembly 12 is made up of two Teflon cups 14 which contain specially polarized magnets 16 and a steel disc keeper 18.

The body portion 2 is formed at one end as a straight tube fitting to sealably receive and hold securely a large diameter hard-wall flexible plastic tube 20 by means of a nut 22 and a ferrule 24. A supply line 26 is constituted by a flexible supply tube 28 (FIG. 2 only); a steel connector tube 30 which is pressed into a supply hole 32 in the body 2; and an aligned hole 34 in the latching disc 6. The hole 34 opens into the sealed space in the cover tube 4, that is, that portion of the space left open when the actuator assembly 12 is moved away from the latch disc 6 as shown in FIG. 1.

A plurality of signal lines 36 communicate with the supply line 26 upstream of the flow space between the actuator 12 and the latching member 6. The signal lines commence as slots 38 in the body 2 emanating at right angles from the supply hole 32 as shown in FIGS. 3 and 4. The slots are covered by the disc 6 to form a closed channel. From the extremities of the slots 38 signal holes 40 extend rearwardly and have securely received in them steel signal connectors 42 which lead in turn to signal tubes 44. The four signal holes 40 are of equal diameter and are physically and functionally interconnected by the slots 38. Of course it would be possible to have only a single signal channel. It would also be possible to vary the diameter of the signal channels or the slots to effect a variety of responses in a fluidic circuit. In any arrangement, with a plurality of signal channels it is possible to use less than all of them simply by blocking those not in use.

The venting arrangement is best seen in FIGS. 1 and 2. Vent holes 46 in the disc 6 communicate with the sealed space in the cover 4 and then with holes 48 (see also FIG. 3) in the body 2 forming a fluid venting channel 50 to and as a part thereof with the large conduit 20. The large conduit 20 will connect to a fluidic logic box carrying the supply and signal tubes to the logic box. The vented fluid will provide a positive pressure in the logic box rendering an added measure of safety from contamination.

It should be noted that all the lines are parallel to and symmetrical about the main axis of the body 2, with the supply line in the center, thus rendering the sensor easy to mount and place in a confined area of a mechanism or near a part whose motion is to be sensed.

Now the operation of the sensor will be explained. The sensor utilizes one of the phenomena of magnetism. If the magnetized material, in this instance cylindrical in shape, is polarized along its axis so that North is on one face and South on the other (instead of North and South on one face only), each magnetic pole can be used for attraction purposes. The phenomenon made use of is that an attractive force at one pole can be made greater than an attractive force at the opposite pole by a different mass at equal distances from respective ends of the magnet thereby causing the magnet to move in the direction of the greatest force. In other words, by bringing a greater mass into close proximity to one of the magnetic poles when the opposite pole of the magnet is initially and normally attracted to a smaller mass, the magnet will be drawn away from the smaller mass toward the greater mass. Therefore, as employed in this sensor, the magnetic spool 12 is normally held by the small mass, the latching disc 6, until an external mass as represented by a ferromagnetic actuator 52 as shown in FIG. 1, is brought to within a prescribed distance from the sensor. The small attractive force is then overcome and the magnet moves a deliberate set distance to rest against the end of the tube 8. When the actuator 52 is removed from the effective proximity to the sensor, the magnetic spool 12 which is still under the influence of the smaller mass moves back against the latching disc 6.

In this totally enclosed and sealed sensor the action of the magnetic spool 12 takes the place of the obstruction normally required in a back-pressure sensor to partially or completely close off the otherwise venting jet, to create a signal. The latching disc 6 is of such a size, shape and therefore mass, that it provides a minimum yet sufficient attractive force to draw the nearer pole of the magnetic spool actuator assembly 12. The assembly's function in the position against the disc 6 as shown in FIG. 3 is to close the vent holes 46 as well as the supply hole 34 forcing the supply pressure into the signal line 36 as indicated by the arrows in FIG. 3 along the slots 38 and then into the signal holes 32. The fluid supply is thereafter directed to any one or number of fluidic or pneumatic logic devices via the signal lines 36.

When the sensor is considered actuated as shown in FIG. 1, a sufficiently larger and external ferromagnetic mass 52 or perhaps the opposite pole of a similarly polarized magnet is brought into proximity to the magnetic spool's magnetic pole opposite the one nearest the steel disc 6. The spool 12 is thereby drawn away from the disc 6 allowing the air to flow into the space between the magnetic spool 12 and the disc 6 and then venting through vent holes 46 and 48 and on through the plastic conduit 20 which eventually leads to atmosphere. The result is a sudden pressure drop at the slots 38 and consequent loss of signal to the signal lines 36. Also, an aspirating effect is produced in the slots 38 which are perpendicular to the signal line thereby augmenting the deterioration time of the signal pressure.

The distance the spool 12 is allowed to move is preferably at least one half the diameter of the small supply hole 32 so that when the external actuator mass is removed, the steel disc 6 attracts the magnetic spool 12 back again thereby closing off the central supply line at the hole 32 and also the venting holes 46 thus restoring the signal once more to the associated logic circuit via the signal line 36. Theoretically, the signal is initiated before the magnetic spool 12 touches and closes off the central supply hole 32 so that according to a rule of thumb, as soon as the spool 12 comes within one quarter of the diameter of the supply hole 32 a signal pressure will be built up.

In applying the magnetic phenomenon, it should be appreciated that the distance between the magnet and the respective masses is also a factor where force applied to move the magnet will decrease as distance increases. However, forces developed drop off rapidly as distance increases and where in the most common applications, a positive and rapid actuation of the sensor is desired, distances are of limited value as a design variable as regards balancing the magnet effects. Instead the distance between the magnet spool 12 and the disc 6 is chosen on principles applied to fluidic devices in order to assure good flow in the venting position (FIG. 1) and rapid creation and decay of the signal flow during operation of the sensor. Distance between the actuating mass 52 and sensor head, that is, the closest pole of the magnetic spool 12 should be close as possible in the actuating position in order to move the magnet rapidly and positively away from the disc 6 to cause rapid decay of the signal pressure. The actuating mass should move a relatively large distance away to complete the cycle at which time the magnetic spool 12 moves back against the latching disc 6.

Another feature of the sensor is that the large diameter plastic tube 20 which is preferably of the hard-wall type, serves two functions; firstly, to house and protect the small vulnerable, low pressure soft wall tubing 28 and 44 which attach to the supply connector 30 and the signal connector 42 respectively; and secondly, to act as a means of conveying the vented ultra-clean fluidic air back to a panel box where it helps to pressurize the box slightly which is controllably vented to atmosphere thereby preventing any back contamination.

The entire sensor can, therefore, be submersed in oil, water or any non-destructive fluids, or subjected to the most severe particle contaminated atmosphere.

A sensor model as described above was tested over a 1-year period. Over 100 million cycles were accumulated on a test unit mounted on a machine that imposed severe conditions on the model with no indication of wear or detriment to the logic devices and circuitry integrated with it. The testing was done for a considerably length of time in the speed range of 400-500 cycles per minute. During the entire test period, the model sensor was mounted in an oil bath chamber of the test unit. No contamination of the fluidic circuitry occurred nor did any malfunction or failure to function occur.

Certain alternative and more specific embodiments of the device are possible as follows:

Limit switch mode

If the latching disc 6 as shown is replaced by a similar disc which does not have the vent holes 44 and the slots

38 are omitted and the signal line is continued through the disc 6 into the flow space, then the device will operate as non-venting limit switch, essentially a two-way valve which can be used as an interlock in any fluidic or pneumatic system. Resetting of the sensor can be accomplished by bleeding the pressure from signal line with the supply pressure shut off.

Flip-flop mode

A second disc of ferromagnetic material such as steel, may be incorporated in the face 54 of the tube, that is, the tube 8 as shown in FIGS. 1 and 3 may be interchanged with one having such a second disc. The mass of the second disc is sufficient to retain the actuator assembly 12 once the assembly has come into contact with it. The sensor in this mode can be considered to be normally latched open, that is, with the signal on and the actuator assembly 12 against the disc 6 as in FIG. 3. In this configuration, the sensor must be actuated by an external magnet which when brought into proximity to the sensor in the manner described earlier in the general description, will draw the actuator assembly 12 away from the disc 6 and into contact with the second disc at 54. When the actuator is withdrawn the spool 12 will not return to its original position but will remain against the second disc and the device will continue to vent until it is manually reset. Thus an on or off signal of any desired time interval can be attained.

The basic principles described herein can be easily employed in either large or miniature size. By varying air pressure, magnetic flow densities, magnet size, attractive mass magnitude, and judicious choice of materials, a sensor of extremely small or large size can be made. It is easily possible for example, to make a sensor the size of a common pencil. A sensor of this size would be extremely sensitive and have very little influence on the object being sensed.

FIGS. 1 to 4 show an embodiment of a signal fan-out of four. However, a fan-out of one, two or three can be achieved merely by blocking one or more of the existing signal lines. A larger number of signal lines can also be achieved while still maintaining symmetry about the sensor axis.

The various passageways and connector diameters can be varied to produce signals of differing pressures and elapsed times all from the same sensor and from the same time of actuation thereby triggering different fluidic logic elements accordingly.

As mentioned above, the actuating member can be a magnet. It is a significant advantage that when the actuating member is a magnet, the sensing range can be increased substantially over 0.030 inch. Conventional open nozzle type sensors have a normal range limit of 0.020 inch.

The capability of the sensor to operate in an analogue mode can be increased by a further embodiment. In this case, the disc 6 is also a magnet, axially polarized so that in conjunction with the spool 12 like poles are facing. Thus the tendency is for the gap (FIG. 1) between the disc 6 and the assembly 12 to remain due to the magnetic repulsion between them. The external actuator is a magnet whose like pole also faces the spool thus also tending to push the assembly 12 away from it. Thus, with proper determination of the mass of the disc 6 and of the external actuator, and of the respective gaps between them and the assembly 12,

movement of the external actuator urges the spool 12 toward the disc 6 in a proportional manner, only completely closing the hole 34, if at all, in the most extreme case. Thus the signal pressure can be caused to increase or decrease which can actuate in turn discrete fluidic devices either digitally or proportionally as the circuit design requires.

By a simple modification, all of the modes described can be adopted to a single basic unit by interchange of parts. This modification is to put the slots 38 in the disc 6 rather than in the body 2. This will not affect the general mode since the bypass portion of the signal line will be still provided by slots in the disc. However, by replacing the disc with one as described for the limit switch mode, the same body can be used. For the other modes either the disc or the cover is changed as described in each case.

While the invention has been described in terms of certain embodiments and modes of operation for purposes of disclosure it is intended to cover all changes and modifications without departure from the spirit and scope of the invention.

What is claimed is:

1. A fluidic magnetic proximity sensor for use in a fluidic circuit comprising; a body portion; a non-magnetic cover sealably attached to the body portion and defining a sealed space therein bounded by a sensing face in the body portion for receiving a magnetic actuator and permitting oscillatory movement thereof toward and away from the sensing face; a ferromagnetic latching member attached to the sensing face of the body portion and forming a part thereof; a magnetic actuator within the sealed space and oscillatory into and out of contact with the latching member, the magnetic actuator and the latching member being substantially mated when in contact and defining a flow space between them when out of contact and the magnetic actuator being a specially polarized magnet so that with respect to its axis of movement one end is a South pole only and the other end is a North pole only; a fluid supply channel extending through the body and the latching member into communication with the flow space and closable by the magnetic actuator when it is in contact with the latching member and communicable at its entry with a fluidic circuit supply; at least one venting channel extending through the body and the latching member into communication with the flow space and closable by the magnetic actuator when in contact with the latching member so that a fluidic supply flowing from the supply channel will flow through the flow space into the vent channel when the magnetic actuator is in its position away from the sensing face; at least one signal channel extending through the body into communication with the supply channel upstream of the flow space and at a higher resistance to the flow of fluid from the supply channel than the vent channel when the flow space is present and communicable with the fluidic circuit so that fluid will not flow through the signal channel when the flow space is present but will instead flow through the venting channel.

2. The sensor of claim 1 wherein the body portion has a longitudinal axis in common with the axis of movement of the magnetic actuator and wherein the supply, venting and signal channels therein are parallel

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to the axis excepting a bypass channel constituting a portion of the signal channel which extends angularly between the supply channel and the signal channel, the angular relationship causing the signal channel to be at a higher resistance than the vent channel.

3. The sensor of claim 2 wherein the upstream end of the body portion is formed as a straight tube fitting parallel with the axis for sealably receiving a tube and the supply and signal channel are arranged to be communicable with a fluid circuit within the tube and the vent channel opens into the tube.

4. The sensor of claim 2 wherein the sensing face is

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slotted to establish the bypass channel, the slot extending between the signal channel; and the supply channel and the latching member being secured over the slot to establish a closed channel therewith.

5. The sensor of claim 2 wherein the latching member is slotted to establish the bypass channel when secured over the sensing face with the slots against the sensing face which establishes a closed channel and the slots extend between the signal channel and the supply channel.

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