July 29, 1969 D. J. CRAFT 3,457,933

FLUID CONTROL DEVICES

Filed Sept. 15, 1965

FIG.1

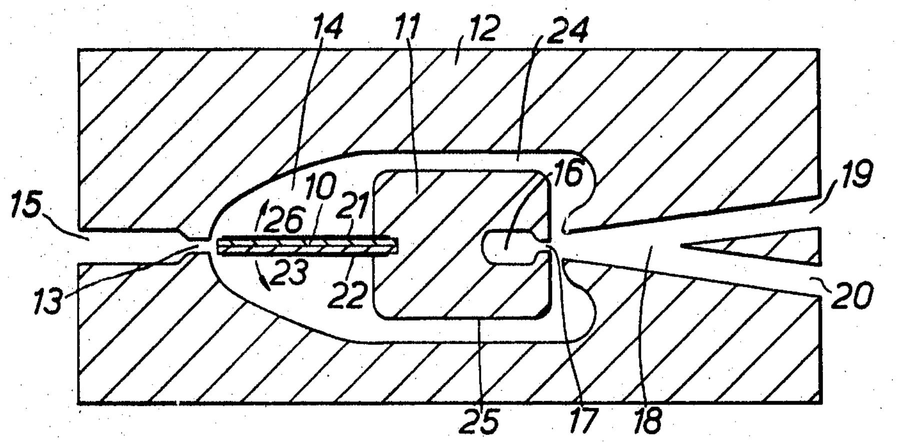


FIG.2.

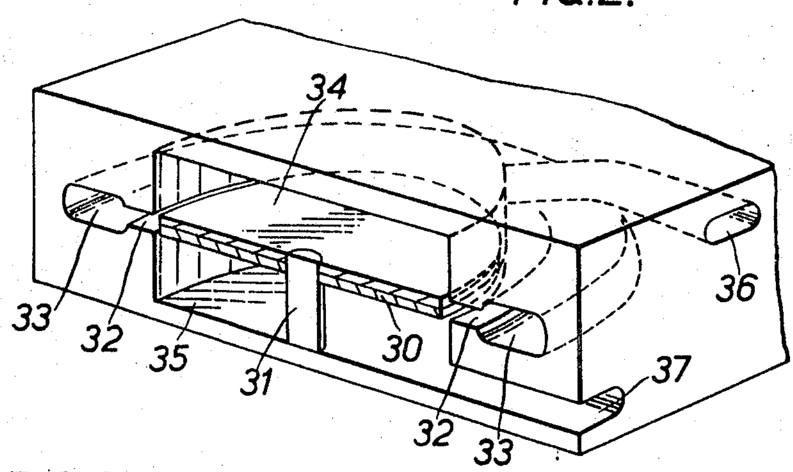
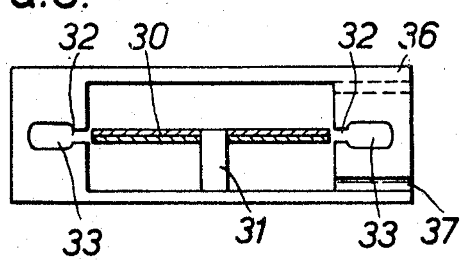


FIG.3.



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FLUID CONTROL DEVICES

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U.S. Cl. 137—81.5 10 Claims

ABSTRACT OF THE DISCLOSURE

A transducer for converting electrical signals into fluid pressure signals uses a piezoelectric lamina to divert a stream of fluid into one or other of two output ports. The output ports are connected to respective control ports of a fluid flip-flop so that momentary bending of the lamina in response to an electrical pulse causes the flip-flop to take up one or other of its stable states.

The present invention relates to fluid control devices and is particularly concerned with transducer arrangements for converting electrical changes into corresponding changes in the setting of fluid operated devices such as may be employed in what have now come to be known as fluid logic systems. Such systems make use of units in which a fluid such as compressed air is employed to effect the movement of valve or similar control members so as to produce switching operations similar to those which can be produced in other circumstances by electrical circuits.

It may however be necessary in such arrangements to obtain the control input from electrical equipment such as a computer and accordingly there is need for a suitable transducer device. The chief object of the invention is to provide for use in arrangements for converting electrical control to fluid control a device which shall be reliable in operation, simple to construct, compact in size and requiring very little power.

According to the invention, the electrical control produces bending of a piezoelectric lamina of the general type which is now widely employed in sound reproducers or record players and this bending action serves to divert a stream of pressure fluid in one direction or the other, so as to obtain a selective output. Thus it is possible if desired to operate a so-called fluid flip-flop to cause it to take up the required one of its two stable states.

The invention will be better understood from the following description of two methods of carrying it into effect, which are illustrated in the accompanying drawings comprising FIGURES 1–3. FIGURE 1 shows a so-called reed type of construction in which a narrow strip of piezoelectric material is clamped at one end so that when it is supplied with a suitable electric potential, bending takes place and the free end of the strip is moved in one direction or the other, dependent on the polarity of the applied potential. FIGURE 2 shows a cutaway perspective view of a modified form using a disc of piezoelectric material instead of a strip and FIGURE 3 is a central section through the disc corresponding to FIGURE 2.

Referring now to FIGURE 1, the piezoelectric strip **10** is rigidly supported at one end in a suitable block **11** attached to the main housing **12** and projects so as to come opposite orifice **13** in the chamber **14** formed in the housing to have the shape shown. This orifice may be any suitable shape, for instance circular or elongated so as to match the end of the strip. Arrangements are provided for supplying control fluid to it through a suitable channel **15**. Block **11** also has a channel **16** to which operating

fluid is supplied and escapes through an orifice **17** which is located opposite a channel **18** in the main housing **12** which channel diverges shortly into two branches **19** and **20**. Two electrodes **21** and **22** are provided on opposite surfaces of the strip.

When the strip **10** is in its unstressed neutral position, it is symmetrically located in the chamber **14** and the system is balanced and the operating fluid from the channel **16** will tend to divide equally between the channels **19** and **20**. When electrical potential is applied to the strip, however, it is caused to bend, for instance downwards in the direction indicated by the arrow **23** and consequently the control fluid from the supply channel **15** tends to pass through the upper channel **24** rather than the lower channel **25** and thus causes the operating fluid from the other supply channel **16** to be deflected along the channel **20**. Similarly, if the strip is energised so as to cause bending upwards in the direction indicated by the arrow **26**, the control fluid from the supply channel **15** passes predominantly along the lower channel **25** and deflects the operating fluid from the supply channel **16** into the channel **19**. The channels **19** and **20** may lead to the opposite control ports of a fluid flip-flop and this can therefore be moved in one direction or the other by a momentary bending of the strip **10** in response to a suitable electrical pulse. Alternatively the strip may be subjected to continuous bending so that pressure fluid is continuously applied more effectively to one of the channels **24** and **25** than to the other and hence similarly to the channels **19** and **20**.

In the arrangement of FIGURES 2 and 3, the piezoelectric material is in the form of a disc **30** which is rigidly supported at its centre by the post **31**. When it is not subjected to any electrical potential, its edge is opposite a circumferential slit **32** in the support block to which pressure fluid is supplied in any suitable manner, for instances by way of the circumferential channel **33**. In these circumstances the fluid is applied equally to the chambers **34** and **35** above and below the disc from which channels **36** and **37** extend to for instance the control ports of a fluid flip-flop.

When the disc is energised with potential of one polarity by way of electrical connections (not shown but similar to those shown in FIGURE 1), it will bend either upwards or downwards to take up a slightly dished configuration and consequently the pressure fluid will be applied to the lower chamber less strongly than to the upper one, or vice versa. As a consequence there is a difference in fluid pressure applied to the control ports by way of channels 36 and 37 and the flip-flop connected thereto is therefore operated to the appropriate condition.

The piezoelectric member may be a bimorph of known type constructed of any of the materials which are known to have suitable properties, for instance lead zirconate-titanate. In the embodiments described above potential is applied between two electrodes located on the outer surfaces of the two layers of piezoelectric material. In this case the layers are so disposed in relation to each other that when an electric field of a particular polarity is applied, the direction in which one tends to expand is substantially perpendicular to the corresponding direction in the other. Alternatively, potential may be applied between a central electrode located between the two layers and a pair of interconnected electrodes, one located on the outer surface of each layer. In this case, the applied electric field has the opposite polarity in the lower layer to that which it has in the upper. Therefore the directions in which the layers tend to expand under the influence of electric fields of the same polarity are arranged parallel to each other.

The arrangement has the advantage of cheapness and ease of incorporation in integrated quid circuits, and also extremely long life. A further advantage is that it involves negligible power consumption and that it is compatible with high-speed electronic logic techniques. Thus the output from a computer or similar high-speed device may be required to control a large number of fluid toggles. The type of transducer described acts as a very low leakage capacitance and to operate the transducer it is necessary to charge this capacitance. This need take only a few microseconds, but the charge is maintained for a considerable time, for instance of the order of 30 seconds, and during this time the common electronic equipment can continue with other operations. If the transducer is to stay in one state for a much longer time, the common equipment need only give it a refresher charge at widely spaced intervals as necessary.

The invention accordingly provides a highly advantageous transducer of small size and long life which operates with economy and reliability and is thus capable of linking electric and fluid logic circuits in a very efficient manner.

I claim:

1. A transducer for converting electrical signals to fluid signals comprising a chamber, a piezoelectric lamina, of the type which bends when an electric field is applied thereto, extending across said chamber to divide same into two parts, two exhaust ports, one communicating with each part of said chamber, a support member having said lamina rigidly mounted thereon, an orifice in one wall of said chamber arranged to confront the edge of said lamina furtherest from the support member and electrode means for applying an electric field to the lamina whereby the lamina can be caused to bend to deflect fluid flowing into the chamber through the orifice into one or other of the exhaust ports.

2. A transducer as claimed in claim **1** in which said lamina is in the form of a strip, one end of which is attached to said support and the edge of the other end of which confronts the orifice.

3. A transducer as claimed in claim **1** in which said lamina is in the form of a disc attached to said support member at its centre, said chamber is cylindrical and said orifice comprises a slit extending round the circumference of said chamber and confronting the peripheral edge of said disc.

4. A transducer as claimed in claim **1** in which the exhaust ports are connected to respective control ports of a fluid flip-flop.

5. A transducer as claimed in claim **4**, in which the lamina is in the form of a strip, one end of which is attached to the support member and the edge of the other end confronts the orifice.

6. A transducer as claimed in claim **4** in which the lamina is in the form of a disc attached to the support member at its centre, said chamber is cylindrical and said orifice comprises a slit extending round the circumference of the chamber and confronting the peripheral edge of said disc.

7. A transducer as claimed in claim **1**, in which the piezoelectric lamina comprises two layers of piezoelectric material and the means for applying an electric field thereto comprises a pair of electrodes, one located on the outer surface of each of said layers.

8. A transducer as claimed in claim **1**, in which the piezoelectric lamina comprises two layers of piezoelectric material and the means for applying an electric field thereto comprises a first electrode located between said layers and a pair of interconnected electrodes, one located on the outer surface of each of said layers.

9. A transducer as claimed in claim **1** in which the lamina and means for applying an electrical field thereto comprise a capacitance having a low leakage current.

10. A transducer as claimed in claim **1**, in which the position of the lamina is such that when no electric field is applied thereto, the edge confronting the orifice is symmetrically disposed with respect thereto.

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U.S. Cl. X.R.

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