United States Patent

Hilford

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[54] **SOLENOID OPERATED PUMP**

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[58] **Field of Search**.....417/413, 416, 417, 418; 318/119, 129, 134; 310/23, 34

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[57] **ABSTRACT**

The present invention relates to an electric solenoid operated, diaphragm pump of the type having a mechanically operated electrical switch for controlling cyclical solenoid energization. Prior pumps of this class passed a large electrical current through the switch contacts, leading to premature switch failure. The present application discloses an electronic circuit that minimizes the electrical current flow through the switch contacts. It also discloses an optical arrangement for replacing the mechanically operated electrical switch.

3 Claims, 4 Drawing Figures

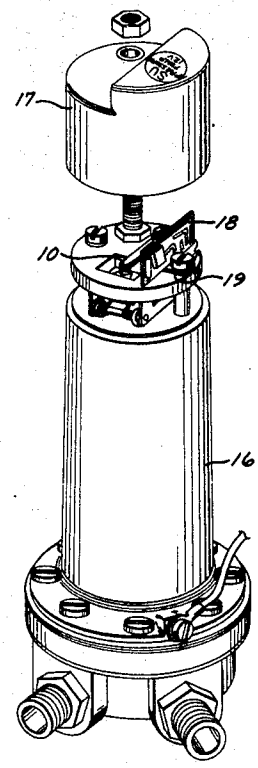
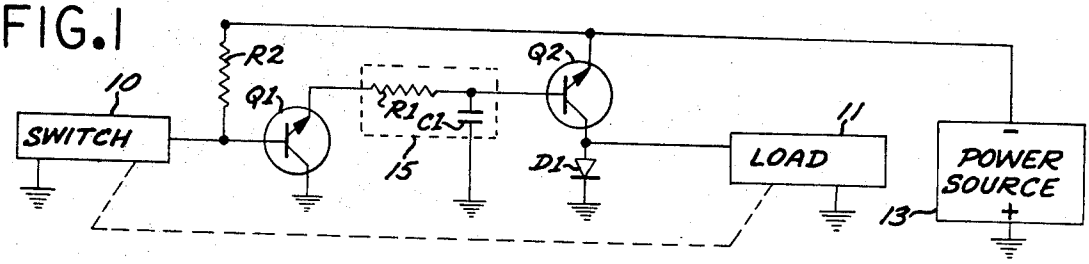


FIG.1



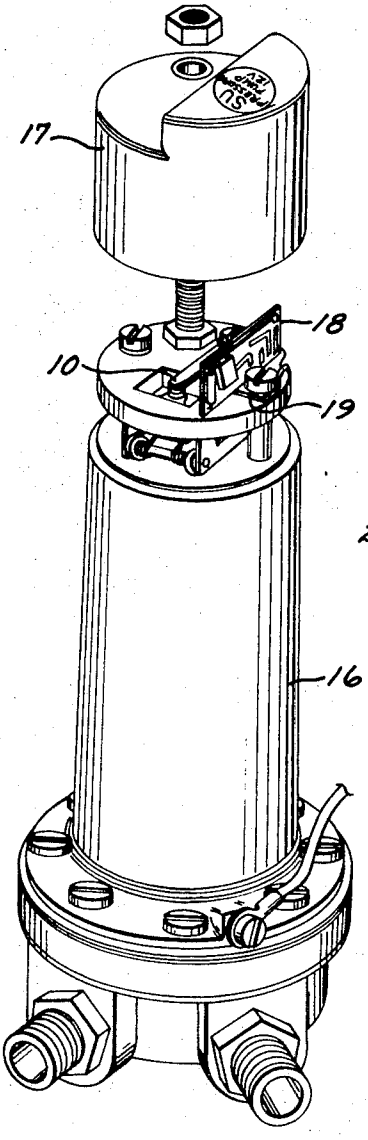
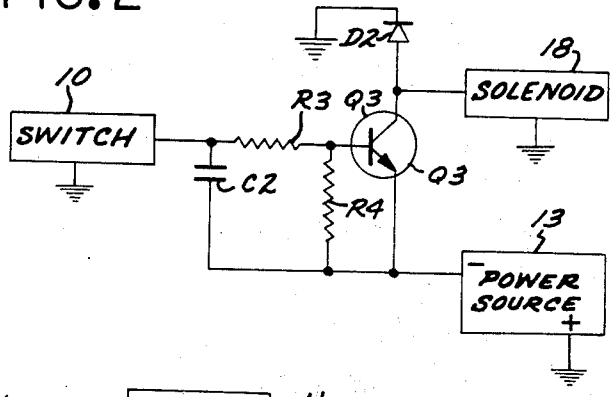


FIG.3

FIG.2



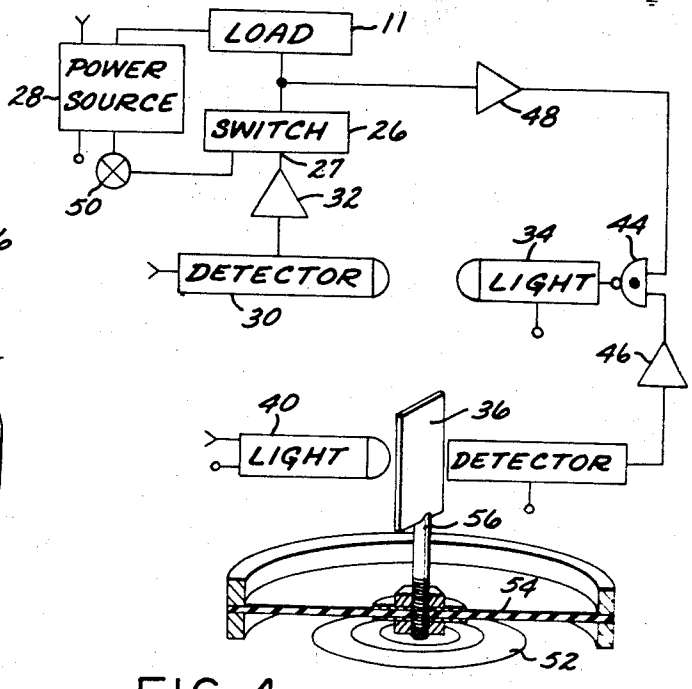


FIG.4

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SOLENOID OPERATED PUMP

BACKGROUND

In practically all of the present day automobiles a fuel pump is needed for pumping the fuel from a lower, remote tank location to the engine. Whereas most of the present day automobiles have fuel pumps that are mechanically operated by means of a mechanical interconnection with the engine, a number of technical reasons make this mechanical interconnection undesirable.

One solution to the above problem is to use an electrically driven fuel pump; this having among its other advantages, the capability of being positioned at almost any desired location, since it is free of the prior need for a mechanical interlinkage with the engine. Other advantages of the electrically driven fuel pump are that the automobile owner can, by changing or adjusting the electric fuel pump, change the rate at which fuel is delivered to the engine and they can be arranged to deliver fuel to the engine at different rates in response to predefined criteria.

Thus electrically driven fuel pumps are becoming quite popular as replacement items and are being used as original equipment on many automobiles.

While electric fuel pumps are popular for their many advantages, they have had one important inherent shortcoming. Operating life has been shortened by electrical contact failures.

It is therefore a principal object of the present invention to provide an improved electrically operated fuel pump.

It is a further object to provide an improved electrically driven fuel pump that has greater reliability and longer life than prior pumps.

It is a still further object to provide an electrically driven fuel pump in which high current switching is accomplished electronically.

That these objects, and others, are realized in the invention will be apparent from a study of the following detailed description taken in conjunction with the drawings, of which:

FIG. 1 shows an electronic circuit for providing improved fuel pump operation;

FIG. 2 shows another electronic circuit for providing improved fuel pump operation;

FIG. 3 is a pictorial view of one embodiment of an electrically driven fuel pump embodying the invention; and

FIG. 4 is another embodiment of the electrically driven fuel pump.

INTRODUCTION

A fuel pump comprises a pump housing and a pump diaphragm that is normally fastened at its perimeter to the pump housing. The central portion of the pump diaphragm is adapted to oscillate longitudinally relative to the pump housing. As the pump diaphragm oscillates, it alternately assumes convex and concave states or, sometimes only the degree of convexivity or concavity is changed. In one state of the diaphragm the pump draws fuel from the fuel tank into a pump chamber, through an intake tube connected between the fuel pump and the fuel tank. When the diaphragm changes position toward the opposite state fuel is forced to flow from the pump chamber to the carburetor of the engine. Suitable valves are incorporated into the pump system to prevent reverse flow. In the electrically driven fuel pumps, one end of a driving rod of suitable magnetizable material is attached to the center of the oscillatable pump diaphragm. The driving rod extends into a solenoid and a means is provided for biasing the rod and diaphragm to one diaphragm state. When electricity is made to flow through the wires of the solenoid, it develops a magnetic field that exerts a longitudinal force on the co-axial longitudinal driving rod. This magnetic force causes the driven rod to move such that the diaphragm is moved against the bias means to the opposite state.

When the flow of electric current through the solenoid is terminated, the magnetic force disappears and the bias means, generally a spring, exerts a restoring force that repositions the rod and diaphragm to their initial position. By causing the electricity in the solenoid to alternately flow and to stop, the desired oscillatory movement of the driving rod and pump diaphragm can be obtained.

In order to achieve continuous diaphragm oscillation, electrical fuel pump controls comprise an electrical switch having a pair of mating electrical contacts one of which is actuated by motion of the rod and diaphragm.

Normally, the switch is "closed"; i.e., there is engagement of the switch contacts. Therefore, as soon as the ignition key of the automobile is turned on, electricity flows through the closed switch contacts and through the wires of the solenoid. This electric flow produces the above described magnetic force and resulting longitudinal movement of the rod. The movement of the rod compresses the bias spring and stores energy in it. After a predetermined amount of movement the switch contacts are separated. This "opens" the switch, and terminates the flow of electric current through it. The magnetic force thereupon disappears. The bias spring returns the drive rod to initial position in which the switch contacts are returned to the normal closed switch condition, however, immediately when the switch closes, the flow of electric current is resumed and the cycle is repeated to produce a continuous diaphragm oscillation and fuel pumping action. In this way, the electric fuel pump is activated as soon as the ignition key is turned on and it remains activated for the duration of automobile operation. It should be noted that whenever the automobile's ignition key is turned off, the pump automatically reverts to a normal quiescent, closed switch position wherein the pump is ready to resume operation as soon as the ignition key is turned on.

The diaphragm oscillates with the drive rod to accomplish the pumping action. Operating frequency is determined by the mass of the moving parts and the spring rate of the bias spring. It will be determined also by the flow rate of fuel into and out of the pump cavity and by the inductance of the solenoid.

Prior electric pumps have been characterized by short switch life due, primarily, to contact pitting and burning. Electrical considerations dictate the use of high solenoid currents and high current levels promote the heating that accounts in part for contact pitting. Pitting is also caused by arcing which follows from inclusion of the solenoid inductance and from contact "-

bounce". While the arc is in existence, it actually carries material from one switch contact to the other. Eventually, the "carried" material produces a crater at one switch contact, and may produce a protrusion of deposited material at the other switch contact. Depending upon operation conditions, one or a plurality of "pits" may form in the switch contacts. In any case, the optimal clean, contiguous surface to surface relation of the switch contacts is destroyed and current carrying capacity becomes progressively worse. This pitted condition of a switch contact surface produces an electrical condition known as a "high".

SYNOPSIS

Broadly stated, the present invention interposes an electronic circuit between an electric switch and an electric load. The circuit minimizes the electric current flow through the switch contacts while maintaining the desired load current. By-pass circuits are incorporated in the circuit for by-passing high frequency transients and inductive "kicks".

DESCRIPTION

It was pointed out above, that prior art electric fuel pumps required a large electric current for their operation. Representative pumps draw as much as three or four amperes of electric current. In the circuit of FIG. 1, current of that magnitude is controlled by a switch carrying only a small fraction of that amount of current.

FIG. 1 includes a switch **10** and a load **11**. These elements correspond to the switch and to the solenoid previously discussed, although the disclosed invention may be used for applications other than that of an electric fuel pump. The switch **10** senses the position of the driving rod, and the state of the pumping diaphragm and is here called a sensing switch. In the prior art, the sensing switch is electrically connected directly in series with the load **11**; but in the present invention, an electric circuit is interposed between sensing switch **10** and load **11**. The sensing switch **10** is connected between a power source **13** and the base of an NPN transistor Q1 whose collector is connected to ground and whose emitter is connected through an RC filter **15** to the base of NPN transistor Q2. The collector of Q2 is connected to the negative side of a d.c. power source **13** whose positive terminal is grounded. Bias for Q1 is developed across resistor R2 which is connected from the base of Q1 to source negative. In this embodiment the low pass filter **15a** comprises a resistor R1 connected from the emitter of Q1 to the base of Q2. A by-pass capacitor C1 completes the filter. It is connected from the base of Q2 to ground. When the switch contacts of sensing switch **10** are open, no electrical signal is applied to the base electrode of transistor Q1, so that transistor Q1 is cut off. As a result, no current flows to solenoid **11**. The bias or spring holds the switch, driving rod, and the diaphragm in their normal quiescent positions.

When the switch contacts of sensing switch **10** are closed, the bias resistor R2 is short circuited and the base of Q1 goes positive. This transistor is turned on to its saturated state and its emitter electrode provides a sensing signal through coupling resistor R1 of network **15** to the base electrode of transistor Q2. The voltage drop across R1 causes the base of transistor Q2 to become negative and it is turned full on. Current flow through D1 is prevented because of its polarization. Instead, current flow is through the load **11**. In a representative example, the parameters are such that transistor Q1 draws only half a milli-ampere of current. This minimized sensing signal current flows through the switch contacts of switch **11** with little deletarious effect thus leading to a long lived reliable sensing switch. A much larger current is permitted to flow through the solid state switch Q2. When the load **11** is the solenoid in a commercially available fuel pump, the Q2 solenoid current is about 3 amperes. The waveshape of current flow through the load is complex because of the inductive character of the load. However, it is less complex, permitting more freedom to the designer, than it would be if the load circuit included the arcing contacts of a mechanical switch. In the invention arcing has been diminished by limiting current flow. Moreover, the filter serves to isolate the solid state switch and load from high frequency current change resulting from contact bounce.

When the load is inductive, cessation of current flow results in the generation of a counter electromotive force. That force is dissipated by permitting current flow through the diode D1. By this arrangement, Q2 is protected against application of excessive inverse voltage and the solenoid is protected against excessive interturn voltage.

FIG. 2 shows another circuit for achieving similar results. Here, an electronic circuit **17** is connected between the sensing switch **10** and a solenoid **18** in the manner discussed above but circuit **17** comprises a single transistor Q3 having its base electrode connected to the switch **10** through a coupling resistor R3. The output of transistor Q3 is connected to solenoid **11**. Resistor R3 is part of a low pass filter network which also includes a capacitor C2 connected from the junction of switch **10** and resistor R3 to ground and a resistor R4 connected from the junction of R3 and Q3 to ground.

The solenoid **18** is connected to positive ground from the collector of Q3 in parallel with a diode D2. The diode is polarized to short circuit the solenoid when its magnetic field is collapsed, as described above, and a counter e.m.f. results. In this case, R4 provides a bias circuit that keeps Q3 turned off until the base of Q3 is rendered less positive by closure of switch **10** to complete a circuit through R3 and R4. When the switch **10** is closed, current flows from source **13** through the switch and resistors R3 and R4. The potential change across the resistors results in the base of Q3 being rendered more positive. This change in potential comprises a sensing signal operative to control the switch transistor Q3. Q3 is turned full on until the bias is changed by the opening of switch **10**.

This arrangement in FIG. 2 results in greater current flow in the switch contacts than does the circuit of FIG. 1. Some of the more desirable switch contactor materials perform better if they are subjected to an intermediate current flow in the amount of several milli-amperes rather than the micro ampere current that flows in the switch of FIG. 1. This increased current is provided in the preferred circuit of FIG. 2.

As pointed out above, many electric fuel pumps experience premature failure because of the excessive

pitting at the switch contacts. In those cases where the pump structure is such that new switch contacts may be installed, a cap portion of the pump housing is removable for this purpose. Rather than installing new switch contacts, or in addition to installing new switch contacts, it may be desirable to modify the fuel pump by inserting the circuit of FIGS 1 or 2; and this is readily accomplished as will be shown in FIG. 3. That figure shows a typical electrical fuel pump housing 15 that has its cap 17 removed. A portion of the switch 16 is visible. In operation it is oscillated vertically by the end of the above discussed longitudinally positioned driving rod (not visible). In order to make the disclosed modification, the capacitor employed in previous pump designs is removed. A miniaturized printed wiring board 18 is mounted on a bracket such as bracket 19; and is interconnected with the switch 10 and the solenoid wires 18 as taught above. Once this modification has been made, the electrical portion of the fuel pump is ready for long, reliable usage.

It will be recalled that the invention minimizes the problems associated with switch contacts but the embodiment of the invention shown in FIG. 4 completely obviates the switch compact problem entirely. In the schematic block diagram of FIG. 4, pump diaphragm 21 is shown to have a longitudinal driving rod 22 affixed to its center portion. The driving rod oscillates longitudinally as indicated by arrow 23.

In the embodiments of FIGS. 1 and 2, the driving rod actuates the switch mechanically and its placement relative to the driving rod determines over what portion of the cycle the switch will be closed. In the embodiment of FIG. 4 the switch is a solid state device 26 which is actuated by electrical signals applied to its terminal 27. Closure of the switch results in completion of the circuit from source 28 through switch 26 to load 11 and then back to the source. Switch control signals are applied to terminal 27 from a means for providing a signal in response to light and lack of light. That means comprises a light detector 30 in series with a phase reversal amplifier 32. The detector 30 is arranged to receive light emanating from a source 34 when the light source is energized, provided, however, that the shield 36 has been lowered sufficiently to clear the path from the light source detector. The duration of the energizing part of the cycle of solenoid exitation can be controlled by controlling the length of the shield 36. However, in the preferred form depicted in FIG. 4 a second light source 40 and light detector 42 are employed. They are placed on opposite sides of the path of shield 36 movement at a point below the detector 30 and source 34. Light source 34 is energized through a NAND gate 44 when the gate is opened by the absence of signals applied to it from two phase reversal amplifiers 46 and 48. Phase reversal amplifier 46 is connected between gate 44 and the light detector 42. The other phase reversal amplifier 48 is connected from the output of solid switch 26 to the other input of the gate 44.

The electrical circuit includes an ignition switch, one element 50 of which is shown in series between source 28 and the solid state switch 26. That circuit is completed when the ignition switch is closed. In addition, other elements are shown of the ignition system energize the several amplifiers and the detectors and the light source 40 whenever the ignition switch is turned on.

Initially, part of the electrical pump system is energized. In the mechanical portion of the pump, the bias spring 52 will have lifted the pump diaphragm 54 to its uppermost position, lifting the driving rod 56 so that the shield 36 will be lifted and interposed between detector 30 and source 34 and between detector 42 and its light source 40. Initially, switch 26 is open. When the ignition switch is first turned on, electrical power from power source 28 will be applied through ignition switch segment 50 and the solid state switch 26 to the load 11. As soon as that happens, the potential applied at the input of amplifier 48 will turn that amplifier on so that a signal is applied to gate 44 from that amplifier. However, detector 42 is shielded from its source 40 by the shield 36. Accordingly, that detector has no output and no input is applied to amplifier 46. In that circumstance, there is an output from amplifier 46 which is applied to the gate 44 along with the output from amplifier 48 to maintain its gate in zero state. Consequently, light source 34 remains dark.

But load 11 has been energized and a magnetic field is created which forces the driving rod 56 downwardly. Shortly after beginning its downward movement the shield 36 passes below the line between detector 30 and source 34 to the position shown in FIG. 4. However, light source 34 is still not illuminated by the gate 44 so that no signal is applied to the detector 30 and no signal is applied by the detector to its phase reversal amplifier 32. Thus, the signal applied at terminal 27 of the solid state switch 26 is unchanged and that switch remains open. Eventually, the rod 56 is moved downwardly in sufficient degree so that the shield 36 clears the path from light source 40 to detector 42. At that time the detector applies an input signal to amplifier 46 which forces its putput to be zero or low. The NAND gate 44 reacts to the zero output of amplifier 46 by going into a one state. The high output of gate 44 turns on light 34. Light from the source 34 is received at detector 30 and that detector applied a signal to amplifier 32. As a result, that amplifier's output changes state and applies a signal to terminal 27 to shut off the solid state amplifier 26. The magnetic field emanating from solenoid 11 collapses and the diaphragm 54 is returned to initial position by the bias spring 52. When shield 36 is lifted it shuts off light to detectors 42 and 30 and the system is reset and the cycle repeated.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art.

I claim:

1. An electric fuel pump comprising:

a pumping mechanism mounted for reciprocation;

means comprising a driving rod affixed to said pump mechanism for causing said mechanism to be reciprocated;

reciprocating means comprising a solenoid surrounding said driving rod for developing a magnetic force that causes said driving rod to move in one direction and a return spring;

energizing means comprising a solenoid switch actuatable for energizing and de-energizing said solenoid;

sensing means for sensing the position of said driving rod and producing a signal when said driving rod occupies a selected position; and

actuating means for utilizing that signal for actuating said solenoid switch;

said sensing means comprising a first light source and first light sensor and a shield mounted for movement with said driving rod from a position in which it is interposed between said first light source and said first light sensor to a position in which it is not interposed between said first light source and said first light sensor to a position in which it is not interposed between said first light source and said first light sensor when said driving rod is moved between said selected position and another position.

2. The invention defined in claim 1 in which said sensing means comprises a second light source and a second light sensor mounted such that said shield is interposed between said second light source and said second light sensor when said driving rod occupies said selected position; and

means for preventing operation of said first mentioned light source when said shield is interposed between said second light source and said second light sensor.

3. The invention defined in claim 2 in which said sensing means further comprises a NAND gate in series with said first light source, three reversing amplifiers, and in which said solenoid switch comprises a solid state switch arranged with an input terminal such that the switch is closed unless a signal is applied to its terminal, one of said reversing amplifiers being connected between said first light sensor and the input terminal of the solid state switch, another of said reversing amplifiers being connected between a terminal of the solenoid and one control terminal of the gate, and the third of said reversing amplifiers being connected from said second sensor to the other control terminal of the gate.

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