

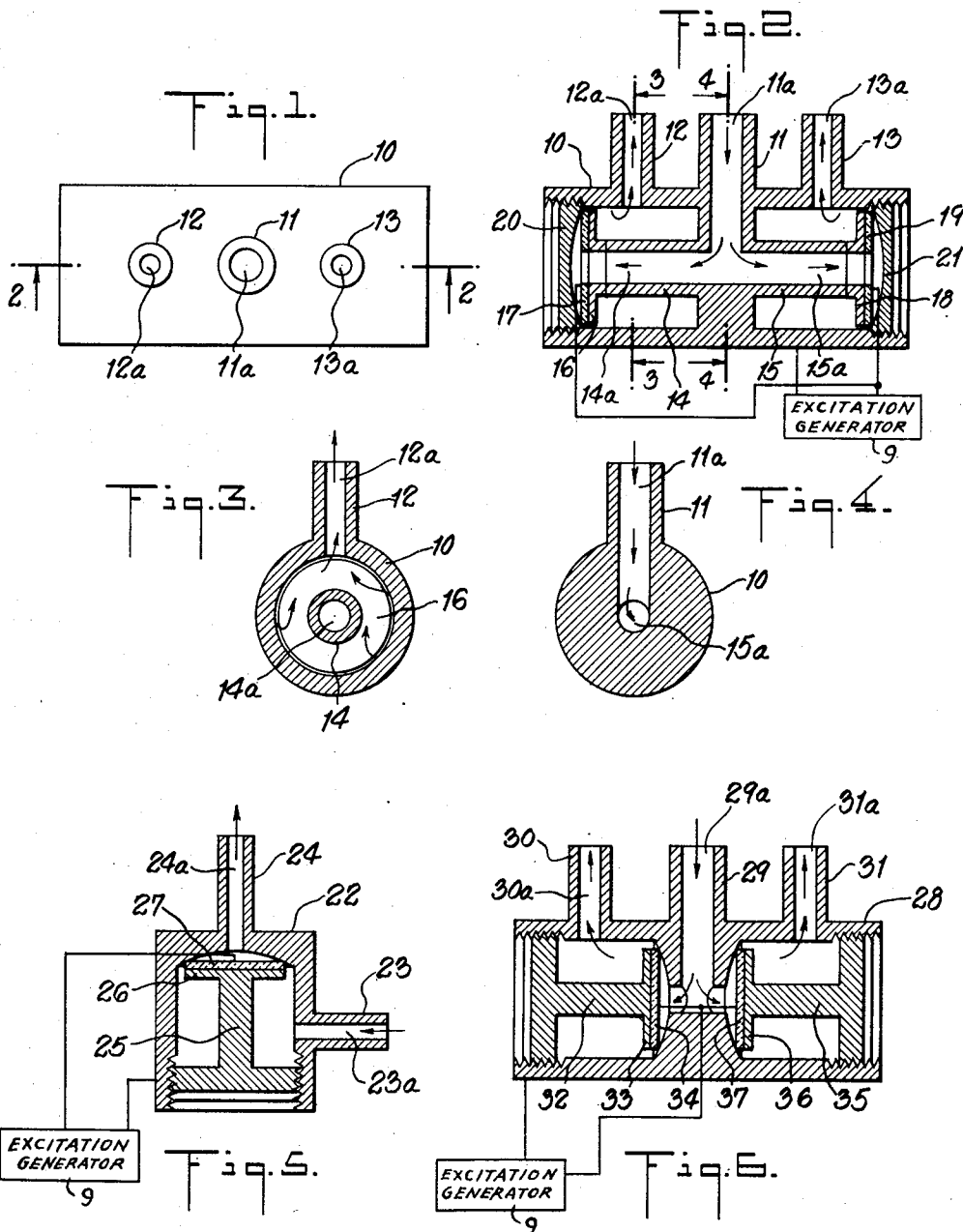
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P. B. ONCLEY

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VALVE FOR FLOW CONTROL OF LIQUIDS

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INVENTOR.  
PAUL B. ONCLEY  
BY  
*Cyrus D. Samuelson*  
ATTORNEY

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## VALVE FOR FLOW CONTROL OF LIQUIDS

Paul B. Oncley, Princeton, N.J., assignor to Gulton Industries, Inc., Metuchen, N.J., a corporation of New Jersey

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My invention relates to valves for flow control of liquids and more particularly to such valves which utilize a piezoelectric ceramic element to control the valve's operation.

In various types of high speed missiles, jet engines and other devices, it is necessary to control the flow of the liquid propellant over quite a short duty cycle. Up to now, the valves used for this work have been of the servo-controlled magnetic type. These valves have required comparatively bulky, complicated control systems and have, as a consequence, been expensive.

In missiles and other air borne devices, it is vital that as little space as possible be occupied by the various separate instruments and associated equipments. It is, therefore, extremely urgent that all possible steps be taken to reduce the size, weight and operational complexity of each separate element which is a part of the complete system. However, it is of paramount importance that there be no sacrifice in performance as a result of the reductions enumerated above.

Accordingly, it is a principal object of my invention to provide a valve for the flow of liquids which is efficient in operation over a short duty cycle.

It is a further object of my invention to provide such a valve which is simple to control.

It is a still further object of my invention to provide such a valve which is small in size and weight.

It is a still further object of my invention to provide such a valve which may be produced economically.

It is a still further object of my invention to provide means for utilizing valves of my invention in combination to control the flow of liquid to more than one outlet orifice.

These and other objects, advantages, features, and uses will become more apparent as the description proceeds when considered in view of the accompanying drawings, in which:

Figure 1 is a plan view of a preferred embodiment of my invention,

Figure 2 is a cross-sectional view along the lines 2-2 of Figure 1,

Figure 3 is a cross-sectional view along the line 3-3 of Figure 2,

Figure 4 is a cross-sectional view along the line 4-4 of Figure 2,

Figure 5 is a cross-sectional view, similar to Figure 2, of a further embodiment of my invention, and

Figure 6 is a cross-sectional view, similar to Figure 2, of a still further embodiment of my invention.

In the drawings, wherein for the purpose of illustration, are shown preferred embodiments of my invention, the numeral 10 designates the housing. Inlet pipe 11 surrounds inlet channel 11a and outlet pipes 12 and 13 surround outlet pipes 12a and 13a respectively. Support 14, which surrounds channel 14a, supports inert backing 16 to which is affixed piezoelectric ceramic element 17. Support 15, which surrounds channel 15a, supports inert backing 18 to which is affixed piezoelectric ceramic ele-

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ment 19. End plugs 20 and 21 serve to properly seal the combination. Excitation generator 9, which is shown schematically, serves to supply excitation voltage to elements 17 and 19.

I prefer to fashion my piezoelectric ceramic elements of barium titanate, alone, or combined with additive materials such as strontium or lead titanate. However, any other ceramic piezoelectric, natural piezoelectric or other type of transducer material may also be employed.

In Figure 5, housing 22 is equipped with inlet pipe 23 which encloses channel 23a and with outlet pipe 24 which encloses channel 24a. Support 25 is threaded into housing 22 and supports inert backing 26 to which is affixed piezoelectric ceramic element 27. Excitation generator 9, which is shown schematically, serves to supply excitation voltage to element 27.

In Figure 6, housing 28 is equipped with inlet pipe 29 and outlet pipes 30 and 31. Pipes 29, 30 and 31 enclose channels 29a, 30a, and 31a, respectively. Support 32 is threaded into 28 and supports inert backing 33 to which is affixed piezoelectric ceramic element 34. Similarly, support 35 is threaded into housing 28 and supports inert backing 36 to which is affixed piezoelectric ceramic element 37. Excitation generator 9, which is shown schematically, serves to supply excitation voltage to elements 34 and 37.

The effective functioning of my invention resides in the utilization of center-supported piezoelectric ceramic transducer elements such as have been described by Abraham I. Dranetz and Hugh J. Cullin in their joint application for Letters Patent, Serial No. 502,459, assigned to the assignees hereof. In the aforesaid application, the inventors describe center-supported transducers which vibrate in bending mode. I make use of the bending or flexural mode of vibration of center-supported piezoelectric ceramic transducers to produce the valves of my invention.

Figure 5 illustrates a valve of my invention with a single inlet and a single outlet. Support 25 is threaded into housing 22 so that 27 fits snugly against the concave inner surface of housing 22. The excitation system, electrical connections and the electrodes of 27 are not shown in the drawing. The excitation is applied to 27 between the electrode on the outer face of 27 (not shown) and housing 22. The unit is designed so that 27 will vibrate under the influence of excitation voltages of the order of 200-300 v. at frequencies up to 500 c.p.s. as supplied by excitation generator 9. I prefer to utilize square wave pulses for the operation of the device but continuous wave or other signals may also be used.

Liquid flows, as indicated by the arrows in Figure 5, in channel 23a into housing 22. When the circumference of 27 is moved away from 22 by the application of excitation of the proper voltage and frequency, the liquid flows around the circumference of 27 into channel 24a. When 27 is in contact with 22, the flow of liquid from 23a to 24a is cut off. It can therefore be seen that the flow from 23a to 24a proceeds in short pulses depending upon the frequency of vibration of 27. Inert backing 26 and center support 25 serve to enable 27 to vibrate in bending mode as described in the application of Abraham I. Dranetz and Hugh J. Cullin, previously referred to.

The amplitude of vibration of 27 is determined by the voltage applied. The width of the annulus through which the liquid flows into 24a increases as the voltage applied increases. The frequency of opening of the annulus increases as the excitation frequency increases.

Figure 6 illustrates a valve of my invention wherein two elements similar to that of Figure 5, described above, are utilized to control the flow from a single inlet channel 29a alternately into two outlet channels 30a and 31a. 34 and 37 are oppositely polarized and the electrodes on

their faces (not shown) are tied together electrically. Excitation is applied between the housing and the face electrodes by excitation generator 9. The direction of liquid flow is in the direction indicated by the arrows of Figure 6.

If it is desired to supply outlet channels 30a and 31a at the same time and cut off the supply simultaneously, 34 and 37 should be polarized in the same direction and should have their outer face electrodes electrically connected.

If it is desired to have the flow from 29a applied alternately to 30a and 31a and to polarize 34 and 37 in the same direction, it is necessary to use an insulated housing 28 and electrically connect the face electrode of 34 (not shown) to 36 and the face electrode of 37 (not shown) to 33. Excitation is then applied between 36 and 33.

The principle of operation of the individual units of Figure 6 is the same as that previously discussed for the operation of Figure 5. The cooperative features of Figure 6 permit various possible combinations as discussed immediately above. It is within the contemplation of this invention to bring the various electrical connections to a terminal board (not shown) so that elements 34 and 37 may be electrically connected and excited such that liquid flows in 30a and 31a, alternately or simultaneously, as desired. 34 and 37 require the same excitation voltages and frequencies as 27.

Figures 1 through 4 illustrate a valve of my invention wherein the flow from inlet channel 11a is directed to outlet channels 12a and 13a through channels 14a and 15a, respectively in the directions shown by the arrows in the figures. 14a is cut through the center of support 14, backing 16 and piezoelectric ceramic element 17 and 15a is cut through the center of support 15, backing 18 and piezoelectric ceramic element 19. End plugs 20 and 21 must be insulated either from housing 10 or from the face electrodes (not shown) of 17 and 19 respectively.

If 17 and 19 are oppositely polarized and their face electrodes are electrically connected, flow to outlet channels 12a and 13a will alternate under the influence of excitation applied between housing 10 and the face electrodes by excitation generator 9. Under the same conditions of electrical connections and excitation and with 17 and 19 polarized in the same direction, flow to 12a and 13a will be simultaneous.

If 17 and 19 are polarized in the same direction and alternate flow to 12a and 13a is required, housing 10 must be an insulator, the face electrode of 17 must be electrically connected to 18, the face electrode of 19 must be electrically connected to 16 and excitation must be applied between 16 and 18.

17 and 19 will respond to the same excitation voltages and frequencies as described above for the piezoelectric ceramic elements of Figures 5 and 6.

Liquid from 11a fills the spaces between 17 and 20 and 19 and 21. 17 and 19 vibrate in bending mode under excitation. When the periphery of 17 moves away from 20, the liquid in 11a and 14a flows out from around the circumference of 20 to outlet channel 12a. Similar action takes place with respect to 19 and 13a. It is within the contemplation of my invention to utilize a single element such as 17 in a valve similar to that illustrated in Figure 5.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in con-

nection with specific exemplifications thereof will suggest various other modifications and applications of the same. For example, the valves of my invention may utilize a single output channel in conjunction with a plurality of input channels, thereby permitting mixing of liquids in the valve system. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplifications of the invention described herein.

Having thus described my invention, I claim:

1. A valve for flow control of liquids comprising a housing; in said housing, an inlet channel and at least one outlet channel; a piezoelectric ceramic circular element; a piezoelectrically inert backing, said piezoelectric ceramic circular element being mounted on said piezoelectrically inert backing; supporting means supporting said backing at the center of said backing, said supporting means being mounted in said housing; at rest, said circular element being in contact with said housing such that there shall be no flow of liquid from said inlet channel to said outlet channel; excitation means applied to said piezoelectric ceramic circular element such that the contact between said circular element and said housing is varied in accordance with said excitation; said backing being of dimensions such that it vibrates cooperatively with said piezoelectric ceramic circular element.

2. A valve for flow control of liquids as described in claim 1 wherein said piezoelectric ceramic circular element is a disc.

3. A valve for flow control of liquids as described in claim 1 wherein said piezoelectric ceramic circular element is a ring.

4. A valve for flow control of liquids as described in claim 1 wherein there are a plurality of output channels and a piezoelectric ceramic circular element associated with each of said output channels.

5. A valve for flow control of liquids comprising a housing; in said housing, an inlet channel and at least one outlet channel; a circular transducer element; an inert backing, said transducer element being mounted on said backing; supporting means supporting said backing at the center of said backing, said supporting means being mounted in said housing; at rest, said circular element being in contact with said housing such that there shall be no flow of liquid from said inlet channel to said outlet channel; excitation means applied to said circular transducer element such that the contact between said disc and said housing is varied in accordance with said excitation; said backing being of dimensions such that it vibrates cooperatively with said transducer element.

6. A valve for flow control of liquids as described in claim 5 wherein said circular transducer element is a disc.

7. A valve for flow control of liquids as described in claim 5 wherein said circular transducer element is a ring.

8. A valve for flow control of liquids as described in claim 5 wherein there are a plurality of output channels and a circular transducer element associated with each of said output channels.

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