Sept. 5, 1961 R. J. LAMBERT 2,999,192

SOLENOID ACTUATOR AND CONTROL MEANS THEREFOR

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FIG. 1

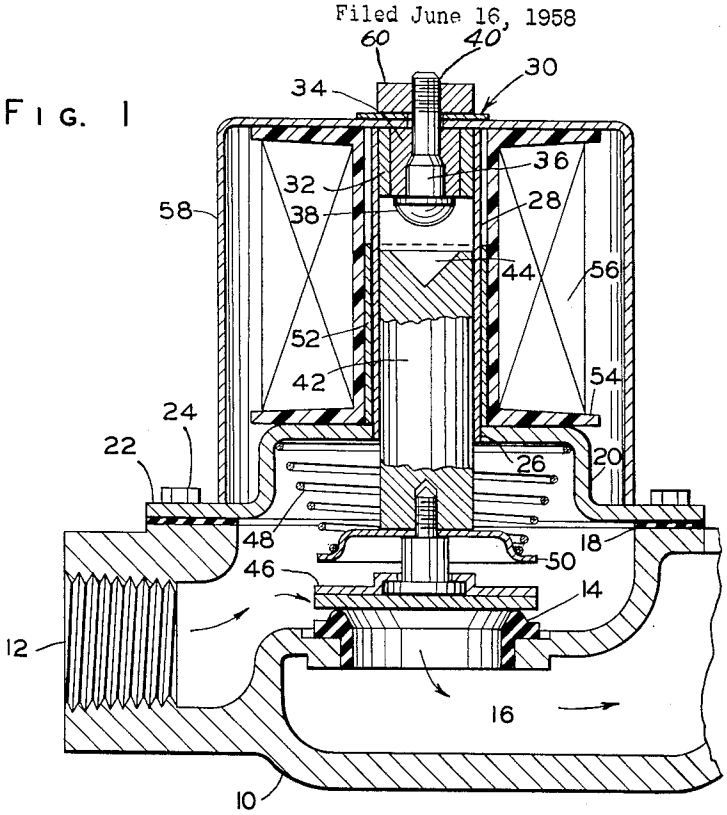
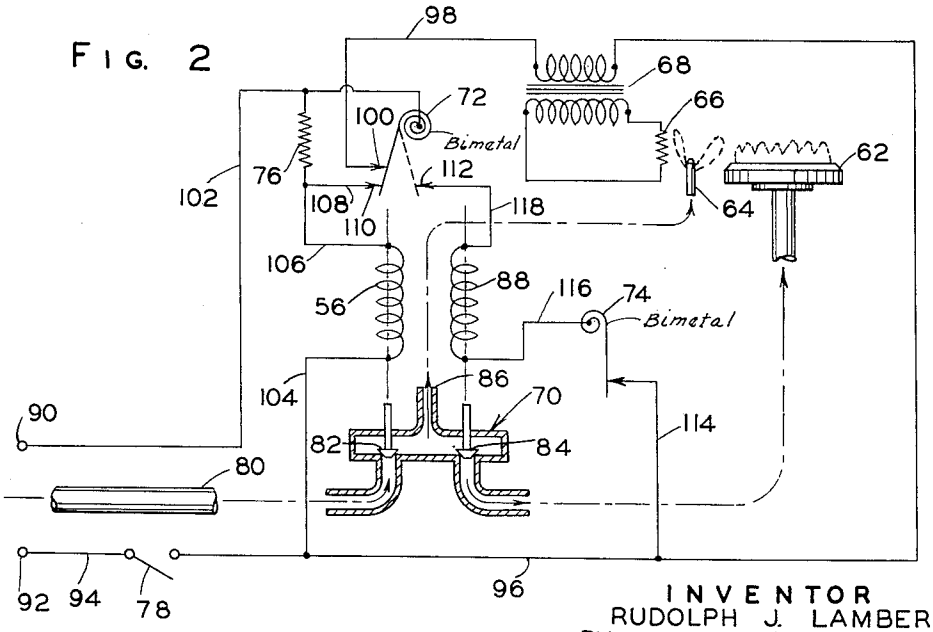


FIG. 2



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SOLENOID ACTUATOR AND CONTROL MEANS THEREFOR

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This invention relates to solenoid actuators, and particularly to means incorporated therein which reduces the effectiveness of the available magnetomotive force to pull the plunger in from its extended position yet is substantially inoperative to reduce its effectiveness to hold the plunger in its attracted position once it is moved there.

It is desirable in some uses of a solenoid actuator to operate it in such manner that sufficient electrical current is passed through its winding under certain conditions to effect the pull-in of the plunger from its extended position and then under other conditions, and when the plunger is in its attracted position, to reduce the flow of electrical current through said winding to a point which while yet sufficient to hold the plunger in its attracted position is insufficient to effect the pull-in of the plunger from its extended position. This method of solenoid operation may be utilized as a safety feature in a burner control system in a manner disclosed in the commonly assigned, copending application of Claude M. Garner, Serial No. 648,174, filed March 25, 1957.

In the Garner disclosure a double-throw, flame sensitive switch, when in its no-flame or cold position, completes energizing circuits through its cold side contacts for effecting the opening of a normally closed solenoid operated primary fuel control valve to supply fuel to a pilot burner and for effecting the operation of a pilot burner ignition device. The flame switch subsequently responds to flame when established at the pilot burner to open its cold side contacts and close its hot side contacts. When the cold side contacts of the flame sensitive switch open, the energizing circuits for the primary fuel valve and pilot burner ignition device are broken, but a parallel circuit including a resistor connected across the flame sensitive switch maintains energization of the primary control valve at reduced current. The closing of the hot side contacts of the flame sensitive switch completes a full energizing circuit for a normally closed secondary fuel control valve in series with the primary control valve, it being necessary for both primary and secondary control valves to be open if fuel is to flow to the main burner.

The resistor connected across the flame sensitive switch is of such value as to reduce the current flow through the primary valve circuit to a value which while being sufficient to hold the primary valve open once it is open is, however, insufficient to pull the primary valve open from its closed position. Thus, in the event of a momentary electrical power failure during main burner operation which would permit the closing of both primary and secondary valves and thereby extinguish both pilot and main burners, the primary control valve will not be reopened upon a resumption of the power supply until the flame sensitive switch has had time to respond to the loss of pilot flame to break its hot side contacts, thereby to prevent reopening of the secondary fuel valve and to close its cold side contacts and thereby re-establish a pilot flame.

Variations in the voltage of the available power supply source and spring loading of the solenoid plunger tend to limit the use of this method of solenoid actuator operation. For any solenoid with a given load there is a critical energizing current value at which the plunger will pull in, and a somewhat lower critical current value at which it will drop out. It will be seen that the differential in these critical values is reduced by a plunger load

such as a return spring, which due to its rate, increases the load as the plunger approaches its attracted position. In other words, as the plunger approaches a stronger magnetic field, the force of the spring bias is also increasing, so that the differential in current values at which the solenoid plunger pulls in and drops out is reduced as the spring rate is increased. The use of a return spring is necessary, however, in many cases; for example, to insure the return of the plunger when the solenoid actuator is to be mounted in different positions or when a valve attached to the actuator plunger is to be firmly seated when the actuator is de-energized. Moreover, the necessity of providing some means of kicking off the plunger from its magnetic stop member to prevent sticking due to residual magnetism indicates the use of a return spring having a substantial rate.

Having selected or designed a solenoid actuator with a predetermined plunger load and stroke and having determined the critical pull-in and drop-out current values, a safety control circuit may now be designed including means, such as a resistor, to limit the current flow through the solenoid winding once the plunger has been pulled in so that the plunger will remain in an attracted position but will not pull in from its extended position. Even though the plunger load may include a return spring of high rate, there will usually remain a sufficient differential in pull-in and drop-out current values within which the described method of operation may be reliably accomplished provided, however, that the power supply voltage remains substantially constant. If, on the other hand, the power supply voltage varies upward from the nominal voltage for any reason during limited energization of the solenoid winding so as to effect an increase in the current flow through the winding by an amount which is as great as the reduction in current flow effected by the resistor, the device would fail as a safety device and the plunger would pull in following a momentary power interruption, and if the power supply voltage varies downward any appreciable amount from the nominal supply voltage during limited energization of the winding, the solenoid plunger will drop out.

In view of present power distribution facilities, variations from nominal rated voltages within which devices of the instant character are required to operate reliably have been established by underwriter associations and are in the order of −15% to +10%. Thus for a device of this character rated nominally at 115 volts, A.C., the device would be required to operate reliably from 98.75 volts to 126.5 volts, a variation of 27.75 volts. In order to construct a solenoid actuator which can be operated reliably in the foregoing manner under conditions including high spring rate loading and wide supply voltage variation, applicant has provided means incorporated in the solenoid actuator for increasing the differential in pull-in and drop-out current values for any plunger stroke.

An object of the invention is to provide a solenoid actuator having means operative when the plunger is in its extended position to reduce the magnetic force acting to attract the plunger, which means is rendered substantially ineffective to reduce the magnetic force tending to attract the plunger when the plunger is moved toward its attracted position.

A further object of the invention is to provide a solenoid actuator which, under conditions of wide voltage variation in the power supply, may be operated on reduced current so as to hold in at the lowest supply voltage but not pull in at the highest supply voltage.

A further object is to provide means in a solenoid actuator for shunting a portion of the magnetic flux available to pull the solenoid plunger in from its extended position, which means is substantially ineffective to reduce the available magnetomotive force tending to hold the plunger in after it is pulled in.

These and other objects and advantages will become apparent when reading the following description in connection with the accompanying drawing.

In the drawing:

FIG. 1 is a cross-sectional view showing a solenoid actuator constructed in accordance with the present invention, associated with a valve which it actuates; and

FIG. 2 is a diagrammatic view of a burner control system in which the solenoid actuator is operated in a manner which illustrates the utility of its particular construction.

Referring to the drawing, numeral 10 indicates a fragmentary portion of a valve body having an inlet 12, a valve seat 14, and a passage 16 leading to a second, series arranged valve seat (not shown). The valve body has an opening 18 which is covered by an inverted cup member 20. Member 20, which is constructed of magnetic material, has a flange portion 22 attached to the valve body by screws 24. Member 20 is further provided with a central aperture 26 into which is projected the lower, open end of a non-magnetic plunger guide sleeve 28. The upper end of non-magnetic sleeve 28 is closed by a shaded, magnetic stop member generally indicated at 30, which stop member comprises an outer ring 32 of magnetic material, an inner shade ring 34 of conducting, but non-magnetic, material, and a central plug 36 of magnetic material. The central plug 36 has a hemispherical head 38 at its lower end and an upper end portion 40 which is threaded and extends upward beyond the rings 34 and 36.

The lower end of the guide sleeve 28 is rigidly connected to the member 20, as by soldering or brazing, and the outer ring 32 of stop member 30 is rigidly attached in the upper end of the guide sleeve by any suitable means, such as by brazing, which will provide a fluid tight seal. The inner shade ring 34 and the plug 36 are pressed-fitted into the outer ring 32. Mounted in the guide sleeve 28 for free sliding movement is a plunger 42 of magnetic material. The upper end of plunger 42 is provided with a conical recess 44 which cooperates with the hemispherical head 38 to center the upper end of the plunger in the guide sleeve. At its lower end, which extends downwardly beyond the end of guide sleeve 28, the plunger carries a valve 46 which cooperates with the valve seat 14. A conical return spring 48, which bears at its upper end against the bottom of cup 20 and at its lower end against a flange member 50 on the lower end of the plunger, urges the plunger downward and normally biases the valve 46 on its seat.

Surrounding the non-magnetic sleeve 28 and extending upward from the member 20 to a point slightly above the upper end of plunger 42 is a sleeve 52 of magnetic material. Slipped over sleeve 52 and resting on member 20 is a spool 54 of dielectric material which contains a winding 56. An inverted cup 58 of magnetic material forms a cover for the winding 56. The cup 58 has a central perforation in its bottom which receives the upper threaded end 40 of the plug 36, and the rim of the cup 58 is firmly held against the flange 22 of member 20 by a nut 60.

FIG. 2 of the drawing diagrammatically illustrates a gas burner control system incorporating a solenoid actuator of the above-described construction. The primary elements of the control system are: a main burner 62, a pilot burner 64, an igniter 66, an igniter transformer 68, a dual valve generally indicated at 70, a flame sensitive switch 72, a space thermostat 74, a resistor 76, and a line switch 78. The dual valve 70 is connected in a gas supply conduit 80 and comprises a primary control valve 82 controlling the inlet and a secondary control valve 84 controlling an outlet leading to main burner 62. A fuel outlet 86 between valves 82 and 84 supplies fuel to pilot burner 64. In this arrangement valve 82 controls the supply of fuel to the pilot and main burners, and when valve 82 is open, valve 84 controls the supply of fuel to the main burner. Valves 82 and 84 are normally closed and are opened by a pair of solenoid actuators having windings 56 and 88, respectively. The solenoid actuator operating the valve 82, and having the winding 56, is similar to the actuator shown in FIG. 1 and described hereinbefore. The solenoid actuator operating the valve 84 and having the winding designated as 88 may be of conventional construction.

The flame sensitive switch 72 is illustrated as having the form of a bimetal coil which has a normal, cold position, as indicated in solid line, and which responds to the existence of an adequate pilot flame at pilot burner 64 to move to a hot position indicated by dotted line. The space thermostat 74, also being indicated as having the form of a bimetallic coil, is responsive to the temperature of the space being heated to open and close, respectively, as the space temperature rises above or falls below a preselected point.

The circuits for energization of the actuator windings 56 and 88 and igniter 66 are connected across an available power source through a pair of terminals 90 and 92. When it is desired to operate burner 62 the line switch 78 is closed. This action completes circuits for the energization of actuator winding 56 to open valve 82 and the energization of igniter 66. The circuit for energization of the igniter 66 extends from terminal 92 through a lead 94, the line switch 78, a lead 96, the primary winding of igniter transformer 68, a lead 98, the cold contact 100 of flame sensitive switch 72, and a lead 102 to terminal 90. The circuit for energization of the actuator winding 56 extends from terminal 92 through lead 94, switch 78, lead 96, a lead 104, winding 56, a lead 106, lead 108, cold contact 110 of a flame sensitive switch 72, and lead 102 to terminal 90.

Energization of winding 56 through the described circuit effects opening of primary control valve 82, permitting fuel to flow through outlet 86 to the pilot burner 64 where it is ignited by igniter 66. When flame sensitive switch 72 responds to flame established at the pilot burner, it moves to its dotted line position, thereby breaking with its cold side contacts 100 and 110 and making with a hot side contact 112. This action completes a circuit for energization of winding 88 which extends from terminal 92 through lead 94, line switch 78, lead 96, a lead 114, the space thermostat 74, a lead 116, the winding 88, a lead 118, hot side contact 112 of switch 72, and the lead 102 to terminal 90. Energization of winding 88 effects opening of valve 84, thus permitting fuel to flow to main burner 62. The burner 62 will now operate in an on and off manner under the control of space thermostat 74.

When flame sensitive switch 72 moves from its cold to hot position, the described circuits for energization of the igniter 66 and actuator winding 56 are broken. Energization of winding 56 is maintained, however, at a reduced current value, under these conditions, through the resistor 76, which is connected from lead 106 to lead 102 across the switch 72. The value of resistor 76 is such that the current flow through winding 56 is reduced to a point wherein the actuator is incapable of pulling valve 82 open from a closed position, but is yet sufficient to hold the valve open. This arrangement prevents the reopening of primary control valve 82, in the event of a momentary interruption of power, until the flame sensitive switch has had time to respond to the loss of flame and re-establish a pilot flame.

Under conditions of substantially constant power source voltage, the value of resistor 76 may be readily determined and will have such value as to effect a current flow through winding 56, which is somewhere safely between the critical pull-in and drop-out current values. If, however, the power source voltage varies considerably from time to time, or as between installations, the current flow through the winding may, as a result, fall below that required to hold the valve open or rise high

enough to effect pull-in of the valve when the resistor is in circuit. It will be seen, therefore, that the differential in pull-in and drop-out current values of the solenoid with its load must at least be slightly greater than any variation in current value likely to be encountered due to line voltage variation if the solenoid is to be reliably operated as described. Frequently, however, the desired spring loading of the solenoid and line voltage variation require a greater differential in pull-in and drop-out current values than it is possible to attain in a practical solenoid design for any given stroke of the plunger.

By providing the sleeve **52** of magnetic material, a greater differential in pull-in and drop-out current values for any given plunger stroke and load is attained. When the plunger **42** is in an attracted position with the plunger contacting stop member **30**, a low reluctance flux path is provided which extends from magnetic stop member **30** through the casing **58**, the flange **20**, and plunger **42** back to the stop member. This is a continuous path of high permeability except for a small gap at the point where the lower end of the non-magnetic guide sleeve **28** enters the central aperture in flange **20**.

When the plunger **42** is in a down position, as shown in FIG. 1, a large gap exists in the low reluctance flux path between the upper end of the plunger and stop **30**, and the reluctance at this point is, therefore, relatively high. Under these conditions, the sleeve **52**, which surrounds the non-magnetic guide sleeve, provides a lower reluctance path than the plunger **42** to the extent of its permeability and to the extent which it embraces the magnetic circuit. As a result, the flux density in the plunger being relatively low under these conditions is reduced proportionately an appreciable amount, thereby requiring an appreciably higher magnetomotive force to effect a pull in of the plunger than would be necessary without the sleeve **52**.

However, when the plunger **42** is pulled in and contacts the magnetic stop **30**, the flux density in the plunger and stop member is greatly increased to the extent that the shunting effect of sleeve **52** becomes proportionately negligible. As a result no appreciable increase in magnetomotive force is required to hold the plunger in due to the presence of sleeve **52**.

The effectiveness of sleeve **52** was found to increase with its length and wall thickness, but at a much higher rate with length increase as the maximum effective length of the sleeve was approached. The maximum effective length of the sleeve for any wall thickness thereof was attained when the sleeve **52** extended upward from flange **20** to a point just short of that wherein the upper end of the sleeve acted to shorten the gap between the upper end of the plunger and the stop **30**. It was further found that little effect was attained when the length of the sleeve **52** was less than two-thirds of the length of that portion of the plunger which extends above the flange **20** when the plunger is in a down position.

The foregoing description and drawing are intended to be illustrative and not limiting, the scope of the invention being set forth in the appended claim.

I claim:

In an arrangement wherein a solenoid having a spring-returned reciprocating plunger is operated on a variable voltage power supply first at a voltage level which effects the pull in of the plunger from its returned position and subsequently at a lower voltage level which will not effect the pull in of the plunger from its returned position but will hold it in once it has been pulled in; the improvement which consists in providing means comprising an elongated member of magnetic material adjacent said plunger and coextending sufficiently therewith when the plunger is in a returned position as to divert such portion of the available magnetomotive force, which would otherwise act to pull in the plunger, as will increase the required voltage necessary to pull in the plunger by a substantial amount so that the differential in minimum required pull-in and hold-in voltages is greater than it would otherwise be.

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