

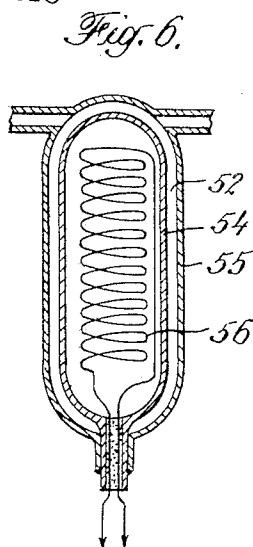
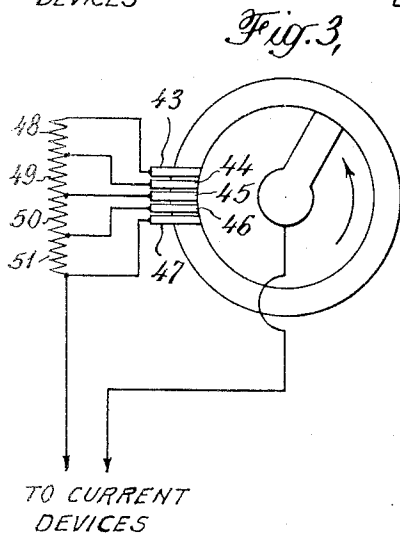
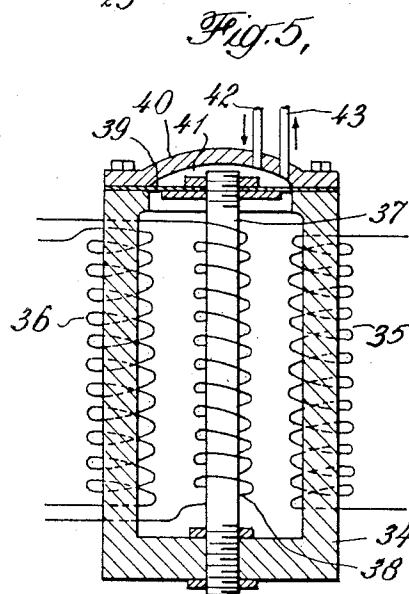
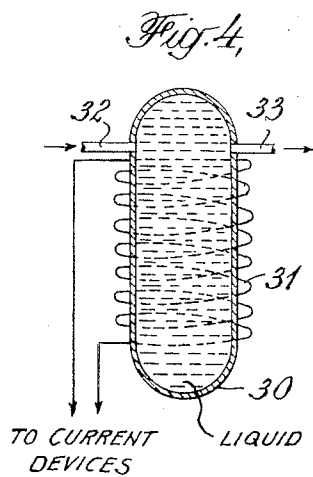
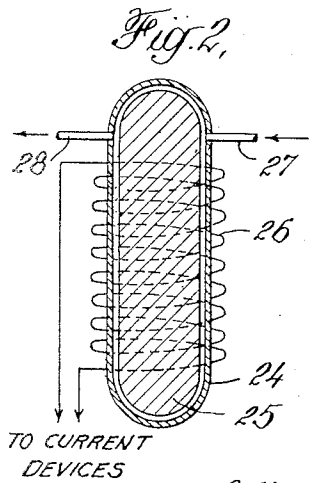
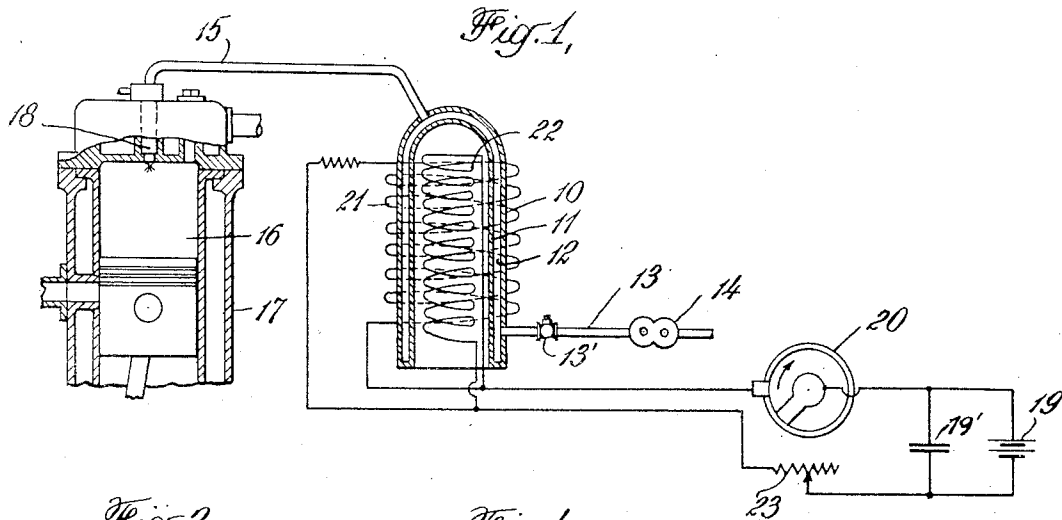
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2,317,166

PUMPING DEVICE

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## UNITED STATES PATENT OFFICE

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## PUMPING DEVICE

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12 Claims. (Cl. 103-1)

This invention relates to pumping devices and has particular reference to fuel injecting devices for use in internal combustion engines.

Fuel injectors of the type now commonly used in connection with Diesel type of engines are complicated, mechanically actuated devices, which because of the precision required in preparing the parts, are extremely expensive to manufacture and also to maintain in operating condition within the close tolerances required in order to assure smooth operation and equalized injection of the fuel into the cylinders.

The principal object of this invention is to provide devices for pumping or delivering increments of the fluid by means of magnetostriction.

Another object of the invention is to provide pumping devices which are actuated electrically and do not have relatively movable parts which require close machining or adjustment to obtain proper operation of the devices.

A further object of the invention is to provide pumping devices which are extremely simple and include no parts which can get out of order through operation or continued use.

The invention in its most general aspects includes a reservoir or chamber including a magnetostrictive element which causes the chamber to contract and expand in response to variation in a magnetic field in which the magnetostrictive element is disposed, thereby causing the chamber to act as a pump.

The phenomenon of magnetostriction is the property of such metals as nickel, iron, cobalt and their alloys to change their physical dimensions with changes in their degree of magnetization.

This phenomenon, as indicated above, is utilized in the present invention to produce a pumping operation by alternately magnetizing and demagnetizing or varying the magnetization of a reservoir which is adapted to receive a fluid and thus varying the capacity of a chamber, whereby a flow of the fluid into and out of the chamber takes place.

The volume and rate of flow of the liquid pumped by the device is controlled by the size of the chamber and variations in the degree of magnetization of the chamber, temperature and elasticity of the walls and the fibre stress set up in the magnetostrictive material of the chamber, all of which are controllable within close limits to cause accurate delivery of the liquid. Devices of this type are characterized by extreme simplicity, absence of moving parts which might

wear or get out of order, and ease of control in the pumping action.

For a better understanding of the present invention, reference may be had to the accompanying drawing in which:

Figure 1 illustrates diagrammatically a typical form of pumping mechanism and control therefor used as a fuel injector for an internal combustion engine of the Diesel type;

Figure 2 is a view in section of a modified form of pump embodying the invention;

Figure 3 is a diagrammatic illustration of a control device for preventing surging in pumps embodying the present invention;

Figure 4 is a view in section of a still further form of pumping device;

Figure 5 is a view in vertical section of another form of pumping device; and

Figure 6 is a view in section of a modified form of the device.

In the form of the invention disclosed in Figure 1, the pumping mechanism embodying the present invention consists of a tubular element 10 having a curved upper end which receives and is joined to a similar smaller element 11 to form a reservoir or chamber 12 which is annular in cross-section and of hemispherical shape at its upper end. The elements 10 and 11 may be joined at their lower ends by welding or in any other desired way. The chamber 12 communicates through a conduit 13 and intake check valve 13' with rotary pump 14 which supplies fuel under pressure to the reservoir 12. An outlet conduit 15 communicating with the chamber 12 is connected with the cylinder or combustion chamber 16 of the engine 17. A loaded valve 18 is provided at the inner end of the conduit 15 and forms a fuel injecting nozzle for delivering the fuel to the combustion chamber 16 of the cylinder.

The wall member 10 which forms with member 11 the chamber 12 may be made of any suitable magnetostrictive material which contracts upon being subjected to a magnetic field, such as, for example, a nickel-iron alloy, pure nickel, cobalt or a cobalt-iron alloy. The inner wall 11 may be made of, for example, a non-ferrous metal which will not contract when subjected to magnetization, or the inner member may be formed of a magnetostrictive material which expands when magnetized. With any of these constructions, when the inner and outer walls 10 and 11 are placed in a magnetic field that varies in intensity, the volume of the chamber 12 decreases and the fuel in the chamber 12 is

forced outwardly through the conduit 15 and into the combustion chamber 16. A suitable check valve 13' is located in the conduit 13 between the chamber 12 and the pump 14 to prevent back pressure created by the contraction of the chamber 12 from forcing the fuel back into the source of supply, thus positively forcing the fuel into the combustion chamber of the engine 17.

In order to magnetize the wall elements 10 and 11 a coil may be wound on the outside of the member 10 and a coil wound on the interior of the member 11. These relative positions of the coils with respect to the members may be varied of course. For example, the outer wall may expand under magneto-strictive stresses, providing the intake stroke, and the delivery stroke is effected when the magnetic field collapses. These coils are connected to a suitable source of electrical energy 19, across a condenser 19' which can be charged and discharged to cause energization of the coils 21 and 22 and to a commutator or timing device 20, which intermittently energizes and deenergizes the coils 21 and 22. The intensity of the magnetization may be varied by means of a rheostat 23 which can be adjusted manually as by means of a throttle or automatically by a governor, as may be desired, in order to compensate for variations in the amount of the fuel required to vary or maintain the speed and load of the engine 17. Also, a thermostat may be used to compensate for the effect of variations of temperature on magneto-striction.

In operation, as the timing device 20 operates, magnetic fields are set up and broken by the coils 21 and 22, and in response to the variations in magnetization the chamber 12 is increased or reduced in size, thereby varying the volume of fluid that can be contained in the reservoir 12, and injecting fuel into the combustion chamber 16 of the engine 17.

With a ferro-magnetic alloy containing approximately 30% nickel forming the material of the inner or expanding chamber, the volume within the wall member 10 for a 4 cylinder 100 horse power, 2 cycle Diesel engine operating at 1,000 R. P. M. may be of about 120 cubic inches capacity per cylinder. For a 6 cylinder, 100 horse power, 4 cycle automobile gasoline engine at 3400 R. P. M., the capacity of the chamber would be about 60 cubic inches per cylinder. These dimensions should not be construed as meaning that the chamber 12 must contain this quantity of fuel, but that the over-all dimensions of the space within the confining wall 11 should be of about these magnitudes.

In Figure 2 is disclosed another form of pumping device utilizing the phenomenon of magneto-striction which consists of a capsule-like housing or chamber 24, preferably formed of non-magneto-strictive material, within which is supported a body of solid metal 25. The body 25 preferably is made of magneto-strictive material, such as, for example, a ferro-magnetic alloy containing 29% nickel and 70% iron, so that its volume will vary in response to variations in the strength of a magnetic field. Wound around the exterior of the chamber 24 is a solenoid coil 26, by means of which the body 25 may be caused to contract and expand in response to variations in the field strength of the solenoid 26. Inlet and outlet conduits 27 and 28 are also provided which communicate with the chamber 29 formed between the members 24 and 25, and may be provided with any desired type of valve

which is capable of being actuated in response to variations in the volume of the chamber 29.

In Figure 4 a similar type of device is disclosed which includes a capsule-like reservoir or hollow member 30 made of magneto-strictive material, about which is wound an electromagnetic coil 31. This device differs from the device disclosed in Figure 2 in that no center element is provided, and accordingly the body may be filled completely with liquid such as, for example, fuel, and contraction and expansion of the body 30 will cause liquid to be drawn in through the inlet conduit 32 and forced outwardly through the outlet or discharge conduit 33.

A still further form of the invention is disclosed in Figure 5, this device being actuated in response to differential expansion and contraction of a frame member and a magneto-strictive rod. As illustrated in Figure 5, the device includes a frame member 34 provided with magnetic windings 35 and 36 which cause the side members thereof to increase and decrease in length in accordance with the variation in the magnetic field. Rigidly supported in the base of the frame 34 is a rod 37 formed of magneto-strictive material which varies in length oppositely to the increase or decrease in length of the frame 34. A magnetic field in which the rod is disposed is provided by means of an electromagnetic winding 38 around the rod 37. Thus, for example, when the electro-magnetic windings 35, 36 and 38 are energized, the rod may contract in length and the frame 34 increase in length, thereby causing a relative movement between the upper end of the rod 37 and the upper end of the frame 34. In order to utilize these changes in length for pumping operation, the upper end of the rod 37 is fixedly connected to a diaphragm 39 which is retained between the upper end of the frame 34 and a dome 40, which forms with the diaphragm a chamber 41 for receiving liquid. Inlet and outlet conduits 42 and 43 communicate with the chamber 41. In operation, upon varying the magnetic field, the diaphragm 39 will be moved upwardly and downwardly and thereby the volume of the chamber 41 will be varied. By proper selection of inlet and outlet valves, the expansion and contraction of the chamber can be utilized to pump or inject fluids.

Devices of the type described above have substantially instantaneous response to the variation in the magnetic fields. Accordingly, in order to prevent shock or surging during operation, it may be desirable to provide some means whereby the strength of the magnetic field may be varied gradually. A typical form of device for producing this effect is disclosed in Figure 3. This device includes a rotary commutator brush or element 42 which is successively engageable with a series of separate contacts 43, 44, 45, 46 and 47, between which are interposed resistances 48, 49, 50 and 51. Upon engagement of the contact or commutator brush 42 with the contact 43 the entire group of the resistances 48, 49, 50 and 51 is interposed in the circuit which is connected to the electromagnetic coils of the pumping device. As the commutator brush 42 continues to rotate in counterclockwise direction the resistances 48, 49, 50 and 51 are successively shorted out of the circuit and the electrical energy supplied to the coils of the pumping device is increased. This gradual increase in current results in a gradual change in volume of the pumping device, and

thus avoids shock or surging during the pumping operation.

Surging or shock in the pump can also be reduced by means of the form of pumping device disclosed in Figure 6. In this form of the device, the fluid receiving chamber 52 is formed by means of an inner capsule member 54 and an outer capsule 55 which provide a chamber 52 of annular cross-section. The chamber defined by the inner capsule member 54 may be filled under high pressure with a gas, such as, for example, carbon dioxide, nitrogen or other relatively inert gas. The pressure within the chamber may be so related to the pressure of the liquid within the chamber 52 that upon energization of the coil 56 within the capsule 54 expansion of the element 54 will take place. This type of construction has the advantage in that the pressure on opposite sides of the magneto-strictive element 54 may be equalized in order to obtain the maximum amount of expansion and contraction of this member. Accordingly, if the pressure on the interior of the magneto-strictive member 54 is substantially balanced against the operating pressure on the exterior of the member 54 within the chamber 52, full magneto-strictive expansion and contraction can be obtained.

Furthermore, the walls of the member 54 may give slightly in order to prevent the surging or shock which occurs when the member 54 expands rapidly. This construction, of course, may be varied by forming the outer member of magneto-strictive material, as shown in Figure 2, in order to cause contraction or expansion of the outer member 55, or the action of the inner and outer members may be coordinated in other relationships to provide the desired result. With this construction the gas pressure within the inner capsule 54 will tend to act as a shock absorber for the pumping operation.

The elastic deformation due to pressure on the forms of devices described above may be varied by regulating the pressure with which the liquid is delivered to the magneto-strictive pumping chamber. For example, in the form of the invention disclosed in Figure 1, if 1,000 lbs. pressure per square inch is required to operate the valve 18 and inject the fuel into the combustion chamber 16, the pump 14 may be operated at 900 lbs. pressure per square inch, thus requiring only an additional 100 lbs. pressure per square inch or 10% elastic deformation. The use of high operating pressures has the advantage of avoiding vapor lock by dissolving vapors or gases in the liquid being pumped and thereby permitting the use of volatile fuels in engines even when operating at high altitudes and temperatures. In turn, the solution of such vapors or gases prevents inaccuracies in metering the fuel.

While the invention has been described with reference to a number of different forms of the invention, it should be understood that there may be other variations of these forms of the invention, and that the type of magneto-strictive material may be varied. Also the application of the invention to other fields than those described above will be readily apparent. Therefore, the forms of the invention described should be considered as illustrative only and not as limiting the scope of the following claims.

I claim:

1. A pumping device comprising a casing forming a chamber, means forming an inlet and an outlet for said chamber, valves in said inlet and said outlet permitting fluid to flow into and out

of said chamber through said inlet and said outlet, means formed of magneto-strictive material for varying the capacity of said chamber, and a member adapted to be energized to create a varying magnetic field through said means formed of magneto-strictive material to cause said means to expand and contract to vary the capacity of said chamber.

2. A pumping device comprising a casing forming a chamber, magneto-strictive means for varying the capacity of said chamber, means for creating a varying electro-magnetic field about said magneto-strictive means to cause the latter to expand and contract, inlet valve means for introducing fluid into said chamber and outlet valve means for allowing said fluid to escape from said chamber, whereby upon variation in the electromagnetic field, fluid will be introduced into and ejected from said chamber.

3. A pumping device comprising a casing of non-magneto-strictive material, a member formed of magneto-strictive material disposed within said casing and defining therewith a chamber, means forming an inlet and an outlet for said chamber, inlet valve means permitting fluid to flow into said chamber, outlet valve means permitting fluid to flow out of said chamber, means for creating an electro-magnetic field about said member, and means for varying the intensity of said field to cause said member to expand and contract.

4. A pumping device comprising a casing, a member within said casing and defining therewith a chamber, means forming an inlet and an outlet for said chamber, at least part of one of said casing and member being formed of magneto-strictive material, means for creating an electro-magnetic field about said part, valves in said inlet and said outlet permitting fluid to flow into said chamber through said inlet and out of said chamber through said outlet in one direction and means for varying the strength of said field to cause said part to expand and contract and vary the capacity of said chamber.

5. A pumping device comprising a chamber, a diaphragm forming one side of said chamber, means forming an inlet and an outlet for said chamber, a magneto-strictive member having a fixed end and another end connected to said diaphragm, means for creating an electromagnetic field about said member, valves in said inlet and said outlet permitting fluid to flow into said chamber through said inlet and out of said chamber through said outlet in one direction and means for varying said magnetic field to cause said member to expand and contract, displace said diaphragm and vary the capacity of said chamber.

6. In a fuel pump for an internal combustion engine, the combination of a reservoir, magneto-strictive means for varying the volume of said reservoir, means for creating an electromagnetic field about said magneto-strictive means, and timing means cooperating with said engine for varying the strength of said field to cause said magneto-strictive means to expand and contract to vary the capacity of said reservoir to force fuel to said engines.

7. The device set forth in claim 6 comprising means for controlling the variation of the strength of the field and the variation in capacity of said reservoir.

8. The device set forth in claim 6, in which the magneto-strictive means comprises a casing forming the reservoir.

9. The device set forth in claim 6, in which the magneto-strictive means comprises a member disposed within said reservoir.

10. The device set forth in claim 6, in which the magneto-strictive means comprises a hollow member filled with gas under pressure disposed within said reservoir.

11. The device set forth in claim 6, in which the magneto-strictive means comprises a rod disposed externally of said reservoir and fixed, thereto.

12. A pumping device comprising a casing, a

hollow member filled with gas under high pressure within said casing and defining therewith a chamber, means forming an inlet and an outlet for said chamber, at least part of one of said casing and member being formed of magneto-strictive material, means for creating an electromagnetic field about said part and means for varying the strength of said field to cause the chamber to expand and contract.

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