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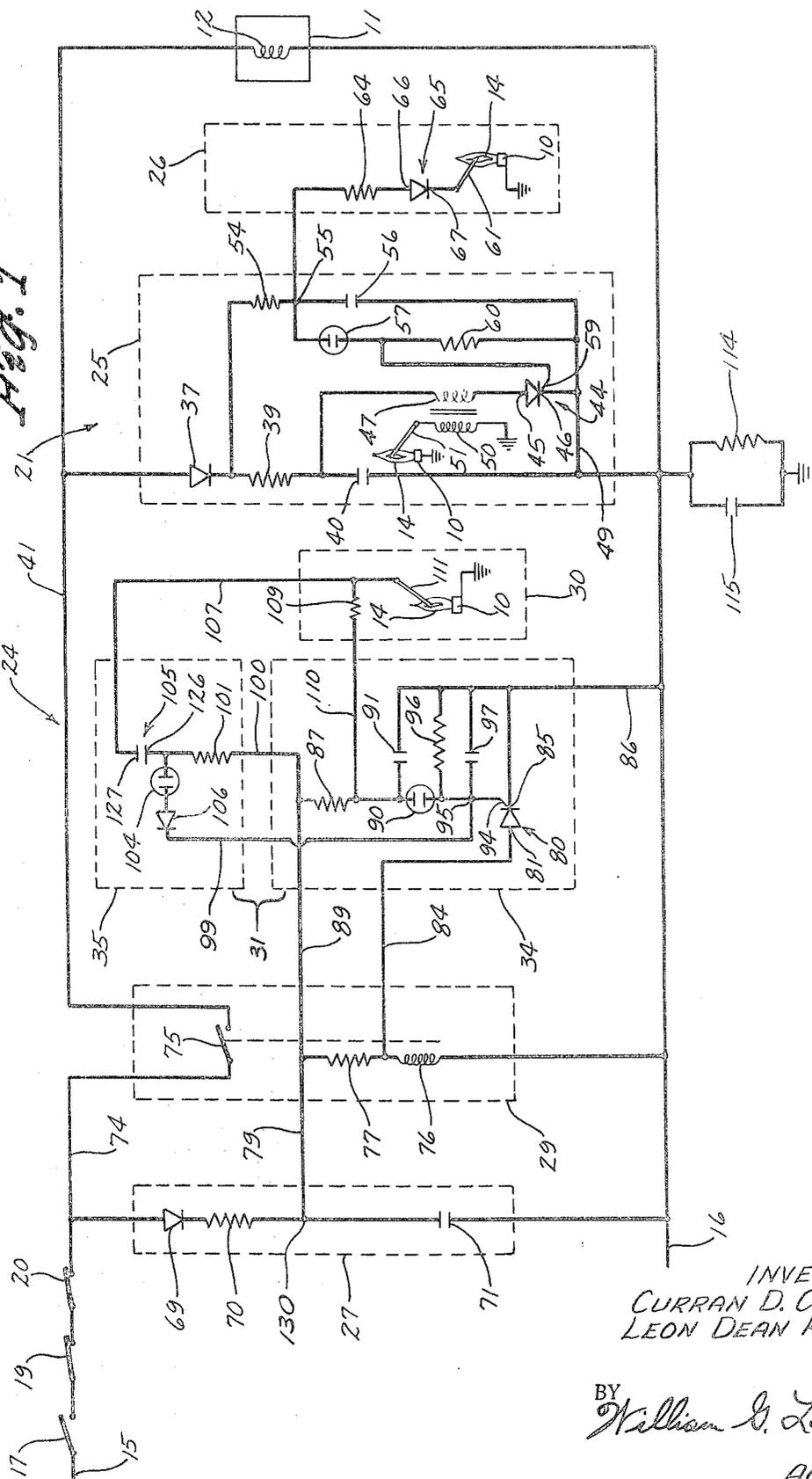
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CONTROL SYSTEM FOR A FUEL BURNER

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Fig. 1



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CONTROL SYSTEM FOR A FUEL BURNER

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ABSTRACT OF THE DISCLOSURE

A control system operable for initiating flow of fuel, producing an ignition spark, sensing presence of flame, extinguishing the spark in the presence of the flame, and interrupting flow of fuel in the prolonged absence of flame. The control includes a solid state switching means and is operable for responding to the presence of a short of the flame rod to the burner as well as being responsive to the prolonged absence of flame.

BACKGROUND OF THE INVENTION

Field of the invention

This invention is related to a fuel burner control and more particularly to a control system including a solid state circuit responsive to predetermined conditions at the fuel burner for controlling energization of a fuel burner valve.

Description of the prior art

Prior patents in the area of burner controls indicate a continuing search for improved safety controls for fuel burners. The use of flame rods, photocells, and thermosensors as flame sensing means in circuit with electronic tubes are shown. These prior controls, however, are subject to various disadvantages and compromises associated with the use of the electronic tubes, and with the flame sensors. The electronic tubes, for example, have disadvantages relating to the required warmup and to the excessive heat buildup and power losses. As to the flame sensing, photocells are not capable of detecting certain flames and thermosensors require excessive operating delays.

SUMMARY OF THE INVENTION

It is an object of the instant invention to provide an improved fuel burner control system.

It is a further object of the instant invention to provide an improved solid state circuit for a fuel burner control system.

It is a further object of the instant invention to provide an improved fail-safe fuel burner control system responsive to predetermined conditions at the fuel burner.

It is a further object of the instant invention to provide an improved fuel burner control system responsive to a flame condition and to malfunction of the flame sensing circuit.

It is a further object to provide an improved fuel burner control system operable to provide improved spark ignition and flame sensing.

It is yet a further object of the instant invention to provide an improved fuel burner control system including spark ignition, direct flame sensing, delayed fuel shut-off, and failsafe protection against malfunction of the flame sensor circuit.

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The instant invention achieves these objects in a control system for a fuel burner with a plurality of cooperative circuits and components including flame sensing means and a solid state switching device responsive to predetermined conditions at the fuel burner for controlling supply of fuel to the burner. A preferred embodiment includes flame rod sensing, electronic ignition, and a shunt detector in addition to the solid state switching means.

Operation of the device and further objects and advantages thereof will become evident as the description proceeds and from an examination of the accompanying drawings which illustrate a preferred embodiment of the invention and in which similar numerals refer to similar parts throughout the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic electrical circuit showing an improved control for a fuel burner and comprising a preferred embodiment of the instant invention;

FIG. 2 is a schematic circuit for a fuel burner system including an alternate embodiment of the instant invention;

FIG. 3 is a fragmentary view showing a portion of a fuel burner nozzle and further showing a portion of the flame sensing means of the instant invention;

FIG. 4 is a fragmentary side view of the burner nozzle and flame sensing means shown in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown a schematic electrical circuit operable for controlling a fuel burner 10 by effecting selective energization and de-energization of a fuel valve 11 including a coil 12. One example of an apparatus including a fuel burner system to which this control is applicable is a clothes dryer. A specific fuel burner for such an appliance is shown in FIGS. 3 and 4. The burner 10 is shown schematically in FIGS. 1 and 2. A flame 14 is shown with the burner and is grounded to the cabinet or chassis of the machine through the burner 10 itself. The schematic representation of the flame 14 and grounded burner 10 is shown at three locations in FIG. 1 but this multiple showing is for convenience in the circuit rather than to indicate the presence of multiple burners.

The circuit of FIG. 1 is supplied with 115 volt A.C. power across input lines 15 and 16 with line 16 being the neutral line at earth ground potential. A manually operable on-off switch 17 is provided in the circuit and is selectively energizable to initiate operation of the apparatus. In addition to the on-off switch 17 in power line 15, two normally closed control thermostats 19 and 20 are provided in the circuit for effective clothes drying operation. A cycling thermostat 19 controls the temperature to a selected range and a high limit thermostat 20 de-energizes the circuit upon reaching a safe maximum high temperature level. A fuel burner valve 11 includes a solenoid coil 12 which is effectively connected between lines 15 and 16 and is energizable for effecting opening of the valve. An additional coil may be provided to establish alternate means for effecting operation of the valve in the interest of safety to insure that the valve operates satisfactorily.

In addition to the fuel valve 11, the major portions of the circuit of FIG. 1 are the ignition means 21 and the

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valve and ignition control means indicated generally as 24. The ignition means 21 includes a spark producing network 25 and flame sensing means 26. The valve and ignition control means 24 generally comprises a D.C. power supply 27, a first control means 29, a flame detector means 30 and a master control network 31 including a second control means 34 and a shunt detector means 35. These major portions of the control circuit of FIG. 1 will be described in greater detail hereinafter.

The spark producing network 25 includes a spark generating circuit comprising a half-wave power supply having a rectifier 37, resistor 39, and capacitor 40 connected in series between lines 41 and 16. The spark generating circuit further includes a silicon controlled rectifier 44 having an anode 45 connected to one side of the primary winding 47 of a transformer and a cathode 46 connected to conductor 49. The other side of the primary winding 47 is connected to the resistor 39 and spark capacitor 40. The secondary winding 50 of the transformer has one side connected to an electrode or ignitor rod 51 positioned adjacent the grounded burner 10 and the opposite side connected to chassis ground.

The spark producing network 25 further comprises a spark trigger circuit operable for actuating the spark generating circuit. The spark trigger circuit includes a resistor 54 connected to the D.C. half-wave power supply between the rectifier 37 and the resistor 39. The other side of the resistor 54 is connected through junction 55 to other components of the spark trigger circuit including capacitor 56 and a discharge device in the form of a neon tube 57. The other side of the neon tube 57 is connected to the gate 59 of the SCR 44 and to a resistor 60. The opposite sides of the resistor 60 and spark trigger capacitor 56 are connected to neutral line 16 through conductor 49.

The flame sensing means 26 comprises a flame rod 61 and a circuit including a resistor 64 connected to the junction 55 and a diode 65 having an anode 66 connected to the resistor 64 and a cathode 67 connected to the flame rod 61. The flame rod 61 is positioned adjacent the fuel burner 10 for contact and envelopment by the flame 14 for conduction of a current through the flame rod 61 and through the flame 14 to the grounded burner 10. The diode 65 will permit current to flow through the flame 14 only in the direction from the flame rod 61 toward the burner 10.

The portion of FIG. 1 referred to generally as the valve and ignition control means 24 includes a D.C. power supply circuit portion 27 composed of a current rectifying diode 69, a resistor 70, and a capacitor 71 connected in series between lines 74 and 16.

A first control means 29 is connected to the D.C. power supply 27 and includes a switch 75 between lines 74 and 41 for controlling A.C. current to the ignition means 21 and the fuel valve 11. In the preferred embodiment shown in FIG. 1, this switch 75 is in the form of a reed switch controlled by a reed coil 76. The coil 76 is connected to the D.C. power supply 27 through the resistor 77 and conductor 79. The other side of the reed coil 76 is connected to line 16.

The master control network 31 is made up of the second control means 34 and a shunt detector means 35. The second control means 34 includes a solid state switching device in the form of a silicon controlled rectifier 80 that is the basic, or main basic, component of the master control network 31. The anode 81 of the silicon controlled rectifier, or SCR 80, is connected to the first control means 29 at a point between the resistor 77 and the reed coil 76 through a conductor 84. The cathode 85 of the SCR 80 is connected to line 16 through conductor 86 and thus the anode to cathode path of the SCR 80 is connected in parallel to the reed coil 76 of the first control means 29.

The second control means 34 further includes an actuation circuit for actuating the SCR 80 from non-con-

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duction to conduction and comprising a resistor 87 connected to the first control means 29 by conductor line 89 and then to the D.C. power supply 27 by the conductor 79. The other side of the resistor 87 in the actuation circuit is connected to a discharge device in the form of a neon tube 90 and to a capacitor 91. The other side of the neon tube 90 is connected to the gate 94 of the SCR 80 through a junction 95. A resistor 96 is connected to the junction 95 and to line 86. The other sides of the actuation capacitor 91 and resistor 96 are connected to line 16 through the conductor line 86. A filter capacitor 97 is connected between the junction 95 and the conductor 86.

The shunt detector means 35 is associated with the second control means 34 by circuit connections therebetween through the pair of conductors 99 and 100 and includes a resistor 101, connected to the conductor 100 on one side and to one side of the neon tube 104 and capacitor 105 at its other side. The neon tube 104 is connected in turn at its other side to a diode 106 that is connected by conductor 99 and by the junction 95 to the gate 94 of the SCR 80. The other side of the capacitor 105 is connected by conductor 107 to the flame detector means 30. In order to distinguish from other capacitors in the circuit of FIG. 1, the capacitor 105 will be referred to as a shunt capacitor 105. It does not operate as a shunt but is used in the shunt detector means 35.

The flame detector means 30 includes a flame detector circuit comprising a resistor 109 connected by a conductor 110 to the actuation circuit 34 at the common connection of one side of the resistor 87, actuation capacitor 91, and neon tube 90. The flame detector means 30 further includes an electrode or flame rod 111 positioned juxtaposed to the burner 10 for contact by the flame 14 and completion of a circuit to ground through the flame and the grounded burner.

The components of the second control means 34, the shunt detector means 35, and the flame detector means 30 are cooperable to provide a plurality of circuits operable for effecting selective actuation of the SCR 80 to conductive condition depending upon predetermined conditions at the fuel burner 10. A first circuit means, operable for conducting actuation current to the SCR 80 at a level below that sufficient to effect a change in the SCR 80 from the non-conductive to the conductive condition, includes the actuation capacitor 91, conductor 110, resistor 109, conductor 107, shunt capacitor 105, neon tube 104, diode 106, conductor 99, junction 95, and the gate 94 and cathode 85 of the SCR 80. This circuit is initially made and indicates an absence of a short of the flame rod 111 to the burner 10.

A second circuit means is operable for conducting a higher current to the SCR 80 when the flame rod 111 is shunted to substantially ground potential by being shorted across the flame gap to the grounded burner 10. The second circuit means includes a conductive path from the grounded burner 10 through the flame rod 111, conductor 107, shunt capacitor 105, neon tube 104, diode 106 conductor line 99, junction 95 the gate 94 and cathode 85 of the SCR 80 to the neutral line 16 through conductor 86 which is at substantially ground potential and thus forms a closed loop through the grounded burner 10. This circuit is made when the flame rod 111 is shorted to the burner 10 and conducts sufficient current to the gate 94 of the SCR 80 to actuate it to a conductive condition. The increased current is possible since the current limiting resistor 109 is excluded from the circuit by conduction across the effectively eliminated flame gap.

A third circuit means comprises the actuation capacitor 91, the neon tube 90, junction 95, the gate 94 and cathode 85 of the SCR 80 and is operable for conducting sufficient current to the gate 94 of the SCR 80 for effecting a change in the SCR 80 from a non-conductive condition to the conductive condition after a predetermined

time delay following the sensing of the absence of flame 14 at the burner 10 and the absence of a shunt of said flame rod 111 to said burner 10. The operation of these circuits therefore provides fail-safe operation of the fuel burner.

To further insure fail-safe operation in the face of combined malfunctions, a resistor 114 and a capacitor 115 are connected in parallel to each other and connected between the neutral line 16 and the apparatus cabinet or chassis. If the cabinet or chassis is properly grounded at time of installation, the neutral line 16 and the chassis, to which the burners 10 are grounded, will all be at earth ground potential. If, however, due to improper installation, the chassis is not earth ground, there is no external path from the chassis-grounded burners 10. This current path is required to prevent the charging of actuation capacitor 91 in the presence of flame 14 at the burner 10. The grounding resistor 114 is connected between the neutral line 16 and the chassis to insure a proper grounding of the chassis. A high resistance is used to limit current flow through the line 16 to chassis ground in the event the line plug is reversed and the neutral line 16 becomes the hot line.

The capacitor 115 is added to insure proper operation in the event of the combined failure including the lack of an earth ground to the chassis and the presence of a short of flame rod 111 to the burner 10 as will be more fully explained hereinafter.

Referring now to FIGS. 3 and 4, there is shown a preferred construction of the flame sensors, or electrodes or more specifically, the flame rods 61 and 111 and ignitor rod 51 mounted adjacent the end of a fuel burner apparatus 10. The flame rods 61 and 111, associated with the circuitry of FIG. 1, are the two longer electrodes as best shown in FIG. 4. The flame rods 61 and 111 are positioned for envelopment by the flame as the burning of the fuel takes place. The ignitor rod 51 is positioned below the flame rods and the ends of all the electrodes are within approximately $\frac{1}{4}$ inch to $\frac{3}{16}$ inch of the closest part of the grounded burner 10. All three electrodes are stainless steel rods and are mounted in a ceramic holder 116 having the electrodes extending from the holder 116 in one direction and having wires 117 connected to the electrodes 51, 61, and 111 extending from the opposite side of the holder 116 and being connected to the circuitry as shown in FIG. 1. Because of their rigidity and short length, there is little chance the electrodes will become shorted to any part of the grounded burner 10, but the circuit is operable for sensing such a failure. The electrode holder 116 is secured to a first bracket 119 by a threaded member 120 and the first bracket is secured in turn to a second bracket 121 mounted on the fuel burner nozzle 124. The second bracket 121 also serves to mount the fuel burner nozzle 124 within the fuel burning apparatus, such as to the base of a dryer. Fixed to the flame port end of the burner nozzle 124 is a flame deflector 125.

By way of example, and not for purposes of limitation, a specific reduction to practice of the preferred embodiment shown in FIG. 1 included resistors and capacitors having specific values as shown in the following table:

RESISTORS (IN OHMS)

FIG. 1 numeral:	Ohms
39	560
54	47,000,000
60	1000
64	680,000
70	560
77	15,000
87	30,000,000
96	1000
101	3,300,000
109	680,000
114	1,000,000

CAPACITORS (IN MICROFARADS WITH VOLTAGE RATING)

FIG. 1 numeral:	Microfarads
40	(200 volts) -- 20
56	(100 volts) -- .005
71	(150 volts) -- 10
91	(100 volts) -- .47
97	(100 volts) -- .1
105	(150 volts) -- .1
115	(200 volts) -- .005

In general, the control system of FIG. 1 is operable for achieving the following: (1) Producing an electric spark for igniting gas from a burner; and (2) Sensing the presence of the flame immediately following ignition and de-energizing the spark-producing means; or (3) Sensing the prolonged absence of a flame, realize the absence of the flame as an abnormal condition and continuing the production of a spark during a predetermined time period followed by a complete valve shutdown in the continued absence of a flame.

This system is operable for reducing the period of sparking to a minimum and thus minimizing the interference that is imposed on the power lines by the production of a spark. In addition, since this control uses flame rods 61 and 111 as flame sensors, they are not temperature sensitive and thus can be preset to cause a system shutdown in less than 25 seconds and thereby avoid the continued excessive flow of unburned gas during a longer period of time which has heretofore been considered acceptable though recognized as undesirable.

A more complete and thorough understanding of the invention will be achieved through a consideration of the sequence and operation of the circuit. Upon closure of the manually operable on-off switch 17, a circuit is completed from power line 15 through the on-off switch 17 and the normally closed thermostats 19, 20 to effect energization of the valve and ignition control means 24 and, upon closing of the reed switch 75, energization of the valve means 11 and ignition means 21. The reed switch 75 is closed substantially immediately upon closing of the on-off switch 17 by virtue of an energizing circuit to the reed coil 76 extending from the power line 15 through the closed on-off switch 17, and the normally closed thermostats 19, 20, through the diode 69 and resistor 70 of the D.C. power supply 27 for charging the capacitor 71, and then through the conductor line 79 and resistor 77 to one side of the reed coil 76. The other side of the reed coil 76 is connected to neutral line 16.

Closure of the reed switch 75 completes a circuit from power line 15 to the ignition means 21 and to the fuel valve 11. Energization of the fuel valve coil 12 opens the fuel valve 11 to permit flow of fuel to the burner 10.

Completion of the circuit to the ignition means 21 completes a circuit to the half-wave power supply including the diode 37, resistor 39 and spark capacitor 40 for charging the capacitor 40 toward the peak voltage of power line 41. The charge on the spark capacitor 40 will be operable for producing a spark upon actuation of the SCR 44 to a conductive condition. Upon completion of the circuit to the ignition means D.C. power supply, a circuit is also completed for causing a small current to flow through the diode 37 and resistor 54 for charging the spark trigger capacitor 56. Capacitor 56 will charge until it reaches a D.C. potential sufficient to cause the neon tube 57 to switch from a non-conductive state to a conductive state. When the neon tube 57 conducts, the spark trigger capacitor 56 is discharged through the neon tube 57 and through the parallel combination of resistor 60 and the gate 59 to cathode 46 of the SCR which up to this point has been in a non-conductive state. When sufficient voltage is impressed across the gate 59 of the SCR 44 and sufficient current is flowing through it, the SCR 44 will switch to a conductive state and permit spark capacitor

40 to discharge through the anode 45 to cathode 46 of SCR 44 and through the primary winding 47 of the transformer.

As the discharge current passes through the primary winding 47 of the transformer, a field is produced which because of the high turns ratio of the primary and secondary windings 47 and 50 causes a high voltage to be developed across the transformer secondary winding 50. This voltage is high enough to cause a spark to be produced at the ignitor rod 51 and to bridge the air gap to the grounded gas burner 10 which is effectively connected to the other side of the secondary winding 50 by a chassis ground. If the fuel valve 11 is operating properly and if unburned gas is present at the burner 10, it will be ignited by the spark.

If the initial spark does not ignite the gas, the ignition cycle will be repeated until the gas is ignited or until a preset time elapses. At the end of each spark, the discharge current from the spark capacitor 40 falls below the latching current requirement of the SCR 44 causing the SCR to become non-conductive. This action then permits the spark capacitor 40 to again charge to the peak line voltage of 41 and await the charging of the spark trigger capacitor 56 to again reach the ignition voltage of the neon tube 57 which will then re-ignite the neon tube for gating the SCR 44 and triggering the spark discharge. Each spark will be produced in less than one second and will continue in the absence of flame for the predetermined time period.

Flame rod 61 is a conductive electrode which is positioned near the burner 10 in such a manner that it will be inside the flame 14 when the burner ignites. As previously indicated, the flame rod 61 is connected to the spark trigger circuit through a resistor 64 and a diode 65. The flame rod 61 and the conductive properties of the flame 14 are utilized to terminate the ignition cycle immediately following burner ignition. The flame rod 61 acts as a flame sensor and forms with the flame 14, a closed loop path across the spark trigger capacitor 56 to prevent a spark when ignition has occurred and flame is present. When the chassis ground is also earth ground, the closed loop path extends from the top of the spark trigger capacitor 56 through resistor 64 and diode 65, through the flame rod 61 and flame 14 to ground, and then through the neutral line 16 and conductor 49 to the lower side of capacitor 56. When the chassis ground is not earth ground, the resistor 114 provides a chassis ground path to close the loop around the capacitor 56.

Spark production is terminated as soon as possible after the ignition has been accomplished because of the desirability of preventing further electrical interference resulting from the spark ignition. As previously indicated, a spark at the ignitor rod 51 cannot be produced unless sufficient D.C. voltage is present across the spark trigger capacitor 56 to cause the neon tube 57 to discharge and thereby cause the SCR 44 to conduct. The flame rod 61 is connected to the capacitor 56 through the resistor 64 and rectifier 65. Since the flame 14 is conductive, a closed loop path across capacitor 56 is completed through resistor 64, diode 65, flame rod 61, and flame 14, the grounded burner 10 and through the chassis ground to the neutral line 16. This closed loop discharge path in conjunction with the resistor 54 creates a voltage divider network which causes the voltage at the junction point 55 to remain well below the ignition voltage of the neon tube 57, thus preventing the neon tube 57 for igniting and triggering the SCR 44. Or stated differently, the current is allowed to leak across the flame 14 and thereby prevents the charging of the capacitor 56 to a voltage sufficient to fire the neon tube 57.

A further factor of safety is provided in that the values of the components for the D.C. power supply 27 and the first control means are selected to insure that when the voltage level across lines 15 and 16 is sufficient to close the reed switch 75 there will be sufficient voltage to the

spark capacitor 40 to produce an acceptable spark at the burner 10.

Should the fuel fail to ignite after a prolonged period of time, it is necessary that the fuel valve 11 be closed and that the ignition means 21 be de-energized. This is the function of the master control network 31 that has been energized substantially immediately upon closing of the on-off switch 17. Upon energization of the control system, the actuation capacitor 91 begins to charge. The value of the capacitor 91, however, is chosen so that the charge accumulates relatively slowly and will charge to the ignition voltage of the neon tube 90 in the actuation circuit only after a predetermined length of time.

Note that a flame detector means 30 comprising a flame rod 111 and a flame detector circuit including the resistor 109 is connected to the junction of the resistor 87, the actuation capacitor 91, and neon tube 90 to form a closed loop around the actuation capacitor 91 in the same manner as the flame sensing means 26 associated with the ignition means. The closed loop includes conductor 110, resistor 109, flame rod 111, the flame 14, the grounded burner 10 and the chassis ground to the neutral line 16 which is in turn connected to the capacitor 91 through the conductor 86. The flame 14 envelops the flame rod 111 and forms the closed loop path around the actuation capacitor 91 to prevent it from charging to the ignition point of the neon tube 90 whenever a flame is present at the burner 10. Should there be no flame at the burner, the capacitor 91 will charge slowly by a circuit extending from the junction 130 of power supply 27 through the diode 69, resistor 70, conductors 79 and 89, and resistor 87. Upon reaching a given breakdown voltage, the actuation capacitor 91 will discharge through the neon tube 90 and through the gate 94 and cathode 85 of the SCR 80. The SCR 80, having sufficient voltage impressed upon it and carrying sufficient current from the gate 94 to the cathode 85, will change from a normally non-conductive state to a conductive state to permit the flow of current from the anode 81 to the cathode 85. Conduction of current across the SCR 80 will effectively shunt and cause de-energization of the reed coil 76 for opening of the reed switch 75. Upon opening of the reed switch 75, the gas valve 11 and ignition means 21 are de-energized. The resistor 77 is sufficiently small and capacitor 71 sufficiently large to permit the latching current to continue to flow through the SCR 80 and cause it to remain in a conducting state until the circuit is broken.

The delayed shut-off control is operable after a given period of time, such as approximately 10 seconds in the preferred embodiment. This time delay between the sensing of the absence of the flame and the actual shut-down of the gas valve 11 and ignition means 21 permits adequate time for the air to be purged from the gas line, for example, and for the gas to be re-ignited if such is possible. The time delay thus avoids shutdown in case of momentary malfunctions.

The preceding discussion covered operation of the control for controlling the valve means 11 and ignition means 21 in the case of relatively normal failures, such as failure of the gas supply system, failure of the gas valve to open, or failure of the spark generator circuit to produce a spark for igniting the gas. There also exists other possible, but more improbable, failures relating to the shorting of the electrodes or to the lack of grounding of the appliance which might take place in an apparatus utilizing a control circuit similar to that shown in FIG. 1. More specifically, these failures include the shorting of the flame rods 61 and 111 together, the shorting of flame rods 61 or 111 to ground, and the shorting of various combinations of the flame rods 61 or 111 to the ignitor rod 51 or to ground. The circuit shown in FIG. 1 is designed to fail-safe in the event that one of these failures should take place even though such a failure is unlikely because of the design and location of the electrodes.

One possible failure associated with the flame rods is that of one of the flame rods contacting or becoming shorted to the other flame rod. Should this condition occur, there are two fail-safe procedures. On the one hand, because of the positioning of the rectifier **65** in series with flame rod **61**, the spark trigger capacitor **36** will be effectively placed in parallel with actuation capacitor **91** and current flow through **54** will charge them both when the flame rods are shorted to each other. The current path is as follows: A common charging path is taken up to the junction point **55** following the resistor **54** and then the spark trigger capacitor **56** is charged by a circuit that extends from junction point **55** to neutral line **16** through conductor **49**. In parallel with that, actuation capacitor **91** is charged by a circuit extending from the junction point **55** through resistor **64**, diode **65**, flame rod **61** contacting flame rod **111** and through resistor **109**, conductor **110**, actuation capacitor **91**, and conductor **86** to neutral line **16**. The parallel connected capacitors will be charged to a given voltage by this circuit. Actuation capacitor **91**, however, will be further charged by current flow through resistor **87**, which because of rectifier **65** current is prevented from flowing toward the spark trigger capacitor **56**. The actuation capacitor **91** charges toward the ignition point of neon tube **90** and when it reaches that point the SCR **80** will be triggered and the system will be shut down.

On the other hand, since spark trigger capacitor **56** is in parallel with actuation capacitor **91**, the voltage across capacitor **56** does not rapidly rise to the ignition point of neon tube **57** as under normal operations; however, if the ignition voltage of neon tube **57** is sufficiently lower than that of neon tube **90**, a spark will be generated before actuation capacitor **91** can fire neon tube **90** to shut down the system. The gas will ignite and sensor **111** in the flame will cause the voltage across actuation capacitor **91** to decrease and a near normal operation will take place. This operation, therefore, will occur if neon tubes are selected and installed so that the ignition voltage of neon tubes are selected and installed so that the ignition voltage of neon tube **57** is lower than that of neon tube **90**. Diode **65** provides isolation between the spark producing network **21** and the second control means **34** if flame rod **61** is shorted to flame rod **111** and if neon tube **57** ignites before neon tube **90** so that the charge on capacitor **91** will not be affected by the rapid discharge of capacitor **56**.

Another possible failure, though improbable, would be that of the flame rod **111** becoming shorted to ground through the grounded burner **10** or through other foreign objects. A shunt detector circuit **35** is associated with the flame detector means **30** and the second control means **34** to sense such a failure and to insure fail-safe shutdown of the ignition means **21** and fuel valve **11**. This shunt detector circuit **35** while being operable for detecting such a failure must also operate in such a manner as to permit satisfactory operation of the control when the flame rod **111** is not shorted to ground. For example, when the on-off switch **17** is closed and flame rod **111** is not shorted to ground, the circuit is completed for charging shunt capacitor **105** and extends from junction **130** through diode **69**, resistor **70**, conductors **79** and **89**, and resistor **101** to one side of the shunt capacitor **105**. The other side of the capacitor **105** is connected by the conductor **107** to resistor **109** that is connected in turn to actuation capacitor **91**. The other side of capacitor **91** is connected to neutral line **16** through conductor **86**. The shunt capacitor **105** becomes charged very rapidly and establishes what was previously indicated as the first circuit and includes capacitor **105**, neon tube **104**, diode **106**, conductor **99**, the gate **94** and cathode **85** of the SCR **80**, conductor **86** to actuation capacitor **91** and through conductor **110**, resistor **109** and conductor **107** to the other side of the capacitor **105**. The neon tube **104** glows but there is insufficient triggering current flowing to the gate **94** of the

SCR **80** because of the current limiting resistor **109** in the circuit.

Initially, because of the relative capacitances and because of the series connection of shunt capacitor **105** with respect to actuation capacitor **91**, capacitor **105** charges to a much higher voltage than capacitor **91**; however, because of charging current through the separate path through conductors **79** and **89** and resistor **87**, the voltage across actuation capacitor **91** continues to build as it charges toward the ignition voltage of neon tube **90**. The voltage between the bottom plate **126** of the capacitor **105** and the neutral line **16** is held to the maintaining voltage of neon lamp **104** which is in a parallel, voltage regulating, relationship to the series connected capacitors **91** and **105**. The voltage directly across capacitor **105**, however, will be constantly growing smaller as the voltage on actuation capacitor **91** continues to grow larger through the charging current passing through the separate circuit including the conductors **79** and **89** and resistor **87**. Since the ignition voltage of neon tube **90** is greater than the maintaining voltage of neon tube **104**, a point will be reached where the voltage across capacitor **91** will equal the maintaining voltage of neon tube **104** and the voltage across capacitor **105** will be zero. The actuation capacitor **91** will continue to charge for firing neon tube **90** and triggering SCR **80** to a conductive condition. Conduction across the anode **81** and cathode **85** of the SCR **80** shunts the reed coil **76** for opening the reed switch **75** and de-energizing the gas valve **11** and spark ignition means **21**. This then constitutes a proper no-flame operation.

Should the flame rod **111** be shorted to ground, however, the top plate **127** of shunt capacitor **105** is grounded and a very short time constant RC circuit is formed by resistor **101** and capacitor **105**. The shunt capacitor **105** quickly charges to the ignition voltage of neon tube **104** as previously. The neon tube **104** ignites and establishes a closed loop path for capacitor **105**, when a short is present at the flame rod **111**, formed by neon tube **104**, diode **106**, conductor **99**, and the gate **94** and cathode **85** of the SCR **80** to neutral ground line **16**. The other side of the capacitor **105** is connected to ground through conductor **107** and the flame rod **111** to the grounded burner **10**. This constitutes what was previously referred to as the second circuit. In this case, the current through the neon tube **104** is not limited by resistor **109** and SCR **80** receives sufficient current for becoming triggered to a conductive state to effect shunting of the reed coil **76** and opening of the reed switch **75**. If both flame rods **111** and **61** are shorted to ground, the SCR **80** will be triggered as if only flame rod **111** is grounded.

Another possible failure would be that of the flame rod **111** becoming shorted to the ignitor rod **51**. This is similar to the failure in which the flame rod **111** was shorted to ground with the exception that the flame rod **111** is not directly grounded but is grounded through the transformer secondary winding **50**. This places the flame rod **111** at approximately 9500 ohms above ground and places this resistance in the discharge path of the shunt capacitor **105** when the neon tube **104** ignites as in the second circuit described above; however, this amount of resistance does not prevent the SCR **80** from being triggered and as a result the SCR **80** will be conditioned for conduction to effect a fail-safe termination.

A still further failure would be the shorting of sensor **61** to the ignitor rod **51** in which case the resistance in the secondary winding **50** would appear as a very low resistance in a closed loop path across the spark trigger capacitor **56**. In such a circuit, the capacitor **56** would not develop ignition voltage for neon tube **57** and no spark would be generated. The absence of a spark would lead to an absence of flame and the delayed shutdown would proceed in a normal manner. After the predetermined delay for operating the actuation circuit, the SCR **80** would be conditioned for conduction and the reed switch **75** opened. This failure is substantially the same as

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would occur if flame rod 61 or the ignitor rod 51 were shorted to ground.

Still another failure which, with greater improbability, might occur would be that of flame rod 111 becoming chassis grounded with the machine itself not having proper earth grounding. As indicated previously, resistor 114 and capacitor 115 were connected between the neutral line 16 and the chassis or cabinet to insure proper earth grounding of the chassis. In the absence of capacitor 115, and when the chassis ground is not earth ground and when the flame rod 111 is chassis grounded, the closed loop discharge path for shunt capacitor 105 would include neon tube 104, diode 106, conductor 99, and gate 94 and cathode 85 of the SCR 80, conductor 86 to the neutral line 16, resistor 114 to chassis ground, the grounded burner 10, flame rod 111, and conductor 107 to the capacitor 105. The presence of resistor 114, however, would reduce the current to a level insufficient to trigger the SCR 80. With the use of capacitor 115, however, there is a series combination of capacitors 105 and 115 which tend to act as one capacitor of a smaller value with each discharging upon firing of neon tube 104 to establish a closed loop effectively excluding the resistor 114 and operable for triggering SCR 80.

An actual test on a fabric drying apparatus embodying a fuel burner under the control of the circuit shown in FIG. 1 resulted in operation times as follows: The time to shut down after failure of the gas supply while the machine is otherwise operating normally and a flame is present is eight seconds with a line voltage of 115 volts. The time to shut down when there is no flame and the capacitor 91 is initially discharged with the line voltage of 115 volts R.M.S. is 13 seconds. These operating times were obtained using the preferred embodiment and utilizing the specific component values indicated hereinabove.

Referring to FIG. 2, there is shown an alternate embodiment in which the first control means 140 includes alternate components for the reed coil and reed switch combination. The embodiment shown in FIG. 2 would constitute a more complete solid state arrangement in that the reed switch and coil are replaced by a thyristor in the form of a triac 141 operable under certain conditions for conducting alternating current. In such an arrangement, a triggering circuit is completed to the triac 141 from power line 74 through the diode 69, resistor 70, line conductor 79, resistor 144, conductor 145, and resistor 146 and neon tube 147 connected in series with the triac gate 149. In this circuit, the SCR 80 is normally non-conductive but upon triggering of the SCR 80 to the conductive position, the circuit leading from resistor 144 to the gate 149 of the triac 141 is shunted, causing the triac 141 to become non-conductive for deenergizing fuel valve and ignition means that are identical to those shown in FIG. 1 and which would be attached across lines 41 and 16 of FIG. 2. Other components in the circuit constituting the second control means 34 and the shunt detector circuit 35 could be identical to those shown in FIG. 1.

In summary, certain distinct advantages become apparent from the above identified description that are not available in previously known fuel burner control systems. More specifically, the elimination of electronic tubes requiring heaters has eliminated the problem of time delays from heat buildup, the elimination of power loss and the requirements of ventilation. Also, the components comprising the instant invention are more compact and are available at less cost. It is also seen that this improved system has fail-safe features not present in previous devices.

In the foregoing drawings and specification, there has been set forth a preferred embodiment of the invention and, although specific terms are employed, these are used in a generic and descriptive sense only and not for purposes of limitation. Changes in form and the proportion of parts as well as the substitution of equivalents are

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contemplated as circumstances may suggest or render expedient without departing from the spirit or scope of this invention as defined in the following claims.

We claim:

1. A control system for a fuel burner including a fuel valve therefor, comprising: fuel valve actuating means operable for opening said valve means to supply fuel to said fuel burner; ignition means including a timing capacitor and operable for producing a spark to ignite the fuel and produce a flame at said fuel burner; first control means operable in a first electrical condition for effecting an open fuel valve and energizing said ignition means and in a second electrical condition for effecting a closed fuel valve and de-energized said ignition means; a control network including a solid state switching means and operable for controlling said first control means to said second electrical condition to effect closing of said fuel valve and de-energization of said ignition means; and condition responsive means electrically connected to said control network and said ignition means for sensing a condition at said fuel burner, said condition responsive means including flame sensing means juxtaposed to said burner and in closed loop connection to said timing capacitor for completion of a circuit in the presence of flame, said ignition means being responsive to said timing capacitor for producing a spark at said burner after a first predetermined period of absence of flame and for preventing a spark in the presence of flame, said control network being responsive to at least one predetermined condition at said fuel burner other than the presence of flame as sensed by said condition responsive means for controlling said first control means to said second electrical condition after a second predetermined longer period of absence of flame.

2. A control system for a fuel burner as defined in claim 1 wherein said first control means includes a relay having a holding coil and wherein said solid state switching means is normally non-conductive and connected in parallel to said holding coil and is operable for shunting said holding coil upon becoming conductive.

3. A control system for a fuel burner as defined in claim 1 wherein said control network includes an actuation circuit and wherein said solid state switching means is in the form of a silicon controlled rectifier having a gate portion connected to said actuation circuit.

4. A control system for a fuel burner as defined in claim 3 wherein said actuation circuit includes a resistance-capacitance circuit and a discharge device responsive to a predetermined voltage for actuating said silicon controlled rectifier and thereby changing said first control means to said second electrical condition.

5. A control system for a fuel burner as defined in claim 1 wherein said control network includes an actuation circuit controlling said solid state switching means and wherein said condition responsive means includes a flame rod positioned for contact by a flame and conduction therethrough and connected to said actuation circuit for preventing operation of said actuation circuit in the presence of flame at said fuel burner and thereby maintaining said fuel valve open.

6. A control system for a fuel burner as defined in claim 5 and further including shunt detector means responsive to a shunt of said flame rod to substantially ground potential that would otherwise indicate the presence of flame, said shunt detector means being operable for conditioning said solid state switching means to effect actuation of said first control means to said second electrical condition and to thereby effect closure of said fuel valve.

7. A control system for a fuel burner as defined in claim 6 wherein said actuation circuit and said shunt detector means combine to form a first circuit means operable for conducting current to said solid state switching means at a level below that sufficient to effect a change in the electrical condition of said solid state

switching means when said probe is in its normal condition electrically insulated from ground potential, and to form a second circuit means operable for conducting current to said solid state switching means when said flame rod is shunted to substantially ground potential at a higher current level sufficient to effect a change of said solid state switching means from a first conductive state to a second conductive state, and also to form a third circuit means operable for conducting sufficient current to said solid state switching means to effect a change from said first conductive state to said second conductive state upon the sensing by said flame rod of a period of absence of a flame at said fuel burner.

8. In a control system for a fuel burner and including a fuel valve and a flame rod positioned juxtaposed said burner for contact by a flame and conduction therethrough, the combination comprising: first control means operable in a first electrical condition for effecting the opening of said fuel valve; second control means controlling said first control means and including solid state switching means operable from a first electrical state to a second electrical state for initiating closure of said fuel valve through said first control means; first circuit means operable for conducting actuating current to said solid state switching means at a level below that sufficient to effect a change in the electrical state of said solid state switching means when said flame rod is in its normal position electrically insulated from ground potential; and second circuit means operable for conducting a higher current to said solid state switching means when said flame rod is shunted to substantially ground potential, said second circuit means conducting sufficient current to said solid state switching means to effect a change from said first electrical state to said second electrical state.

9. In a control system for a fuel burner as defined in claim 8 and further including third circuit means energizable simultaneously with said first circuit means and operable for effecting a change in said solid state switching means from said first electrical state to said second electrical state after a predetermined period of flame absence at said burner as evidenced by the absence of conduction through said flame rod.

10. In a control system for a fuel burner as defined in claim 8 wherein said solid state switching means is in the form of a silicon controlled rectifier having a gate connected with said first and second circuit means.

11. In a control system for a fuel burner as defined in claim 8 and including a capacitor common to said first and second circuit means and further including means to charge said capacitor to a predetermined voltage level and to discharge said capacitor through one of said first and second circuit means.

12. In a control system for a fuel burner as defined in claim 8 wherein said first and second circuit means includes a discharge device and a common capacitor and wherein said first circuit means includes resistance means that is excluded from said second circuit means upon completion of an electrical circuit through said flame rod.

13. In a control system for a fuel burner as defined in claim 8 wherein said solid state switching means is in the form of a silicon controlled rectifier and wherein said first and second circuit means include a discharge device connected to the gate of said silicon controlled rectifier and wherein said first circuit means further includes resistance means excluded from said second circuit means upon completion of a conductive circuit through said flame rod upon grounding of said flame rod through said fuel burner.

14. A control system for a fuel burner comprising: fuel valve means including holding means operable for opening said valve means to supply fuel to said fuel burner; ignition means including a first time delay capacitor and operable for producing a spark to ignite the fuel and produce a flame at said fuel burner; first control means operable in a first electrical condition for actuating

said fuel valve holding means and said ignition means; second control means including a second time delay capacitor and a solid state switching means operable for changing the energization of said first control means to a second electrical condition for deactuating said fuel valve holding means and said ignition means; and flame responsive means including flame rod means juxtaposed said burner for contact by said flame and completion of a circuit therethrough, said flame responsive means further including closed loop circuit means connected to said first and second time delay capacitors, said ignition means being responsive to said first time delay capacitor for preventing a spark when flame is present at said burner and further responsive for providing a spark at said burner after a relatively short period of absence of flame, said solid state switching means being responsive to said second time delay capacitor after a relatively longer second period of absence of flame at said burner for changing the energization of said first control means to said second condition whereby said spark is rapidly terminated in the presence of flame and whereby deactuation of said fuel valve means and ignition means is delayed in the absence of flame.

15. A control system for a fuel burner as defined in claim 14 wherein said second control means further includes a discharge device and wherein said solid state switching means is in the form of a silicon controlled rectifier having a gate in circuit with said discharge device and operable to a conductive condition responsive to operation of said discharge device.

16. A control system for a fuel burner as defined in claim 14 wherein said closed loop circuit means includes a flame detector circuit connected in circuit with said first capacitor means and further including a flame sensing circuit connected in circuit with said second capacitor means.

17. A control system for a fuel burner as defined in claim 16 wherein said flame rod means includes a first flame rod connected to said flame detector circuit and a second flame rod connected to said flame sensing circuit and wherein said first and second flame rods are electrically insulated from one another and are individually responsive to the presence of flame at said burner.

18. A control system for a fuel burner comprising: fuel valve means including holding means operable for effecting the opening of said fuel valve means to supply fuel to said fuel burner; ignition means operable for igniting the fuel to produce a flame at said burner and including a spark generator circuit and a spark trigger circuit, said spark trigger circuit being operable for activating said spark generator circuit and including a first capacitor; electrode means juxtaposed said burner for contact by said flame and completion of a circuit therethrough, a flame sensing circuit in closed loop connection to said first capacitor and connected to said electrode means, said flame sensing circuit being responsive to the presence of flame at said fuel burner for preventing operation of said spark trigger circuit whereby activation of said spark generator circuit is prevented; first control means controlling said fuel valve holding means and said ignition means and operable for effecting a first condition of energization of first control means and thereby actuating said valve holding means and said ignition means; second control means operable for changing the energization of said first control means to a second condition for de-actuating said valve holding means and said ignition means and comprising a solid state switching means in circuit with said first control means, said second control means further comprising an actuation circuit including a second capacitor and operable for changing the conductive state of said solid state switching means to change said first control means to said second condition; and a flame detector circuit in closed loop connection to said second capacitor and connected to said electrode means, said flame detector circuit means being responsive to pres-

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ence of flame at said fuel burner for preventing operation of said actuation circuit.

19. A control system for a fuel burner as defined in claim 18 and further including shunt detector means associated with said actuation circuit and responsive to a shunt of said electrode means to substantially ground potential that would otherwise indicate the presence of flame, said shunt detector means being operable for initiating operation of said actuation circuit and thereby subsequently effecting closing of said fuel valve means to prevent continued flow of fuel.

20. A control system for a fuel burner as defined in claim 18 wherein said spark trigger circuit and said actuation circuit each include a discharge tube and wherein conduction through said flame sensing circuit and said flame detector circuit prevent charging of said first and second capacitor to their respective firing voltages for preventing operation of said spark trigger circuit and said actuation circuit in the presence of flame at said burner.

21. A control system for a fuel burner as defined in claim 18 wherein said first control means is in the form of a thyristor and wherein said solid state switching means is in the form of a silicon controlled rectifier connected to the gate of said thyristor and operable responsive to said actuation circuit for switching said thyristor to a non-conductive condition.

22. A control system for a fuel burner comprising: circuit means for supplying a voltage; fuel valve means including holding means operable for opening said valve means to supply fuel to said fuel burner; ignition means including a capacitor and responsive to a predetermined minimum voltage for producing a spark and igniting fuel at said fuel burner; first control means operable to a first electrical condition for actuating said fuel valve holding means and said ignition means, said first control means being operable for preventing actuation of said valve holding means when the voltage supplied to said ignition means is below said predetermined minimum voltage whereby said valve means is not opened unless a sufficient voltage is present at said ignition means for producing a spark; and flame sensing means including a closed loop circuit connected to said ignition means for completing a circuit in the presence of flame, said ignition means being responsive to said flame sensing means for preventing a spark when flame is present at said burner.

23. A control system for a fuel burner as defined in claim 22 wherein said first control means includes a reed relay inoperable to said first electrical condition at voltages below said predetermined voltage level.

24. A control system for a fuel burner as defined in claim 22 wherein said first control means includes a thyristor and a voltage responsive device preventing actuation of said thyristor to said first electrical condition at voltages below said predetermined voltage level.

25. A control system for a fuel burner comprising: fuel valve means including holding means operable for opening said valve means to supply fuel to said fuel burner; ignition means including a timing capacitor and operable for producing a spark to ignite the fuel and produce a flame at said fuel burner; first control means operable in a first electrical condition for actuating said fuel valve holding means and said ignition means; and flame sensing means in closed loop connection to said timing capacitor for completion of a circuit in the presence of flame, said ignition means being responsive to said timing capacitor for preventing a spark when flame is present at said burner and for producing a spark at said burner after a relatively short period of absence of flame whereby said spark is periodically produced in the absence of flame and is prevented in the presence of flame.

26. In a control system for a fuel burner and including a fuel valve and a flame rod positioned juxtaposed said burner for contact by a flame and conduction therethrough, the combination comprising: first control means operable in a first electrical condition for effecting the

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opening of said fuel valve; second control means controlling said first control means and including solid state switching means operable from a first conductive state to a second conductive state for effecting closure of said fuel valve; first circuit means including a discharge device and first and second capacitors; charging circuit means for charging said capacitors; said first circuit means being operable upon actuation of said discharge device for conducting actuating current to said solid state switching means at a level below that sufficient to effect a change in the conductive state of said solid state switching means when said flame rod is in its normal position spaced from said fuel burner; second circuit means including said first capacitor and said discharge device and operable upon actuation of said discharge device for conducting to said solid state switching means a higher current at a level sufficient to effect a change from said first conductive state to said second conductive state when said flame rod is shorted to said fuel burner.

27. In a control system for a fuel burner as defined in claim 26 and further including third circuit means including said second capacitor and operable for effecting a change in the conductive state of said solid state switching means from said first conductive state to said second conductive state after a predetermined period of flame absence at said burner and an absence of a shunt of said flame rod to said burner.

28. In a control system for a fuel burner as defined in claim 27 wherein said third circuit means further includes a second discharge device and wherein said charging circuit means is initially operable for charging said second capacitor to a voltage less than the firing voltage of said second discharge device and wherein said charging circuit means is further operable in the absence of flame at said burner for charging said second capacitor to a voltage sufficiently high to actuate said second discharge device and thereby effect a change in said solid state switching means to said second conductive state.

29. A control system for a fuel burner comprising: fuel valve means including holding means operable for opening said fuel valve means to supply fuel to said fuel burner; ignition means for igniting the fuel to produce a flame at said burner, said ignition means including a spark generator circuit, a spark trigger circuit including a first capacitance and operable after a first time delay for activating said spark generator circuit, and a flame sensing means in closed loop connection to said first capacitance and including a first flame rod juxtaposed said burner for contact by said flame and completion of a circuit therethrough, said flame sensing means being operable for preventing operation of said spark trigger circuit in the presence of flame at said burner whereby actuation of said spark generator circuit is prevented; first control means operable in a first electrical condition for activating said fuel valve holding means and said ignition means; second control means including a solid state switching means operable for changing the energization of said first control means to a second electrical condition for deactuating said valve holding means and said ignition means, said second control means further including second capacitance means and operable after a second longer time delay for actuating said solid state switching means whereby said first control means assumes said second electrical condition; and flame detector means in closed loop connection to said second capacitor means and including a second flame rod juxtaposed said burner for contacting by said flame and conduction therethrough, said flame detector means being operable for preventing operation of said actuation circuit in the presence of flame at said burner and during said second time delay following the sensing of the absence of flame at said burner.

30. A control system for a fuel burner as defined in claim 29 wherein said spark trigger circuit is operable for periodically actuating said spark generator circuit when no flame is present during said second time delay period

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whereby the spark is immediately extinguished if flame is present and wherein the spark and fluid flow are continued during the second time delay period if no flame is present.

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