Sept. 9, 1969 F. U. EVERHARD 3,465,790

ELECTRICALLY OPERATED THROTTLE DEVICE

Filed Aug. 24, 1967 2 Sheets-Sheet 1

Fig. 1.

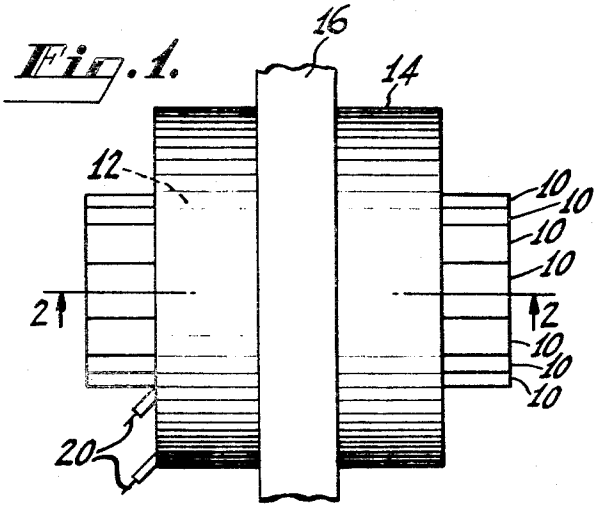


Fig. 3.

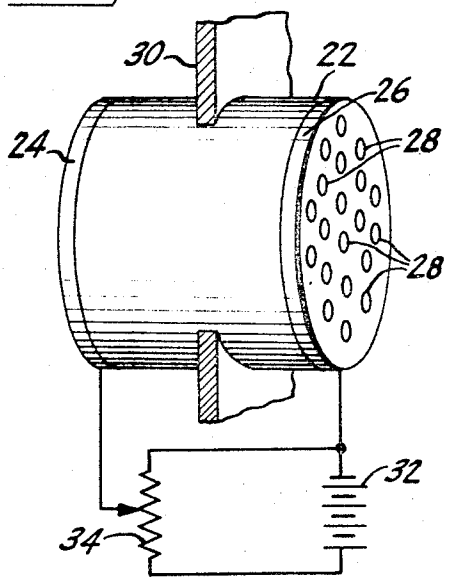


Fig. 2.

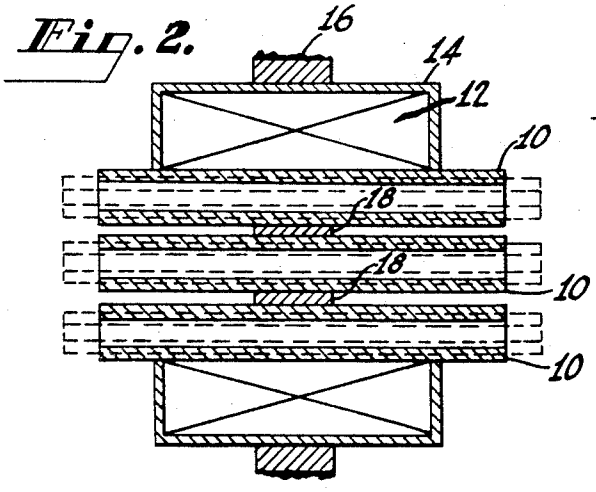
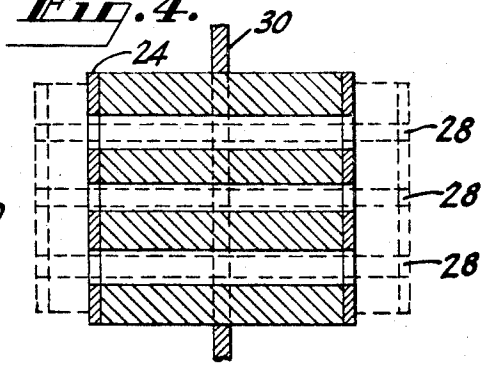


Fig. 4.



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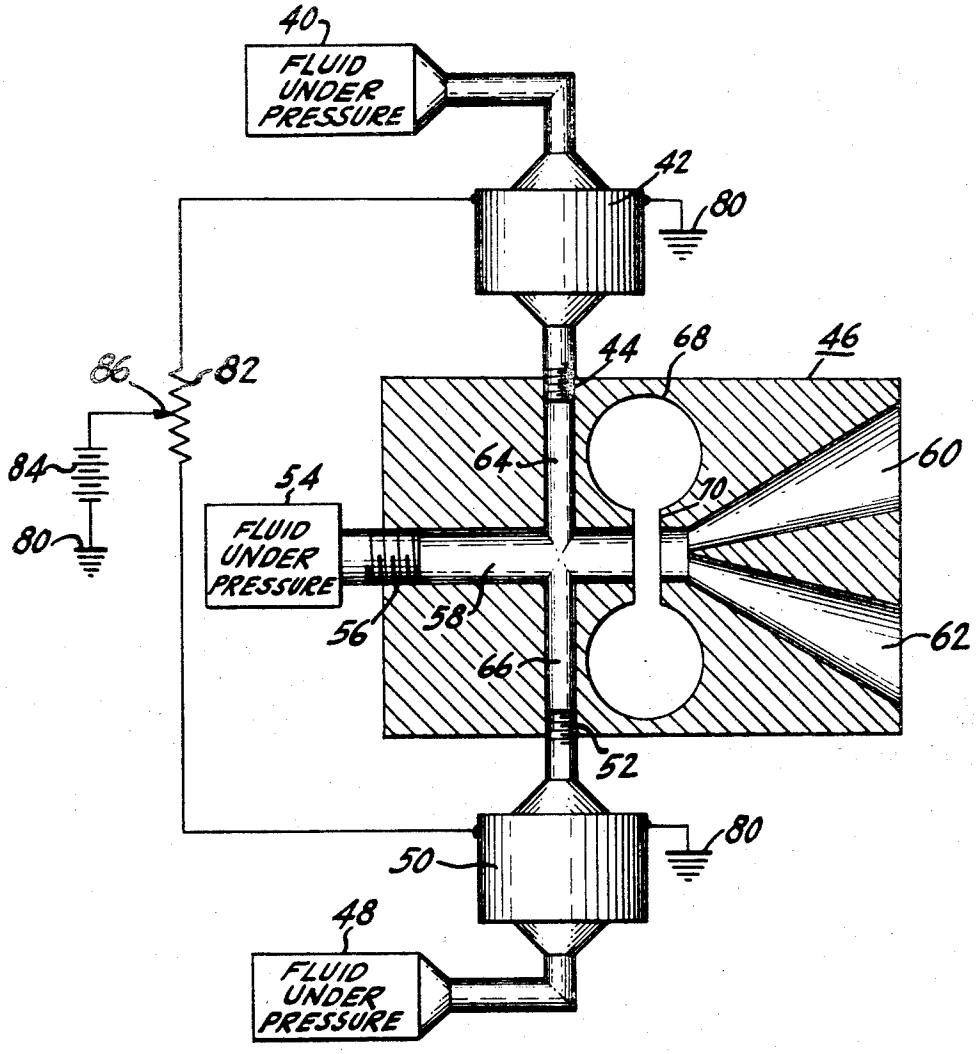


Fig. 5.

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ELECTRICALLY OPERATED THROTTLE DEVICE

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ABSTRACT OF THE DISCLOSURE

Throttle devices for a viscous fluid are disclosed, each comprising one or more tubes whose cross-sectional areas and lengths are varied by application thereto of a magnetic or an electrostatic field.

Many fluid valving means include hinged, relatively movable parts. Such valving means or the hinges thereof wear, and the relatively movable parts thereof may not fit properly after a period of operation. Furthermore, when the valves are to be operated from a distant point, it is advantageous to operate them electrically, whereby mechanical valves require a means to change electrical force to mechanical force for operation of the valve from a distant point.

It is an object of this invention to provide an improved valve having no hinged parts.

It is another object of this invention to provide a valve which may be operated directly by the application thereto of an electrical force.

In accordance with this invention, capillary tubes are provided of a material which is distorted by the application thereto of an electrical force. The distortion causes a change in the diameter and/or in the length of the tube, whereby change in the electrical force changes the resistance to the flow of fluid through the tube. The tube may be made of magnetostrictive material which changes in length and which changes in cross-sectional dimensions upon the application of a magnetic field thereto, whereby the diameter and the length of the tube made of magnetostrictive material vary oppositely as the magnetic field applied thereto is changed. A suitable magnetostrictive material of which the capillary tube may be made is a nickel-iron alloy. Alternately, the tubes may be provided by making holes in a piezoelectric material such as barium titanate, and by applying an electrostatic field to a pair of electrodes applied to the piezoelectric material. The dimensions of the holes and the length of the holes are changed in opposite directions as the electrostatic field applied thereto is varied, whereby the tubes comprising the holes offer a controllable variable resistance to the flow of fluid through the tubes.

The invention will be better understood upon reading the following description in connection with the accompanying drawing, in which:

FIG. 1 is a side elevational view of a magnetostrictive valve in accordance with this invention,

FIG. 2 is a sectional view on the line 2—2 of FIG. 1, including a dotted line showing which is useful in explaining the operation of the device of FIG. 1,

FIG. 3 is a perspective view of a piezoelectric valve in accordance with this invention.

FIG. 4 is a cross-sectional view of the device of FIG. 3 also including a dotted line showing which is useful in explaining the operation of the device of FIG. 3, and

FIG. 5 is a showing partially in section of one example of a useful environment for the valve of FIG. 1 or 3.

Turning first to FIG. 1, a bundle of capillary tubes **10**, made of magnetostrictive material, is provided. A coil **12**, which may be included in a coil enclosure **14**,

is wound around the bundle of tubes **10**. A wall **16**, which may separate two regions containing fluids at different pressures, surrounds the coil enclosure **14**. The wall **16**, the bundle of tubes **10** and the coil form **14** provide, except for the capillary tubes **10**, an impervious wall for fluids that are on opposite sides of the wall **16**. If necessary, packing material **18** (FIG. 2) may be provided between the tubes **10** or between the tubes **10** and the coil enclosure **14**, or both, to prevent fluid flow from one side of the wall **16** to the other side thereof except through the capillary tubes **10**.

To operate the valve of FIG. 1, a controllable current is passed through the coil **12** as by means of the coil terminals **20** producing a magnetic field in the walls of the tubes **10**. Since the tubes are made of magnetostrictive material, the tubes change shape. For example, as shown in dotted lines in FIG. 2, the tubes may lengthen and in the process become thinner making the holes through the tubes smaller. Even though the dimensions of the tubes **10** may vary, fluid cannot flow from one side of the wall **16** to the other side thereof except through the tubes **10**. Therefore, the resistance to the flow of viscous fluid, nearly all fluids being viscous to a greater or lesser extent, through the tubes **10** will be increased when the magnetic field causes lengthening and narrowing of the magnetotsrictive tubes.

Shortening and widening of the capillary tubes **10** will decrease the resistance to flow through the capillary tubes. Therefore, change in the magnetic field, which is considered to be one type of electrical force, by changing the current flow through the coil **12**, results in a controllable throttle action in the flow of fluids from a region of high pressure as at one side of the wall **16** to a region of low pressure, as at the other side of the wall **16**.

By use of piezoelectric material, a voltage field, which is another type of an electrical force, may control a fluid valve. Turning to FIG. 3, a cylinder **22** of piezoelectric material having opposed parallel faces is provided. One electrode **24** is fixed to one of the opposite faces of the cylinder **22** and another electrode **26** is fixed to the other face of the cylinder **22**. Capillary holes **28** are bored through both of the electrodes **24** and **26** and also through the cylinder **22**. The cylinder **22** closes a hole in a wall **30** in a hermetic manner even though, as will be noted, the cylinder **22** changes shape during the operation of the valve of which it is a portion. Suitable packing material, not shown in FIG. 3, can be positioned between the wall **30** and cylinder **22** to insure the hermetic seal at all times. Fluids at different pressures are separated by the wall **30** and communication between the fluids is only through the holes **28**. An adjustable voltage supply is connected between the two electrodes **24** and **26**. This voltage supply comprises a battery **32** shunted by a potentiometer **34**, one end of the potentiometer being connected to the electrode **26** and a point on the potentiometer being connected to the electrode **24**. Upon variation of the position of the point on the potentiometer **34** which is connected to the electrode **24**, the voltage supply between the two electrodes **24** and **26** is also varied, and the shape of the cylinder **22** and therefore the dimension of the holes **28** therethrough will be changed, as shown in dotted lines in FIG. 4 whereby the resistance of flow of a viscous fluid through the holes **28** will be varied. Therefore, by a change in potential applied to electrodes **24** and **26**, the cylinder **22** acts as a variable valve or throttle device.

While the devices of FIGS. 1 to 4 are useful whenever fluid valving or throttling is required, one use thereof is shown in FIG. 5. In FIG. 5, control fluid from a source **40** thereof flows through a throttling valve **42** and into a

control port 44 of a fluid amplifier 46, which is shown in cross-section. The control fluid from a second source 48 flows through a second throttling valve 50 into an opposite control port 52. Fluid, whose flow is to be controlled, flows from a source 54 thereof into a main port 56.

The fluid amplifier 46 comprises a central or main passageway 58 which leads from the main port 56 to two branch passageways 60 and 62 symmetrically arranged with respect to the central line of the main passageway. The control ports 44 and 52 are connected by control passageways 64 and 66, respectively, to the main passageway 58. The several passageways 58, 60, 62, 64 and 66 are so arranged that their center lines are all in the same plane. An annular shaped chamber 68, which is connected to the main passageway 58 at a position between the control passageways 64 and 66 and the branch passageways 60 and 62 by an opening 70, is provided to stabilize the flow of fluid in the passageways 58, 60 and 62 in a known manner. As is known, flow of a small amount of control fluid in the control passageway 64 or 66 determines how the large amount of fluid in the main passageway 58 is divided between the branch passageway 60 and 62.

The valves 42 and 50 may be of the magnetostrictive type or they may be of the piezoelectric type. Let it be assumed that the valves 42 and 50 are of the magnetostrictive type. Then, the coil (not shown) of the magnetostrictive valve 42 is connected between ground 80 and one end of a potentiometer 82. The coil of the valve 50 is connected between ground 80 and the other end of the potentiometer 82. A battery 84 is connectde between a point 86 on the potentiometer 82 and ground 80. By adjustment of the point 86 along the potentiometer 82, the throttling actions of the valves 40 and 50 are varied in opposite directions and more control fluid is allowed to flow into one of the control ports 44 or 52 than into the other control port 52 or 44. In accordance with the operation of a fluid amplifier 46, the fluid from the source 54 will be deflected toward the passageway 60 or 62 on the side of the main passageway 58 adjacent to the control passageway 64 or 66 carrying the least control fluid. Furthermore, since a small flow of control fluid controls a much larger flow of working or main fluid, the device 46 acts as a fluid amplifier.

If the valves 42 and 50 are of the piezoelectric type, the voltage applied to the valves 42 and 50 may be varied in a differential manner by means not shown, to apply more voltage to one valve 42 or 50 and less voltage to the other valve 50 or 42 to cause deflection of the main fluid flow toward one or the other of the passageways 60 or 62.

Modifications of the described fluid valves will occur to a person skilled in the art. The above description is therefore to be considered as illustrative and not in a limiting sense.

What is claimed is:

1. A controllable fluid valve comprising a body of material having at least one hole therethrough of capillary size through which the fluid passes, said material changing its physical dimensions upon application of an electrical force to said body to change the dimensions of said hole, whereby said hole offers controllable variable resistance to the flow of fluid therethrough.

2. The invention as expressed in claim 1 in which said body is of a magnetostrictive material and said body is in the shape of a capillary tube.

3. The invention as expressed in claim 1 wherein a plurality of bodies of magnetostrictive material are bundled together and wherein the means to apply electrical force thereto comprises a coil wound around said bundle of bodies.

4. The invention as expressed in claim 1 wherein said body is of piezoelectric material with one or more holes provided in said body, a pair of electrodes being provided in contact with said body, said electrical force comprising a means for applying a varying voltage between said electrodes.

5. The invention as expressed in claim 1 wherein said body is of piezoelectric material with one or more holes provided in said body, a pair of electrodes provided in contact with said body so that said capillary holes extend through said body and through said electrodes, said electrical force comprising a means for applying a varying voltage to said electrodes.

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