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ELECTRONICALLY CONTROLLED ELECTROMAGNETIC PUMP SYSTEM

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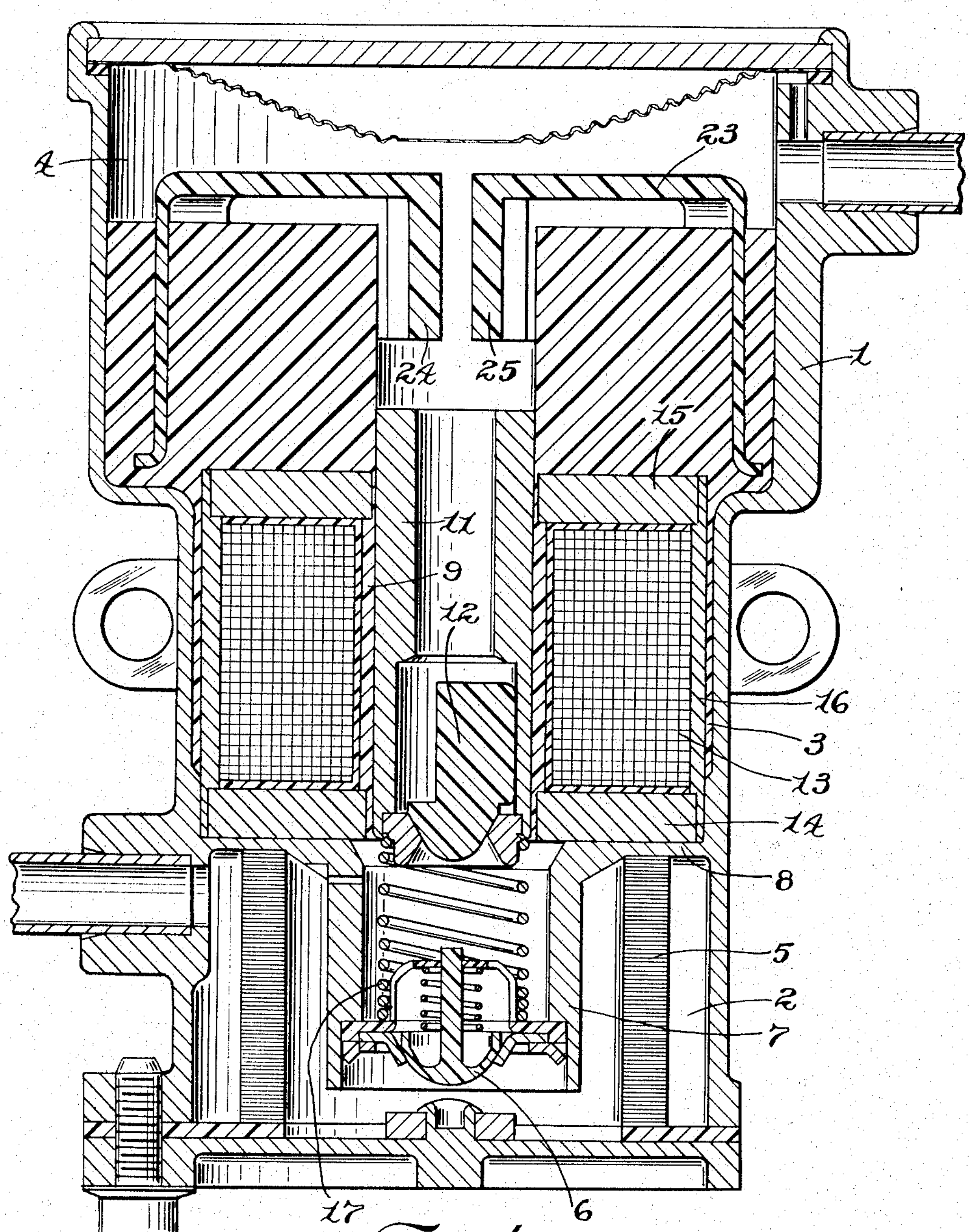

Fig. 1

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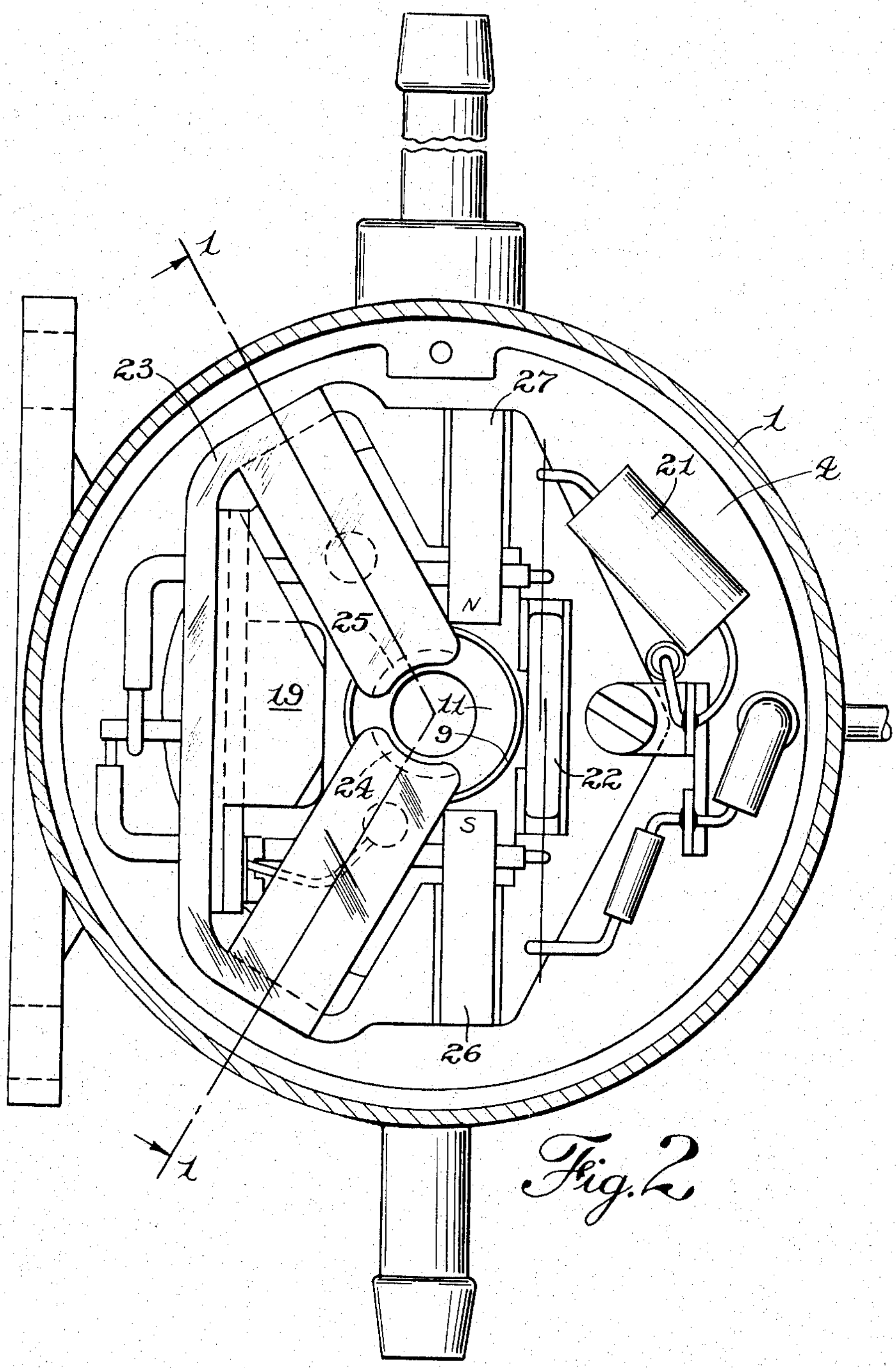

Fig. 2

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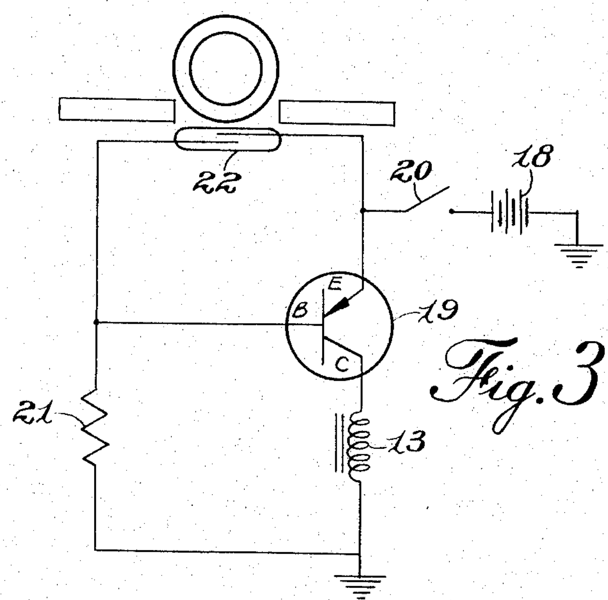

Fig. 3

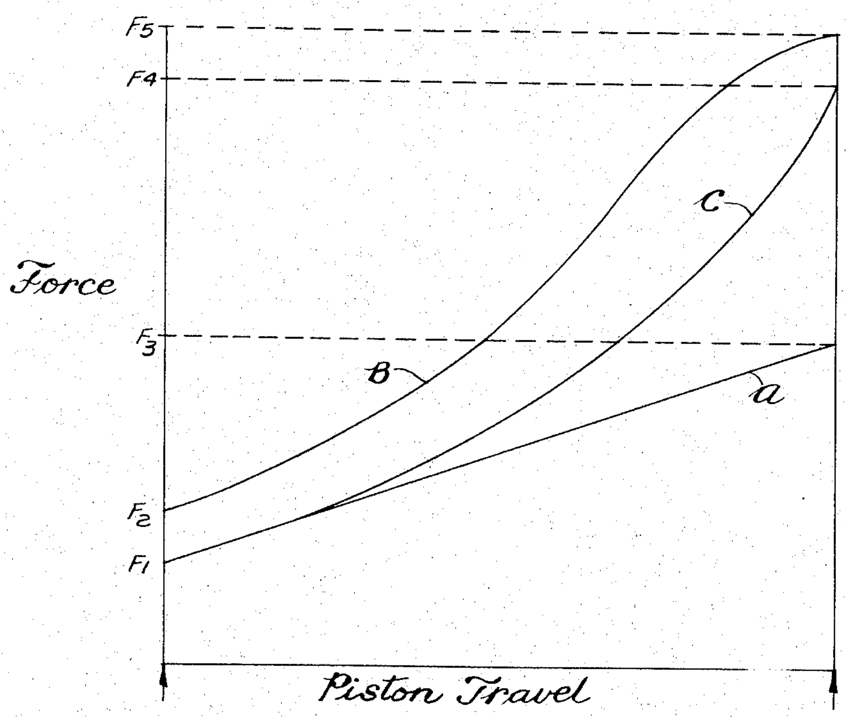

Fig. 4

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ELECTRONICALLY CONTROLLED ELECTROMAGNETIC PUMP SYSTEM

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ABSTRACT OF THE DISCLOSURE

A reciprocating electromagnetic pump having a solenoid to move a piston to the inlet end of the cylinder and a spring urging the piston toward the other end of the cylinder. The solenoid is periodically energized by a magnetic field causing a flux across the outlet end of the cylinder to operate a magnetically actuated switch.

The present invention relates to an electronically controlled electromagnetic pump system, and more particularly a system of the type employing a pump having an electromagnetically operated reciprocating piston for supplying fluid under pressure.

It is an object of the present invention to provide a novel pump system of the above type which is efficient and reliable in operation over long periods of use, which is simple and economical in construction, and which operates consistently irrespective of the attitude of its mounting, and/or subjection to severe vibration.

Further objects and advantages will be apparent from the following description, taken in connection with the accompanying drawing, in which:

FIGURE 1 is vertical sectional view of a preferred embodiment of the invention, taken on the line 1—1 of FIGURE 2,

FIGURE 2 is a top plan view of the structure shown in FIGURE 1, with the top cover removed, and before the insertion of the potting compound,

FIGURE 3 is a wiring diagram of the pump system, and

FIGURE 4 is a graph illustrating the characteristics of applicant's improved form of pump spring as compared to a conventional spring.

In FIGURE 1 there is illustrated a casing 1 comprising an inlet chamber 2, a pump chamber 3 and an outlet chamber 4. The inlet chamber contains a filter 5, and a check valve 6 which is mounted in a sleeve 7 extending downward from a partition 8 which separates the pump chamber 3 from the inlet chamber.

A cylinder 9 of non-magnetic material is axially mounted in the pump chamber 3 in position to connect the inlet chamber 2 to the outlet chamber 4, and a hollow piston 11 of magnetic material, slidably mounted in said cylinder has a second check valve 12 so located therein that reciprocation of the piston causes fluid to flow through the cylinder 9 from the inlet to the outlet chamber. Electromagnetic means for actuating the piston 11 is provided comprising a solenoid 13 located in the pump chamber surrounding the cylinder and piston, having circular pole pieces 14 and 15 connected by a cylindrical housing 16 of magnetic material. A spring 17 urges the piston 11 upwardly to a decentered position with respect to the solenoid, and energization of the solenoid draws the piston down, cocking the spring. When the solenoid is deenergized, the spring expands and moves the piston through its discharge stroke.

Means are provided for periodically energizing the solenoid to cause reciprocation of the piston. As best shown in FIGURES 3 and 2, this means comprises a source of electrical energy 18, the negative pole of which is

grounded, and the positive pole connected through a manual switch 20 to the emitter of a PNP type transistor 19. The collector of said transistor is connected to one terminal of the solenoid 13, the other terminal of which is grounded to complete the circuit so that when the transistor is rendered conductive, the solenoid is energized by substantially the voltage of the power source 18.

In order to render the transistor 19 so conductive, the base of the transistor is connected to the ground, and thus to the negative terminal of the power source, through a current-limiting non-inductive resistor 21. The value of this resistor is so selected that the base current therethrough heavily saturates the collector-emitter junction of the transistor and makes the transistor freely conductive in the solenoid circuit.

In order to periodically render the transistor non-conductive, deenergizing the solenoid 13 and permitting the spring 17 to effect the discharge stroke of the piston 11, the base and emitter of the transistor are connected through a switch 22, the operation of which is controlled by the movement of the piston 11.

The switch 22 is of the type known as a "reed" switch, and comprises a pair of conductors in the form of blades or reeds of elastic magnetic material having cantilever mounts in the ends of a sealed cylindrical capsule, the free ends of the reeds overlapping and normally spaced slightly out of contact. When the switch is placed in a magnetic field with its axis parallel to the path of flux, the overlapping ends of the magntic conductors are drawn into contact and the switch is thus closed.

As shown in FIGURE 2, the switch 22 is mounted in a cradle-frame 23 of non-magnetic material in a position substantially tangent to the pump cylinder 9, adjacent to the upper end of the piston 11 when the piston is at the end of its discharge stroke as defined by the elastic abutments 24, 25 (FIGURE 1) formed on the frame 23. Permanent bar magnets 26 and 27 are mounted in alignment in the frame 23 in substantially the same horizontal plane as the switch 22, on opposite sides of the pump cylinder 9, with unlike poles facing each other and slightly overlapping but spaced from the ends of said switch. By this arrangement, the switch 22 is embraced in the field created by the magnets 26, 27 and is closed by the flux in said field when the piston 11 has been drawn away by the solenoid 13. When the piston is at the upper end of its stroke, however, the piston forms a path of low reluctance for the magnetic flux, by-passing the switch 22 and allowing it to open.

In order to permanently and rigidly anchor all the fixed components in the pump chamber and the outlet chamber, after assembly of the parts, these chambers are evacuated and then filled with a suitable potting compound such as an epoxy resin in liquid state to the level of the upper end of the pump cylinder 9. This cylinder may, of course, be formed of a non-magnetic metal such as brass. However, it is in the purview of the invention to form the cylinder itself of the potting compound as shown in FIGURE 1. For this purpose, a cylindrical mandrel having the diameter of the piston plus normal clearance is inserted prior to the potting operation, and withdrawn after the resin has cured. The resin forming the cylinder may be impregnated with material to reduce friction and improve its physical properties.

Another feature of the present invention relates to special characteristics of the pump spring 17.

An ordinary coiled compression spring has a force-displacement graph which is substantially a straight line throughout its normal operating range. In FIGURE 4, which shows force plotted against piston travel, the curve A shows such a graph of a pump employing a conventional coiled spring. It will be seen that starting with an initial compressive force of F_1, when the piston reaches the end of its downward stroke, the spring exerts a pressure of F_3 to initiate the discharge stroke of the piston. The curve B represents the force exerted on the piston by the solenoid to cock the spring. It will be seen that this force increases as the piston is drawn into the solenoid from an initial force of F_2 to a value of F_5 as the piston approaches the end of its downward stroke. The excessive force represented by F_5 minus F_3 merely accelerates the piston above its most efficient speed, the energy being wasted in turbulence and wire-drawing of the liquid through the check valve 12.

Applicant utilizes a substantial portion of this wasted energy by employing a variable-rate spring designed to have a force-displacement curve conforming approximately to the curve B, whereby more of the energy provided by the solenoid is stored up in the spring and made available for moving the piston through its discharge stroke. Thus, starting from the initial compression F_1, the force increases to the value F_4, the vertical distance between corresponding points on curves B and C remaining on the order of that between F_1 and F_2, which represents the optimum force differential for actuation of the piston. Springs having the desired characteristics may be of volute or truncated conical contour, or may, as illustrated in FIGURE 1, have a gradually increasing pitch so that the convolutions of low pitch progressively come into contact.

In operation, closure of the manual switch 20 connects the positive terminal of the power source to the emitter of the transistor 19. Since at this time the reed switch 22 is open, the current flow through the resistor 21 saturates the collector-emitter junction of the transistor, rendering it conductive and thus causing energization of the solenoid 13. When the solenoid has drawn the piston 11 down out of the vicinity of the magnets 26, 27, the flux between the magnets becomes effective to close the magnetic switch 22. The base current provided by resistor 21 is thus by-passed around the base-emitter junction of the transistor, whereby the flow of current through the solenoid 13 is interrupted. The spring 17 then expands, actuating the piston 11 through its discharge stroke until its upper end enters the field of the magnets 26, 27. The flux through the magnetic reed switch is thereby by-passed through the piston, the switch opens, and the operation is repeated. Since the circuit of the reed switch is non-inductive and of small value, little or not sparking occurs at the contacts, and the useful life of the switch is practically unlimited.

It will be understood that the expressions "up," "down," "vertical," and "horizontal" are here used merely for convenience in referring to the drawing. Actually the pump is completely indifferent to orientation and works equally well in all positions.

The above-described circuit connections are particularly advantageous since the transistor is thereby permitted to operate under BVC's conditions with the inductive collector load. In other words, when the current through the solenoid is interrupted, the surge of counter EMF caused by the collapse of the field around the solenoid finds the transistor with its base shorted to the emitter through the reed switch 22. Under this condition the break-down voltage from the collector to the emitter is so high as to preclude any malfunction. Obviously this arrangement avoids any problem of sparking or radio interference, and takes advantage of the almost unlimited service life of the transistor.

Although certain structure has been shown and described in detail, it will be understood that other embodiments are possible, and changes may be made in the design and arrangement of the parts without departing from the spirit of the invention.

I claim:

1. A pump system comprising a casing having an inlet chamber and an outlet chamber,

a cylinder of non-magnetic material connecting said chambers,

a hollow piston of magnetizable material slidably mounted in said cylinder,

a spring urging the piston toward the outlet end of the cylinder,

a solenoid surrounding the cylinder and piston and adapted, when energized, to draw the piston toward the inlet end of the cylinder,

valve means in cooperation with the solenoid for causing reciprocation of the piston to produce a flow of liquid from the inlet chamber through the piston into the outlet chamber,

and means for periodically energizing said solenoid comprising means providing a magnetic field causing a flux across the outlet end of the cylinder,

a magnetically actuated switch located adjacent the outlet end of the cylinder in position to be actuated by said magnetic field,

and means controlled by said switch for causing de-energization of the solenoid when the piston approaches the inlet end of the cylinder, and means forming a conductor for the flux of said magnetic field by the piston when the piston moves to the outlet end of the cylinder wherein said flux by-passes said switch to allow it to open.

2. A pump as set forth in claim 1 in which the last-mentioned means includes a source of electrical energy,

a transister in circuit with said source and the pump solenoid arranged, when rendered conductive, to cause energization of the solenoid,

and circuit connections from said switch to the transtor and the source of power whereby when the magnetic flux is by-passed from the switch by the piston, the switch operates to render the transistor conductive.

3. A pump system as set forth in claim 1 including further,

means filling the space in the housing between the inlet and outlet chambers, locating and immobilizing the cylinder, the solenoid, and the contained elements of the means for energizing the solenoid.

4. A pump system as set forth in claim 3 in which said cylinder is formed of material similar to said filling means, and its integral therewith.

5. A pump system as set forth in claim 1 in which the means providing the magnetic field comprises poles of opposite polarity located adjacent opposite sides of the cylinder,

and the magnetically actuated switch comprises parallel overlapping magnetic contact blades located within said magnetic field and extending parallel to the direction of flux between said magnetic poles.

6. A pump system as set forth in claim 5 in which the contact blades of the switch are so mounted as to be normally out of engagement, but the overlapping portions are magnetically held together by flux from the magnetic field as long as said flux is not by-passed therefrom by the presence of the piston in the space between said poles.

7. A pump system as set forth in claim 2 in which the circuit connections of said transistor and switch comprise

means for supplying a current through the base-emitter junction of the transistor sufficient to heavily saturate the collector-emitter junction and thus render the transistor conductive for current through the solenoid,

said switch being so connected that, when closed, it by-passes said base-emitter junction of the transistor, stopping the flow of current therethrough and hence rendering the transistor non-conductive for solenoid current.

8. A pump system as set forth in claim 1 in which the means for energizing the solenoid includes

a direct-current source of electrical energy, a transistor,

a conductive connecting one terminal of the source of energy to the emitter of the transistor,

a conductor connecting the collector of the transmitter to one terminal of the solenoid,

a conductor connecting the other terminal of the solenoid to the other terminal of the source of energy,

means including a current-limiting resistor connecting the base of the transistor to said other terminal of the source of energy,

and means forming a connection through said magnetically operated switch from said one terminal of the source of energy to said base of the transistor.

9. A pump system as set forth in claim 1 in which the means for energizing the solenoid includes

a direct-current source of electrical energy,

a PNP type transistor having its emitter connected to the positive terminal of the source of energy, and its collector connected through said solenoid to the negative terminal of said source of energy,

means including a current-limiting resistor connecting the base of the transistor to said negative terminal of the source of energy,

and a shunt circuit including said magnetically operated switch, connecting the base of said transistor to its emitter.

10. An electronically controlled electro-magnetic pump system as set forth in claim 1 in which said spring which urges the piston toward the outlet end of the cylinder is so formed that its compressive force increases at a higher rate than a linear function of the compression stroke.

11. A pump system as set forth in claim 10 in which said spring has a force-displacement curve the contour of which approximates that of the actuation of the piston by the solenoid.

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