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3,465,732

PIEZOELECTRIC CONTROL VALVE

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2 Sheets-Sheet 1

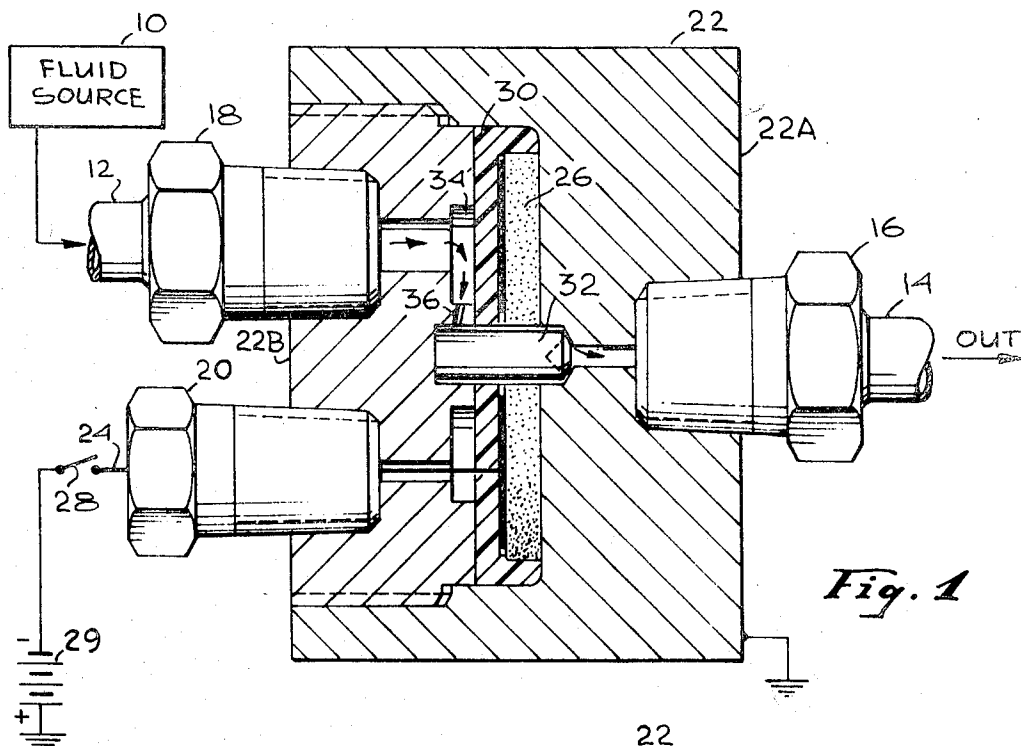


Fig. 1

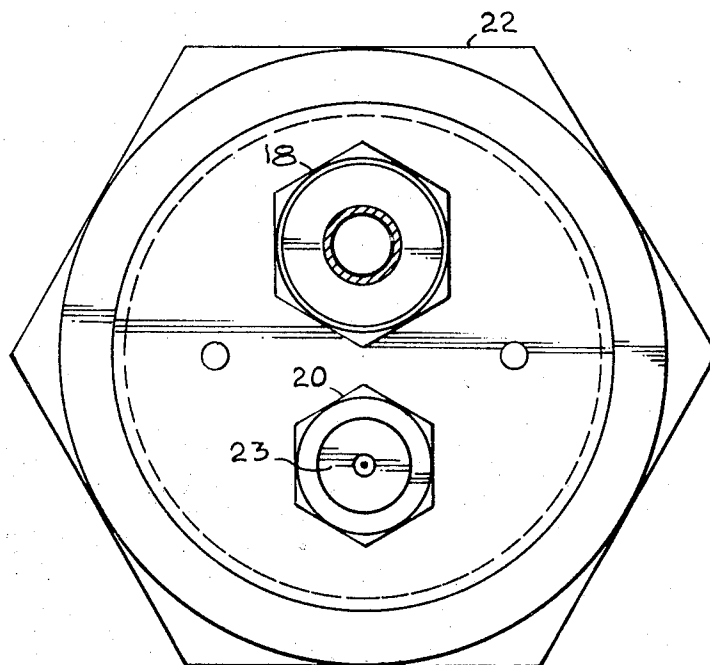


Fig. 2

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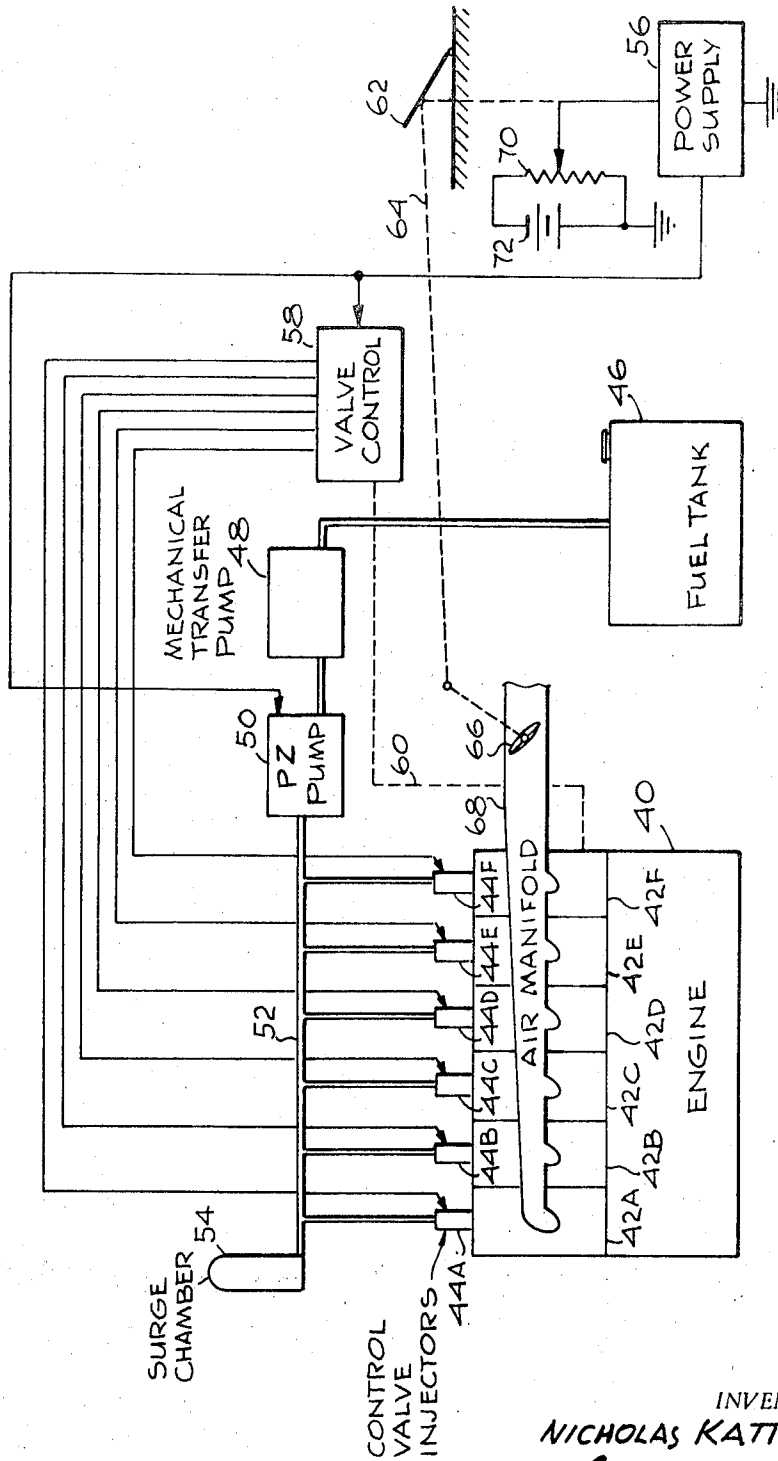
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Fig. 3



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1

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PIEZOELECTRIC CONTROL VALVE

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3 Claims

ABSTRACT OF THE DISCLOSURE

A piezoelectric control valve is provided which comprises a piece of piezoelectric material arranged to provide an opening which has an insert therein such that when the piezoelectric material is not under the influence of an applied electrical field, or is not excited, there is no space between the piezoelectric material and the material of the insert. Upon the application of a potential across the PZ material there is a radial expansion wherein the opening is enlarged to compensate for the radial expansion. If a fluid under pressure is applied to one side of the PZ material and insert, no passage to the other side is permitted until an exciting electrical field is applied to the piezoelectric material. At this time, fluid can pass. The amount of fluid which can pass is determined by the size of the opening, which can be made variable responsive to the amplitude of the voltage applied, the pressure under which the fluid is applied to the valve, and the duration of the electrical potential applied to the piezoelectric material.

BACKGROUND OF THE INVENTION

This invention relates to valves and more particularly to an improved piezoelectric valve.

Valves for controlling the passage therethrough of fluids or gases, take many forms in accordance with the operating function to be performed by said valves. This can range from the common water faucet to fuel flow control valves. One of the systems proposed in connection with internal combustion engines is to provide an electrically controlled valve for each piston. Fuel under constant pressure is applied to each valve and the electrical signals for operating each valve are primarily provided through a distributor, driven by the engine, which is analogous to the spark plug distributor.

Solenoid operated valves have been tried and magneto restrictive valves have also been tried. The problems attendant to these types of valves arise due to the necessary use of magnetic fields and magnetic materials. There are hysteresis effects present which can prevent exact repeatability of operation and to a certain extent can slow down the operation of the valve. Furthermore, basically these devices are inductive in view of the requirement for having a winding through which current flows which too can limit the speed of operation.

An object of the present invention is the provision of a novel piezoelectric valve structure.

Another object of this invention is the provision of a valve structure which operates with repeatability, rapidity and which is controllably variable.

Still another object of the present invention is to provide a valve construction which is relatively inexpensive.

These and other objects of the invention are achieved in a piezoelectric valve structure wherein the piezoelectric material may be, by way of example, in the form of a toroid which has an insert in the central hole completely filling the hole when the piezoelectric material is not actuated by the application of a potential thereacross. In the presence of an exciting or actuating potential, the piezo-

2

electric material moves radially opening a space between the insert and the edge of the piezoelectric material at the center through which fluid may flow.

OBJECTS AND SUMMARY OF THE INVENTION

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a view in cross-section of an embodiment of the invention.

FIGURE 2 is a top view of an embodiment of the invention.

FIGURE 3 is a schematic view illustrating how a valve in accordance with this invention may be used with an internal combustion engine.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGURES 1 and 2 of the drawing which are respectively the cross-sectional and end view of an embodiment of the invention, fluid from a source 10, can enter the valve through the inlet line or tubing 12, at some fixed pressure commensurate with the requirements of the system in which the valve is to function. A metered fluid flow emerges from the output line 14 at some pressure below the supply pressure. The fittings 16, 18, 20, which are shown here are merely exemplary of a means effectuating attachment to the body section 22 of the valve.

The fitting 20 is one wherein the center 3 comprises insulating material for supporting a lead 24 which conducts potential from a source 29 when a switch 28 is actuated. The potential is applied by the lead 24 to the ceramic element 26.

The ceramic element 26 constitutes a toroidal disc which, as is customary, has its upper and lower surface coated with a metal whereby when its lower surface is pressed against the valve housing 22, it is connected to ground. The conductor 24 connects to the metalized coating on the opposite surface of the PZ disc.

The housing 22 comprises a base part 22A into which a closing part 22B may be threaded. Both base and closing parts have suitable openings cut therein to afford insertion of the respective fittings. Also, between the base part and the closing part provision is made for a cavity wherein the piezoelectric disc 26 is placed and may be held in place by a suitable polymeric potting compound 30 which serves both to hold the disc in place and to insulate the top surface of the piezoelectric material to prevent it from being grounded against the housing. The bottom surface of the disc, is coated to serve as an electrode surface, opposite to the one to which the conductor 24 connects, and contacts the housing.

A cylindrical member 32 which is hereafter called an orifice insert, is inserted in the center of the piezoelectric disc 26. The diameter which is specified for this insert depends upon the size of the opening in the PZ material which in turn depends upon the flow requirements through the piezo electric valve. This insert can be made from various materials, either metallic, ceramic or polymeric; the major objective being a leak-free seat contact between the orifice insert and the piezoelectric ceramic element while the latter is in its de-energized condition.

Fluid which enters the pipe 12 is directed via a passageway 34 and through another passageway 36 in the member 22B, which terminates at a cylindrical opening in which the orifice insert is placed. The fluid flows around the orifice insert and fills the passageway in the housing

which surrounds the orifice insert. The piezoelectric material blocks the flow of the fluid until it is actuated.

The piezoelectric valve functions by applying a voltage from the source 29 by closing the switch 28 whereby axial expansion is caused in the piezoelectric element accompanied by a radial contraction. This causes an annular gap to open round the orifice insert permitting the fluid to pass through the gap. Precise control can be exercised over the flow by the adjustment of the gap through voltage control, since the piezoelectric ceramic deformation is proportional to the applied electric field. Upon removal of the applied potential, the piezoelectric disc contracts to its initial state and thus cuts off the flow of fluid.

The advantages of this valve lie in not only the operational and design simplicity and low cost of its production, but also in its performance. The valve can operate at very high speeds and its response is substantially instantaneous. Furthermore, since the PZ material has substantially no hysteresis effects its repeatability in response to a given voltage is accurate. Also, the control obtained is accurate.

FIGURE 3 is a schematic drawing illustrating how the piezoelectric valves in accordance with this invention may be employed with an internal combustion engine. The engine is represented by the rectangle 40, having six cylinders respectively 42A, 42B, 42C, 42D, 42E, and 42F. A valve 44A, 44B, 44C, 44D, 44E, and 44F, is provided for each of the cylinders 42A through 42F. Fuel from the tank 46 is pumped by means of a mechanical transfer pump 48 assisted by a booster pump 50 to a high pressure manifold 52 having a surge chamber 54. The booster pump 50 preferably is a piezoelectric pump. Control voltage for operating the valves 44A through 44F is derived from a power supply 56 and is distributed by a valve control 58, which may be an identical device as the conventional spark distributor and may be identically operated from a shaft driven by the motor drive shaft. The shaft is represented by the dotted line 60. Leads are provided from the valve control to each one of the control valves.

While the engine controls the timing of the operation of the valves, the amount of fuel which is injected through each valve is controlled from the accelerator pedal 62. The accelerator pedal can, through a suitable linkage 64, control the position of the air intake valve 66 (commonly a butterfly valve), which is in the air manifold 68. The accelerator pedal is also connected to a means for controlling the amplitude of the voltage provided from the power supply 56, said means being here represented as a potentiometer 70 which is connected across the source of potential 72. The slider of the potentiometer is moved as the accelerator moves whereby the voltage provided by the power supply 56 to the control valves may be increased upon acceleration or decreased, or even cut-off during deceleration with the flow of fuel passed by the control valves being increased or decreased accordingly.

To accelerate or to increase power, the accelerator pedal 62 is depressed which opens the butterfly valve 66 and increases the voltage applied to piezoelectric valves thereby allowing more fuel and more air into the cylinders. To decelerate or decrease power, the condition is reversed and indeed during the deceleration the flow of fuel can be stopped completely until idle speed of the engine is reached, at which time a preset minimum fuel flow condition and throttle position may be established.

It is well known that the ability to limit the fuel during deceleration may be of great importance in smog elimination.

It is within the scope of this invention to accomplish a fine control of the valves for a minimum smog emission and better combustion by not only operating these together with the butterfly valve but also by sensing both the temperature and manifold pressure and through suitable linkage as controlling the amplitude of the voltage being applied to the control valves.

It should also be noted that by using the piezoelectric pump 50, when the voltage applied to the control valve is increased, the voltage applied to the piezoelectric pump is also increased thus enabling more fuel to be pumped to take care of the greater fuel needs. The surge chamber 54 provides the well known function of minimizing surge effects caused by the pumping operation.

It is to be understood that the shape of the orifice in the PZ material as well as the orifice insert may be varied to be circular or have some other useful configuration, without departing from the spirit and scope of this invention. Also, the orifice insert need not fully extend through the thickness of the PZ material.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. In combination with an internal combustion engine having cylinders into which fuel is injected, of a valve for each cylinder, said valve including piezoelectric material means having an opening therethrough, an insert within said opening dimensioned to block said opening, pump means for pumping fuel from a source to one side of said piezoelectric means at the region thereof adjacent said insert means, means for applying potential to said piezoelectric means individually in timed relation with the operation of said engine for causing motion of said piezoelectric means away from said insert to open a passage for fuel therethrough into said cylinder, and accelerator means for controlling the amplitude of the applied potential responsive to the operation of said accelerator means for controlling the amount of fluid introduced into a cylinder through said valve.

2. Apparatus as recited in claim 1 wherein said pump means includes a piezoelectric pump, and means for controlling the operation of said piezoelectric pump responsive to said accelerator means.

3. Apparatus as recited in claim 1 wherein there is included means for controlling the air intake into each said cylinder responsive to said accelerator means.

References Cited

UNITED STATES PATENTS

2,829,631	4/1958	Wilt	123—139
2,902,251	9/1959	Oncley	251—129
3,004,720	10/1961	Knapp et al.	
3,215,078	11/1965	Stec.	

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