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Goodman

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[54] **BURNER CONTROL SYSTEM**

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[51] **Int. Cl.** **F23n 5/00**

[58] **Field of Search** .... 431/24, 69, 71, 78–80; 307/252.70; 317/148.5 B

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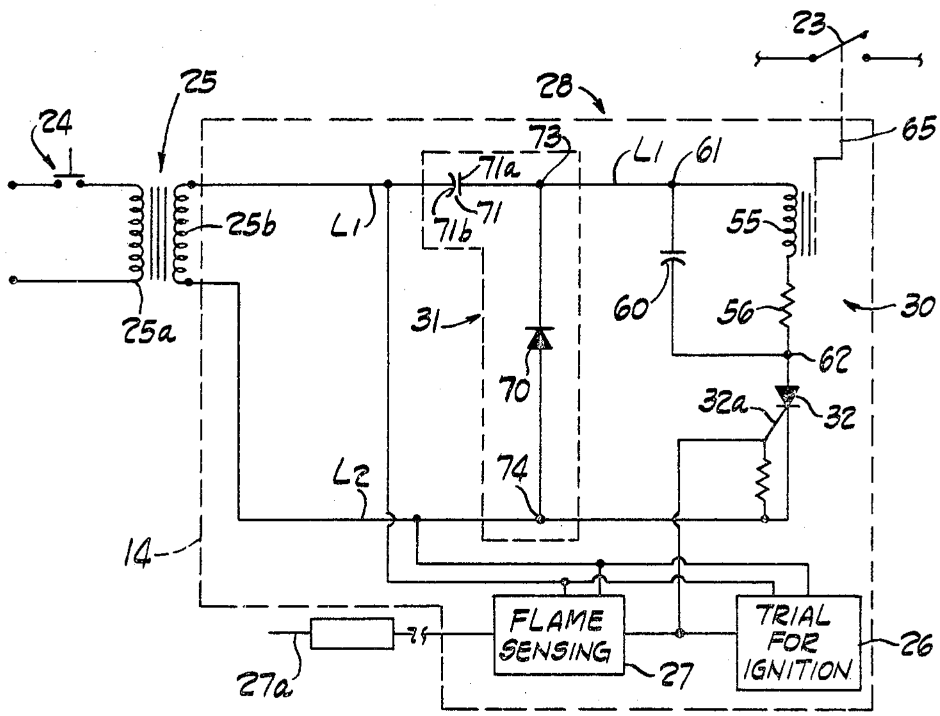
[57] **ABSTRACT**

A burner control system is disclosed including a burner and fuel supply structure controlling the flow of fuel to the burner. Circuitry for controlling operation of the fuel supply structure includes an AC power supply, a voltage doubler arrangement, a relay, and a condition responsive switch for connecting the relay across the voltage doubler. The condition responsive switch is preferably an electronic switch rendered conductive when flame is sensed at the burner. The relay is operatively energized only in response to an applied voltage which is greater than the peak power supply voltage. If any component of the control circuitry short circuits, or otherwise fails, the relay cannot be operatively energized thus preventing the supply of fuel to the burner.

12 Claims, 2 Drawing Figures



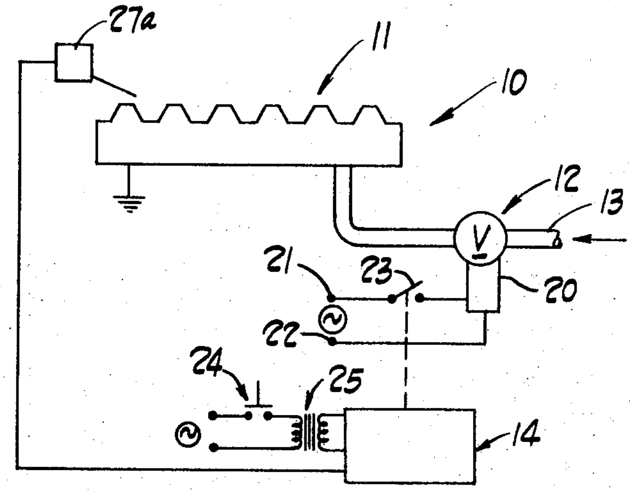


Fig. 1

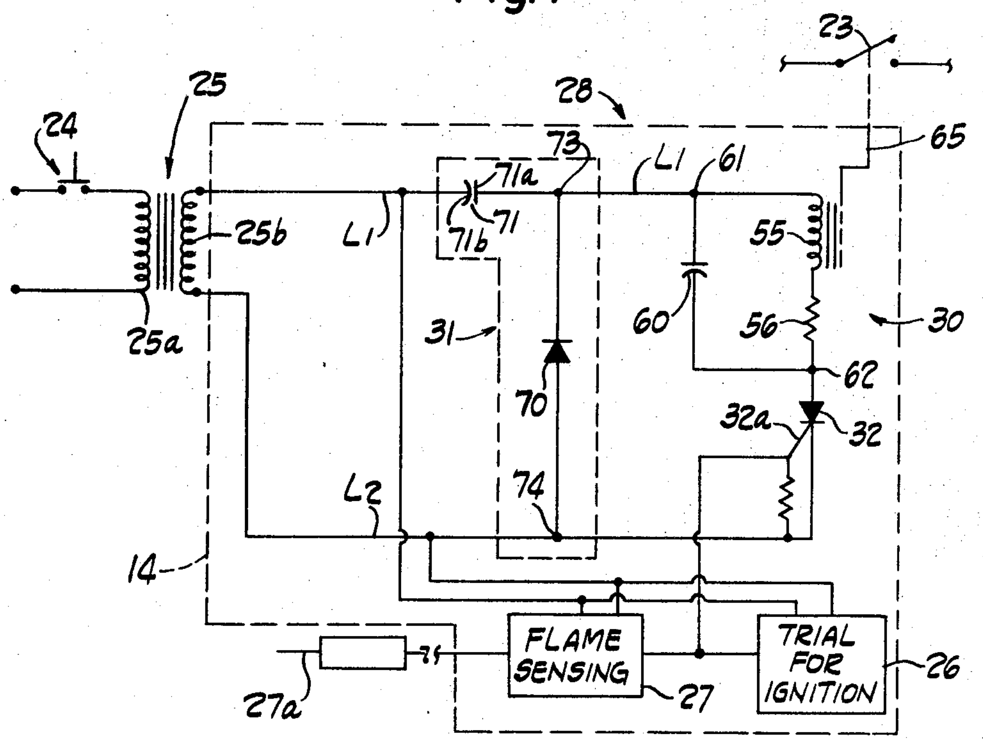


Fig. 2

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BURNER CONTROL SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to burner control systems and more particularly relates to burner control systems in which fuel flow to a burner is maintained in response to combustion taking place at the burner.

The Prior Art

Burner control systems have been developed for terminating fuel flow to a burner when combustion at the burner terminates. In recent years the development of electronic semiconductor devices has enabled development of flame supervising circuits for electronically sensing the presence of flame at burners and controlling fuel valves in response to the sensed flame condition.

Generally, such circuits included a fuel valve operating solenoid coil, or a relay coil for controlling operation of a fuel valve. Energizing circuits for such coils were completed through semiconductor switching devices, such as silicon controlled rectifiers (SCR), or their equivalent.

The conductive condition of the semiconductor elements was controlled by one or more circuits which responded to temperature, physical presence of a flame at the burner, radiation from a flame, or other conditions which indicated that combustion was occuring at the burner.

The design of such circuitry was based upon the premise that so long as the control circuitry functioned properly and flame was present at the burner, the energizing circuit for the coil was completed through the electronic switch. If flame detecting circuitry malfunctioned, or combustion at the burner for some reason terminated, the electronic switch was rendered nonconductive to interrupt the energizing circuit for the coil. Deenergization of the coil terminated the supply of fuel to the burner by closing the fuel valve.

Systems of the type referred to were most frequently applied to combustion equipment employing gas or volatile fuels since continued supply of such fuel in the absence of flame at the burner could eventually result in an explosive accumulation of unburned gas or volatilized fuel.

Due to the potentially dangerous situations which could result from accumulation of unburned fuel, it was necessary to design control systems so that failure or malfunction of any portion of the control circuitry did not lead to accumulations of unburned fuel. This type of design is commonly referred to as "fail safe."

Fail safe control systems utilizing semiconductor elements were necessarily designed so that the combustion detection circuitry produced a combustion indicating signal only when combustion occurred at the burner and then only if the combustion detection circuitry was functioning properly. Likewise, the electronic switch for controlling conduction in the coil energizing circuit was associated with appropriate circuitry for preventing energization of the coil should the electronic switch be short circuited.

Because electronic switches are capable of failing by short circuiting, it was necessary to design flame control circuitry to anticipate such failures. The end result of such design criteria were somewhat extensive and complex circuits frequently including large numbers of relatively expensive components.

Some of these circuits have been extremely effective and reliable and have provided functions not previously performable by mechanical controls. One such system is disclosed in copending application, Ser. No. 780,650, filed Dec. 3, 1968, and now U.S. Pat. No. 3,554,680 entitled Burner Control System and assigned to the assignee of this invention. While effective and reliable, these noted systems have been large and relatively expensive which has limited wide commercial acceptance.

SUMMARY OF THE INVENTION

The present invention provides a new and improved burner control system which is simple in construction and operation, reliable, relatively easily manufactured and relatively inexpensive. The new system utilizes electronic components for controlling operation of a solenoid coil, or relay coil, of a fuel supply means. The system positively prevents energization of the coil should any components of the system malfunction.

In a preferred embodiment of the invention, a solenoid coil, or relay coil which controls operation of a fuel valve is connected across an AC power supply through a voltage doubler arrangement and an electronic switch. The fuel valve is normally closed and the coil is operatively energized to open the fuel valve only in response to a predetermined voltage applied across the coil. This predetermined voltage is greater than the peak power supply voltage. Hence, if the voltage doubler is for any reason ineffective, the coil cannot open the fuel valve even though the coil may continue to be supplied with current from the power supply.

The electronic switch is rendered conductive only when combustion at the burner is sensed, or during a trial for ignition period. The electronic switch is preferably an SCR, or equivalent, and must function properly in order for the coil to be operatively energized. The SCR is oriented so that when it is rendered conductive, it permits energization of the coil only during alternate half cycles of the power supply.

The voltage doubler developes the predetermined voltage during half cycles in which the SCR blocks conduction through the coil. This voltage is applied to the coil during the half cycles when the SCR conducts to operatively energize the coil.

A "flywheel" capacitor is connected across the coil to provide energy for maintaining the coil operatively energized during alternate half cycles when the SCR is nonconductive. Should the SCR become short circuited, the voltage doubler arrangement is rendered ineffective to operatively energize the coil because the flywheel capacitor prevents establishment of the predetermined voltage across the coil. This prevents the fuel valve from being opened even if the SCR shorts out.

This control circuit is hence quite simple in construction, is constructed of few, relatively inexpensive components, and yet is not subject to failing in an unsafe manner.

The new system always fails safely since: (1) when any component of the voltage doubler fails, the predetermined voltage cannot be applied across the coil; (2) when the flywheel capacitor is short circuited or is opened, the coil does not have sufficient power supplied to it to open the valve; (3) when the SCR is short circuited the coil cannot be operatively energized.

In summary, when failure of any component in the circuit occurs, the maximum voltage across the coil is the peak voltage of the power supply. Since this voltage is insufficient to operatively energize the coil, the failure does not result in an unsafe condition.

A principal object of the present invention is the provision of a new and improved burner control system in which a fuel supply means is controlled by a simple, inexpensive, and extremely reliable control circuit.

Other objects and advantages of the present invention will become apparent from a consideration of the following detailed description thereof made with reference to the accompanying drawings which form a part of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a schematic burner control system embodying the present invention; and,

FIG. 2 is a circuit diagram of a portion of the system of FIG. 1.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to FIG. 1, a burner control system 10 is illustrated which includes a burner 11; a fuel supply system 12 for the burner including a gasline 13 and fuel valve V for opening and closing the line 13; and control circuitry 14 governing operation of the fuel supply system 12.

The fuel supply system 12 includes a solenoid coil 20 for operating the valve V from its closed position to its open position. The valve V is normally closed and is opened only when the solenoid is energized. The solenoid 20 is connected across terminals 21, 22 of a suitable electrical power source through a control switch 23. When the switch 23 is closed, the solenoid 20 is energized to open the valve V. When the switch 23 is open, the solenoid 20 is deenergized closing the valve V. The control circuitry 14 controls the operation of the switch 23.

The circuitry 14 is connected to the alternating current power source through a control switch 24, which is preferably thermostatically operated, and a power supply 25. When the switch 24 is closed, the circuitry 14 normally functions to close the switch 23 thus opening the fuel valve. When the switch 24 is open, the circuitry 14 closes the fuel valve.

Referring now to FIG. 2, the power supply 25 is shown as a conventional stepdown transformer having a primary winding 25*a* connected across an alternating current single phase power source through the switch 24, and a secondary winding 25*b* having end taps connected to conductors or lines L1, L2, respectively. The conductor L2 is grounded. For the purposes of this description, half cycles of the power supply during which the voltage level at the conductor L2 is positive with respect to the conductor L1 are referred to as positive half cycles. Half cycles of the power supply producing opposite polarities of the conductors are referred to as negative half cycles.

The circuitry 14 includes a trial for ignition circuit 26, a flame sensing circuit 27, and a fuel valve operating circuit 28 (FIG. 2). These circuits are all connected across the conductors L1, L2 for energization from the secondary winding 25*b*. When the switch 24 closes, the valve operating circuit 28 opens the fuel valve for a "trial for ignition" period. The extent of this trial period is controlled by the trial for ignition circuitry 26. During the trial period, the fuel valve is opened to enable a flame to be established at the burner.

If the fuel ignites, the flame-sensing circuit 27 conditions the circuitry 28 to maintain the fuel valve open so long as flame is present at the burner. When the flame is extinguished, or the control switch 24 opens, or the circuitry 28 malfunctions, the fuel valve closes to terminate fuel flow to the burner.

The valve operating circuitry 28 (FIG. 2) includes a relay circuit 30 connected across a voltage doubler 31 through an electronic switch 32.

The electronic switch 32 is preferably an SCr which is connected between the relay circuit 30 and the conductor L2. The SCR is poled to block conduction through the relay circuit 30 from the conductor L2 to the conductor L1 during positive half cycles of the power supply. The SCR includes a gate electrode 32*a* which is connected in a circuit with the trial for ignition circuit 26 and with the flame-sensing circuit 27. The trial for ignition and the flame-sensing circuits may be of any suitable construction and are not illustrated in detail; an example of such circuitry is shown in the aforementioned copending application, Ser. No. 780,650.

The flame-sensing unit 27 and the trial for ignition circuitry both function to produce 60 cycle pulses during negative half cycles of the power supply 25, under conditions described presently. When either of these units produce pulses, the pulses are transmitted to the gate electrode of the SCR. The SCR is then rendered conductive to complete a circuit through the relay circuit 30 for opening the fuel valve.

The trial for ignition circuitry 26 produces 60 cycle pulses for a limited period after the switch 24 closes. The unit 26 thus provides a limited period of time during which a flame may be established at the burner 11.

For the purposes of this description, the flame-sensing unit 27 is illustrated as utilizing the rectifying effect of a flame to electrical current. This unit produces 60 cycle pulses in response to the presence of flame between a flame-detecting electrode 27*a* and the electrically grounded burner 11. If flame is not established during the trial for ignition period, the pulses produced by the trial for ignition circuitry terminate and the flame sensing unit fails to produce pulses. The SCR is accordingly prevented from further conduction and the relay circuit is deenergized, closing the fuel valve. When flame is established during the trial for ignition period, the flame-sensing unit continues to produce pulses after the period and the SCR maintains the relay circuit conductive during negative half cycles so that the fuel valve is opened.

The relay circuit 30 includes a relay coil 55 and a resistor 56 connected in series with the coil 55. A capacitor 60 is connected in parallel with the relay coil 55 and the resistor 56 between junctions 61, 62.

The relay coil 55 cooperates with an armature 65 which is linked to the switch 23. When the coil 55 is operatively energized to "pull in" the armature 65, the switch 23 closes, thus opening the fuel valve. In order to "pull in" the armature 65 the coil 55 must be provided with a predetermined minimum applied voltage. When this predetermined voltage is applied across the coil, it is operatively energized to effect opening of the gas valve. If, on the other hand, current flows through the coil 55 but the applied voltage is less than the predetermined voltage, the relay, even though conducting, is not operatively energized; that is to say, the armature 65 cannot be pulled in.

The coil 55 is bistable in that once the coil is operatively energized to pull in the armature, the armature remains pulled in even though the voltage applied across the coil diminishes below the predetermined level. The resistor 56 has an impedance which is selected so that the relay coil 55 can only be operatively energized by a voltage applied across the junctions 61, 62 which is substantially greater than the peak power supply voltage; i.e., the peak voltage across the end taps of the secondary winding 25*b*. In other words, the coil 55 is only operatively energized in response to application of a predetermined voltage across it which is greater than the maximum power supply voltage which can be applied to it.

When the voltage applied across the coil 55 and resistor 56 is less than this predetermined voltage, the coil 55, even though conducting, is not operatively energized and the fuel valve cannot open.

The capacitor 60 is a "flywheel" capacitor which maintains the coil operatively energized during positive half cycles of the power supply. The capacitor 60 is charged when the relay coil is operatively energized through the SCR during negative half cycles. During positive half cycles the capacitor discharges through the coil to provide a sustaining current to maintain the armature pulled in.

The voltage doubler 31 developes voltages which are effective to operatively energize the relay coil 55 through the SCR 32. The voltage doubler 31 includes a diode 70 and a capacitor 71 which are connected to produce voltages having peak amplitudes of about twice the peak voltage amplitudes of the power supply during negative half cycles. The diode 70 is connected across the conductors L1, L2 between junctions 73, 74, and is poled to block current flow between the junctions during positive half cycles. The capacitor 71 is connected in the conductor L1 between the junction 73 and the secondary 25*b*. During positive half cycles the capacitor 71 charges through the diode so that at the end of each positive half cycle the plate 71*a* is positive with respect to the plate 71*b* by an amount substantially equal to the peak voltage of the power supply. During the succeeding negative half cycle the voltage level at the plate 71*b* rises and since the charge across a capacitor cannot change instantaneously, the voltage level from the plate 71*a* to the conductor L2 increases accordingly,. This level rises to about twice the peak voltage of the power supply.

The doubled voltage output of the doubler 31 is applied across the relay circuit 30 through the SCR 32. Hence, when the SCR is rendered conductive during negative half cycles, the voltage applied to the coil 55 is more than sufficient to operatively energize the coil. The capacitor 60 connected in parallel with the coil 55 and resistor 56 is charged to about the doubled voltage level since the voltage drop across the SCR is minimal. Hence, the capacitor 60 provides the predetermined voltage to the coil 55 as the capacitor discharges during positive half cycles and the armature remains pulled in.

FAILSAFE OPERATION

From the foregoing, it is apparent that the relay coil 55 is operatively energizable to open the fuel valve only when the SCR 32 is conductive and then only when a predetermined voltage, which is substantially greater than the peak voltage of the power supply, is applied across the relay circuit 30.

If any component of the circuitry 28 fails, the fuel valve cannot be opened and hence the circuit is failsafe. This is true even though the relay coil 55 might be conductive and the peak power supply voltage applied across the relay circuit 30.

If either the capacitor 71 or the diode 70 fails, the voltage doubler will not function and the relay coil 55 cannot be provided with an adequately high voltage to effect opening of the fuel valve. If the plates of the capacitor 71 are short circuited, that capacitor cannot be charged and the predetermined voltage will not be developed. If the capacitor 71 fails to open the conductor L1, the relay coil is disconnected from the power supply. Shorting of the diode 70 causes the both half cycles of the power supply current to appear across the capacitor 71 and prevents the doubler 31 from generating the requisite doubled voltage for operatively energizing the relay coil. If the diode 70 fails open, the capacitor 71 cannot be charged.

If the plates of the capacitor 60 are short circuited, the capacitor 60 can no longer function as a "flywheel" for the relay coil and the valve V will not open. The shorted capacitor also starves the coil 55 for current during negative half cycles. If the capacitor 60 fails open, its flywheeling function cannot be performed.

If the SCR 32 is shorted, it will no longer block current flow during positive half cycles. This charges the capacitor 60 to oppose operation of the voltage doubler and the predetermined voltage is not applied across the relay coil 55 during negative half cycles. If the SCR is open, the coil 55 is disconnected from the power supply.

The resistor 56 will only fail so as to open the circuit through the coil 55, and such failure precludes opening of the fuel valve.

While the relay circuit 30 is illustrated and described as including a relay coil 55, it should be apparent that the disclosed relay circuitry could be modified to provide a valve operating solenoid coil in place of the relay coil 55.

Although only a single embodiment of the invention has been illustrated and described in considerable detail, it will be appreciated that various modifications, adaptations and uses of this invention will become apparent to those skilled in this art and it is the intention to cover hereby all such modifications, adaptations and uses.

What is claimed is:

1. In a burner control system having a burner, and fuel supply means for controlling the supply of fuel to said burner, electrical circuitry controlling the fuel supply means comprising:

a. an alternating current electrical power supply;

b. a fuel supply controlling circuit comprising a voltage responsive element for effecting operation of said fuel supply means and having a first condition in which the fuel supply means prevents the supply of fuel to said burner and a second condition wherein said fuel supply means enables the supply of fuel to said burner;

c. said element operable to said second condition only in response to application of a predetermined voltage thereacross which is greater than the maximum peak voltage which can be applied thereacross directly from said power supply;

d. an electronic switch means connected in a series circuit with said element for completing and interrupting a circuit through said element in response to a detected condition; and,

e. a voltage increasing circuit connected to said power supply and having an output connected across said element and said electronic switch means, said voltage increasing circuit effective to produce an output voltage across said element which is in excess of the predetermined voltage;

f. said electronic means properly operating to complete a circuit across said output of said voltage increasing circuit through said voltage responsive element only during first alternate half cycles of said power supply in response to said detected condition and blocking conduction during all second alternate power supply half cycles and during first alternate power supply half cycles when said condition is not detected; and,

g. means connected to said voltage increasing circuit and said electronic switch means for rendering said voltage increasing circuit ineffective to produce said predetermined voltage when said electronic switch means is improperly conductive during second alternate power supply half cycles whereby said voltage responsive element is immediately operated to and maintained in said first condition regardless of detection of said condition.

2. A system as claimed in claim 1 and further including means for detecting combustion at said burner, said detecting means effective to operate said switch to complete said circuit through said element.

3. In combustion apparatus including burner control circuitry for opening a normally closed fuel valve in response to combustion at said burner, said circuitry comprising:

a. an electrical power supply;

b. a valve operating circuit comprising an operating element for effecting opening of said valve, said valve operating circuit effecting opening of said valve only in response to a predetermined applied voltage across said valve operating circuit which is of greater magnitude than the maximum voltage which can be applied thereacross directly from said power supply;

c. circuit means connected to said power supply and having an output connected to said valve operating circuit for applying at least said predetermined voltage across said valve operating circuit;

d. combustion responsive switching means connected in series with said element, said switching means rendered conductive in response to detection of combustion whereby said valve is maintained open by operation of said valve operating circuit, said switching means remaining nonconductive at all other times during proper operation thereof; and,

e. means cooperating with said switching means and said circuit means for disabling said circuit means from providing said predetermined voltage when said switching means is improperly conductive whereby said operating element is immediately rendered ineffective to open said valve even though said valve operating circuit is conductive.

4. A system as claimed in claim 3 wherein said power supply produces alternating current and said circuit means comprises a voltage doubler connected to said power supply and effective to provide said predetermined voltage to said element.

5. In a burner control system having a burner, and fuel supply means operable to permit and prevent the supply of fuel to said burner, circuitry for controlling operation of said fuel supply means comprising:

a. an electric power supply;

b. a voltage responsive coil element having a first condition in which said fuel supply means prevents the supply of fuel to said burner and a second condition for enabling said fuel supply means to permit fuel flow to said burner;

c. said voltage-responsive coil element operated to said second condition only in response to a predetermined applied voltage greater than the power supply voltage;

d. circuit means for applying said predetermined voltage to said coil element in response to a sensed condition, said circuit means comprising an electronic switch connected between said power supply and said coil for blocking current flow in one direction and rendered conductive to enable current flow in said coil in an opposite direction; and,

e. a capacitor connected in parallel with said coil said capacitor charging when said switch is conductive and discharging when said switch blocks current flow to said element.

6. In a burner control system having a burner, and fuel supply means for controlling the supply of fuel to said burner, electrical circuitry controlling the fuel supply means comprising:

a. an alternating current electrical power supply;

b. a fuel supply controlling circuit comprising a voltage-responsive element for effecting operation of said fuel supply means and having a first condition in which the fuel supply means prevents the supply of fuel to said burner and a second condition wherein said fuel supply means enables the supply of fuel to said burner;

c. said element operable to said second condition only in response to a predetermined voltage thereacross which is greater than the maximum voltage which could be applied thereacross directly from said power supply, said voltage-responsive element being, at all other times, in said first condition wherein said fuel supply means prevents supply of fuel to said burner;

d. an electronic switch means connected in a circuit with said element for completing and interrupting a circuit through said element, said switch means capable of conduction only during first alternate half cycles of said power supply when operating properly;

e. a voltage increasing circuit connected to said power supply and across said element and said switch means, and voltage increasing circuit effective to produce an output voltage across said element which is in excess of the predetermined voltage;

f. combustion detecting means at said burner, said detecting means effective to operate said switch means to complete said circuit through said element; and,

g. means cooperating with said switch means and said voltage increasing means for rendering said voltage increasing means ineffective to provide said predetermined voltage across said element when said switch means is improperly conductive during second alternate power supply half cycles.

7. In a burner control system having a burner, and fuel supply means for controlling the supply of fuel to said burner, electrical circuitry controlling the fuel supply means comprising:

a. an alternating current electrical power supply;

b. a fuel supply controlling circuit comprising a voltage-responsive element for effecting operation of said fuel supply means and having a first condition in which the fuel supply means prevents the supply of fuel to said burner and a second condition wherein said fuel supply means enables the supply of fuel to said burner;

c. said element operable to said second condition only in response to a predetermined voltage applied across said fuel supply controlling circuit which is greater than the maximum voltage which can be applied thereacross directly from said power supply;

d. an electronic switch means connected in a circuit with said element for completing and interrupting a circuit through said element, said switch means being capable of completing said circuit during first alternate half cycles of said power supply and blocking current to said element during second alternate half cycles when properly operating;

e. a voltage increasing circuit connected to said power supply and across said fuel supply controlling circuit and said switch means, said voltage increasing circuit effective to produce an output voltage across said fuel supply controlling circuit which is in excess of the predetermined voltage; and,

f. means connecting said switch means and said voltage increasing circuit for disabling said voltage increasing circuit when said switch means is improperly conductive during second alternate power supply half cycles, said voltage increasing circuit thereby rendered ineffective to produce said predetermined voltage to prevent fuel supply to the burner so long as said switch means is improperly conductive.

8. In a burner control system having a burner, and fuel supply means for controlling the supply of fuel to said burner, electrical circuitry controlling the fuel supply means comprising:

a. an alternating current electrical power supply;

b. a fuel supply controlling circuit comprising a voltage-responsive element for effecting operation of said fuel supply means and having a first condition in which the fuel supply means prevents the supply of fuel to said burner and a second condition wherein said fuel supply means enables the supply of fuel to said burner;

c. said element operable to said second condition only in response to a predetermined voltage thereacross which is greater than the maximum voltage which can be applied thereacross directly from said power supply;

d. an electronic switch means having a control electrode, said electronic switch capable of conduction only during first alternate half cycles of said power supply and blocking conduction during second alternate power supply half cycles;

e. a voltage doubling circuit connected to said power supply and across said fuel supply controlling circuit and said switch means, said doubling circuit effective to produce an output voltage across said element which is in excess of the predetermined voltage;

f. combustion responsive circuitry for providing signals to said control electrode for rendering said switch conductive during said first alternate half cycles, said combustion responsive circuitry effective to provide said signals only in response to combustion at said burner; and,

g. means cooperating with said electronic switch for preventing said voltage doubler circuit from producing said predetermined voltage when said electronic switch is improperly conductive during second alternate power supply half cycles, said voltage responsive element thereupon being operated to its first condition so that fuel supply to said burner is prevented.

9. In a burner control system having a burner, and fuel supply means for controlling the supply of fuel to said burner, electrical circuitry controlling the fuel supply means comprising:

a. an alternating current electrical power supply;

b. a fuel supply controlling circuit including a voltage-responsive coil for effecting operation of said fuel supply means and having a first condition in which the fuel supply means prevents the supply of fuel to said burner and a second condition wherein said fuel supply means enables the supply of fuel to said burner;

c. said coil operable to said second condition only in response to a predetermined voltage thereacross which is greater than the maximum voltage which can be applied thereacross by said power supply;

d. an electronic switch means connected in a circuit with said coil for completing and interrupting a circuit through said coil, said switch means completing said circuit during first alternate half cycles of said power supply and blocking current to said coil during second alternate half cycles.

e. a voltage doubling circuit connected to said power supply and across said coil and said switch means, said doubling circuit effective to produce an output voltage across said coil which is in excess of the predetermined voltage; and,

f. a capacitor connected in parallel with said coil, said capacitor charging to at least said predetermined voltage through said switch means when said coil is in the second condition and discharging through said coil during said second alternate half cycles of said power supply to maintain said coil in said second condition when said switch means blocks conduction.

10. The system claimed in claim **1** wherein said means for rendering said voltage increasing circuit comprises a capacitor connected in parallel with said voltage-responsive element.

11. The system claimed in claim **10** wherein said voltage increasing circuit comprises a voltage doubling circuit including a capacitor connected in series with said fuel supply controlling circuit and a diode connected in parallel with said fuel supply controlling circuit, said doubler effective to provide a pulsating DC voltage to said fuel supply controlling circuit which is greater than the peak power supply voltage.

12. The system claimed in claim **10** wherein said voltage-responsive element comprises a coil and said fuel controlling circuit further comprises a resistor connected in series with said coil to control the voltage drop across said coil when said electronic switch means conducts.

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