

[54] **BURNER CONTROL**

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[58] **Field of Search**..... **431/14, 16, 79**

[56] **References Cited**

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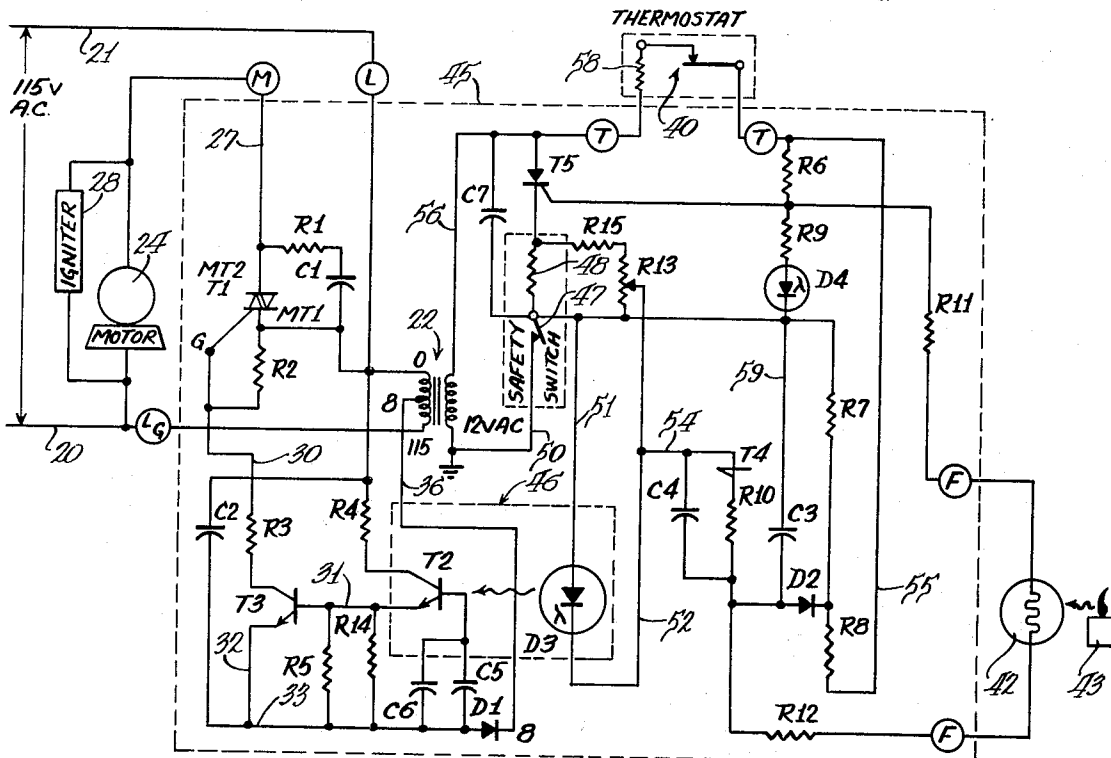
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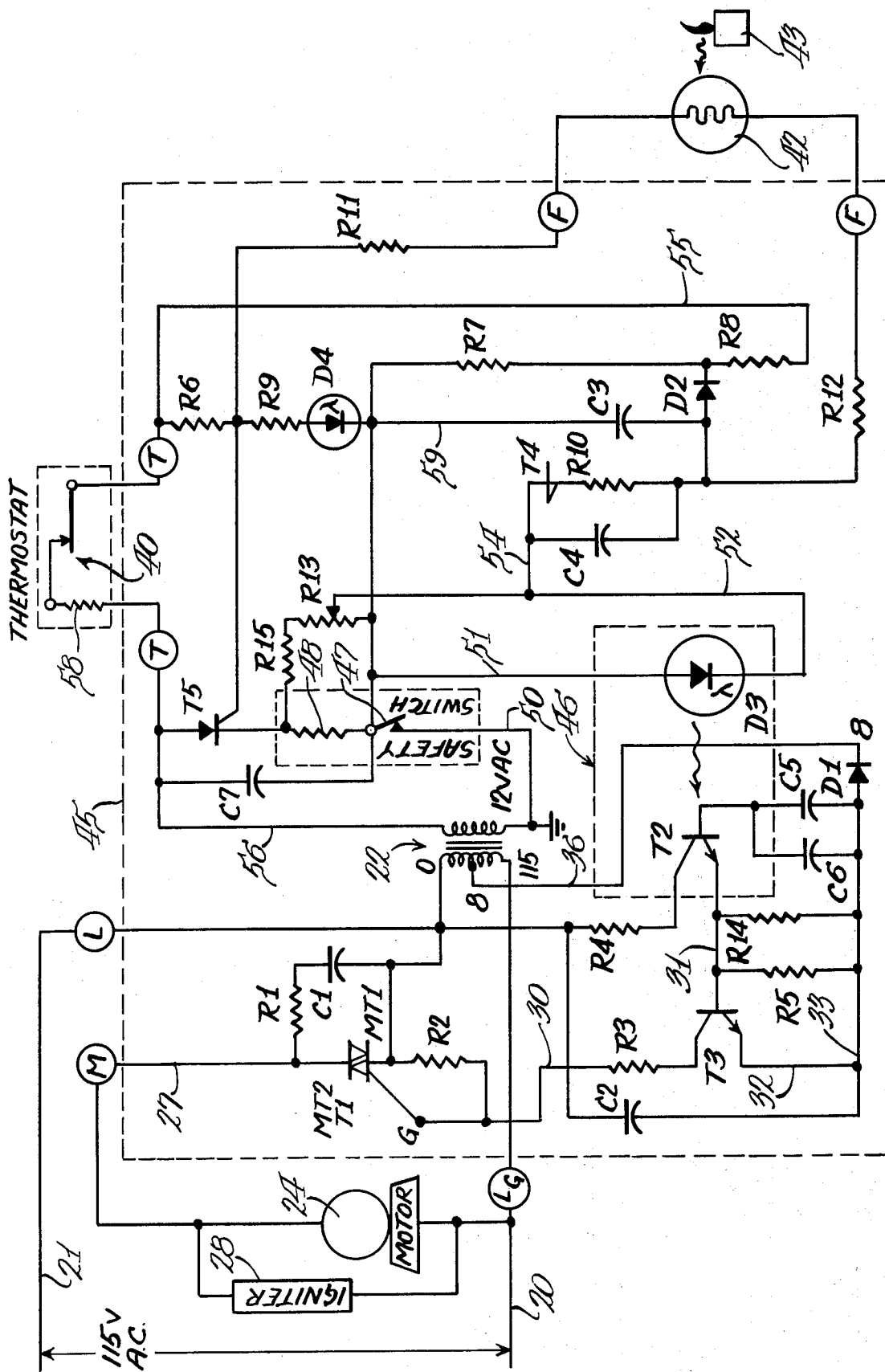
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ABSTRACT

A control system for an oil burner including a motor for pumping fuel to the burner, an igniter for lighting the fuel, and an electronic switch for controlling energization of the motor and the igniter, all in a line voltage circuit, together with a low voltage circuit for controlling operation of the motor and igniter switch including a relay controlling the gate of the switch, a second electronic switch and a thermostat in circuit with the relay for energizing the relay, a third electronic switch for triggering the second switch, a gate circuit for triggering the third switch including a light-sensitive flame detector cell and a light for indicating operability of the flame detection circuitry.

13 Claims, 1 Drawing Figure





BURNER CONTROL

BACKGROUND OF THE INVENTION

The present invention relates to controls for a heating system such as an oil burner of the type utilized in residential buildings, for example, wherein the burner is responsive to a call for heat by thermostat, which is intended to energize a fuel supply means and an igniter for lighting the fuel.

In systems of the type described, there is usually a relatively delicate balance between fuel supply and air supply within which clean, efficient combustion can be expected. If there is a fuel supply without prompt ignition, or if combustion is initiated and then discontinued inadvertently or unexpectedly, it is important that the fuel supply be discontinued promptly in order to avoid conditions which could be harmful to the equipment or dangerous to property or personnel. Accordingly, it is important in burner control systems to provide safe failure in the event the flame does not start when desired, or goes out after starting.

In the past, control systems of the type described have often utilized electro-mechanical controls including moving parts which are subject to wear. As controls have become more complicated, numerous moving parts have led to relatively short life and expensive maintenance problems. Also, the controls have often been incorporated in line voltage circuits which may be dangerous and destructive of circuit components in event of malfunction.

Recently, there have been some controls utilizing electronic components in low voltage circuits in an effort to improve safety and reliability. For example, U.S. Pat. No. 3,624,407 relates to a furnace control with electronic components in a low voltage circuit, including a reed switch controlling the burner responsive to separate energizing and holding coils. U.S. Pat. No. 3,672,811 relates to a burner control, in which all of the control components are included in a line voltage circuit, and the fuel supply is controlled by a light-sensitive relay responsive to both an activating lamp and a holding lamp. U.S. Pat. No. 3,463,600 relates to a burner control with two flame sensors, and a malfunction indicator to signal when one of the sensors is not in working order.

The prior application of Robert J. Lenski, Ser. No. 291,142 filed Sept. 25, 1972, and assigned to the assignee of this application, relates to an improved burner control system with control components in a low voltage circuit with fail-safe capacity and including an electronic switch for triggering a burner control relay and remaining energized so long as the thermostat calls for heat, without the need for separate energizing means and holding means for the relay.

It is desirable to provide an improved burner control system with control components in a low voltage circuit with means preventing operation in event of inadequate line voltage, and with means for indicating inoperation of the flame detection circuitry.

SUMMARY OF THE PRESENT INVENTION

The present invention relates to an improved burner control system in which a thermostat, flame sensor and safety switch are connected in a low voltage solid state circuit, completely isolated from the commercial 110-volt AC power supply. Only a burner motor, for supply-

ing air and fuel, and an igniter, together with a control switch for the motor and igniter, are included in a line voltage circuit. When the thermostatic switch closes, calling for heat, the controls in the low voltage control circuit function sequentially to verify operation of a flame detector cell and a safety switch before energizing the fuel supply and igniter means. If a flame is not established in a short time, the safety switch opens the control circuit to prevent energization of the fuel supply and igniter, and the system cannot be placed in operation again without manually resetting the safety switch.

In a preferred embodiment, the flame detection circuitry includes an indicator light which is normally energized during the time when the safety switch heater is energized to indicate that no flame has been established, or that insufficient light has been sensed by the flame detector, or that a break exists in the flame sensor circuitry. In the event that a flame is established, the indicator light is extinguished when the safety switch heater is deenergized.

Preferably, an electronic switch in the form of a forward breakover diode is used in circuit with a controlling relay and requires a predetermined minimum voltage before operation, so that the control circuit is incapable of operation under conditions where the line voltage is inadequate to establish proper operation of the burner igniter and burner motor.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a burner control circuit embodying the principles of the present invention, utilizing a photoelectric coupling between a low voltage control circuit and a line voltage burner circuit, together with an indicating light for showing malfunction in the flame detection circuitry.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to the drawing, a line voltage circuit includes a line 20 and line 21 connected across the primary winding of a transformer 22. A burner motor 24 for supplying oil and air to a combustion chamber is connected to the line 20 by wire 25 and connected to the line 21 through a wire 27 and a triac switch T1. An igniter 28 is connected in parallel with the motor 24 so that the motor and the igniter are simultaneously energized.

The triac switch T1 includes a main terminal MT2 connected to the wire 27, a main terminal MT1 connected to the line 21 and a gate G connected to a control circuit for triggering the switch when there is a call for heat by the thermostat. A resistor R2 is connected between the triac terminals G and MT1 to eliminate false triggering of the triac due to excessive leakage currents at high temperature or due to electrically generated stray noise signals. A resistor R1 and a capacitor C1 are connected across the triac terminals MT2 and MT1 to limit the rate of rise of voltage across the triac T1 to a safe value when the triac switches from on to off.

The triac T1 is normally in its off or nonconducting state when the thermostat is not calling for heat. The gate G of the triac T1 is biased to render the triac conducting by means of a collector current from a driver transistor T3. The collector of the transistor T3 is connected to the triac gate G by a conductor 30 including

a resistor R3. The resistor combination of R3 and R2 provides proper gate bias voltage and current for the triac T1. The base of the transistor T3 is connected to the emitter of a phototransistor T2 by a conductor 31, and the emitter of the transistor T3 is connected by a conductor 32 to a conductor 33.

The base of the transistor T2 is connected by a capacitor C5 and capacitor C6 to the conductor 33. The capacitors insure stabilization of the high gain transistor pair T3 and T2. The conductor 33 is connected by a conductor 36 and diode D1 to a tap on the primary winding of the transformer 22. The collector of the transistor T2 is connected to a resistor R4. The phototransistor T2 is arranged to respond to light from a light emitting diode D3 in a low voltage control circuit responsive to the thermostat. Light from the diode D3 striking the transistor T2 initiates a base current flow in the transistor T2, as a result of which the phototransistor conducts, amplifying the small light generated base current into considerably more emitter current. The emitter current from the transistor T2 flows into the base of the driver transistor T3, causing it to saturate and conduct collector current to trigger the triac T1.

Diode D1 and a capacitor C2 in the conductor 33 function as a half-wave power supply for the gate trigger circuitry of transistors T2 and T3. Resistor R4 acts as a current limit for transistors T3 and T2.

A resistor R5 and a transistor R14 are connected between the conductors 31 and 33. The resistors provide a finite resistance shunt across the base-emitter junction of transistor T3 to drain off leakage currents at high temperature.

A low voltage control circuit is connected across the secondary of the transformer 22. The low voltage circuit includes a thermostat incorporating a normally open thermostatic switch 40 which is adapted to close responsive to decreasing ambient temperature to call for heat. The low voltage circuit also includes a light sensitive cadmium-type photoresistive flame detecting cell 42 located adjacent to a burner 43 so that the cell is responsive to the presence or absence of a flame at the burner. The cell 42 has a relatively high resistance, on the order of 50K ohms, in darkness in the absence of a flame at the burner 43, and a relatively low resistance, from 300 ohms to 2,000 ohms, depending upon the distance of the cell from the flame, when the burner is lighted.

Preferably, the burner control circuitry is incorporated in an appropriate housing represented at 45, with only the burner motor 24, the igniter 28, the thermostat 40 and the cad cell 42 outside the housing 45. In order to properly connect the control circuitry to the external components of the system, the housing 45 includes a terminal LG for connection to the power supply line 20, a terminal L for connection to the power supply line 21, and a terminal M for connection with the motor 24 and igniter 28. Additionally, the housing 45 includes terminals T for connection of the thermostat, and terminals F for connection of the flame detector cell 32.

The light emitting diode D3 and the phototransistor T2 may be appropriately characterized as a light relay generally designated 46, in which the diode D3 is a controlling relay element and the transistor T2 is a controlled relay element.

In the low voltage control circuit, the light emitting diode D3 is connected to be energized responsive to closure of the thermostatic switch 40, provided that certain other conditions exist, as will appear in the description of the circuitry.

The low voltage circuit includes a safety switch with normally closed switch contacts 47 and a heater coil 48 arranged to cause opening of the contacts 47 after a predetermined period on the order of 15 to 45 seconds. After the switch contacts are opened, they are latched in open condition and must be manually reset by means of a button 49 accessible from the outside of the housing 45. The physical construction of the safety switch may be on the order of that shown and described in the aforementioned U.S. Pat. No. 3,624,407, but the present circuit obviates the need for a temperature compensated switch which has generally been necessary.

In order to provide for energization of the light emitting diode D3 when there is a call for heat, the diode is connected across the secondary winding of the transformer 22 in a circuit including a conductor 50 leading from the transformer secondary (adjacent ground) to the safety switch 47, a conductor 51 leading from the safety switch 47 to the diode D3, a conductor 52 leading from the diode, a conductor 54 leading from the conductor 52 to an electronic switch T4 and resistance R10, diode D2, a conductor 55 including resistance R8 leading from the diode D2 to thermostat 40, and a conductor 56 returning from the SCR T4 to the transformer secondary.

The electronic switch T4 is a forward breakover device, such as various silicon trigger devices. In a preferred circuit, the switch T4 is a silicon asymmetrical AC trigger which is commercially available as ST4. However, other devices may be used, such as a silicon unilateral switch available as 2N4988.9, and a silicon bilateral switch available as 2N4991.

As is conventional, the thermostat 40 includes an anticipator heater element in the form of a very small resistance 58. When the thermostat 40 closes responsive to a call for heat, power is supplied from the transformer secondary winding (+ 12) through the thermostat contacts and to the conductor 55 including resistors R8 and R7. The resistors are thus connected across the transformer secondary winding via the safety switch contacts 47 and which are normally closed. Under such conditions, the resistors draw approximately 200 milliamps alternating current to operate the thermostat anticipator element 58 which is commonly provided to prevent overshooting of the thermostat.

Resistors R7 and R8, together with diode D2, provide a predetermined bias voltage and charge path for a negative power supply capacitor C3 in a conductor 59. On successive negative half-cycle swings of the transformer secondary winding, capacitor C3 charges in stepwise fashion to a negative steady state voltage, controlled by the ratio of resistances R7 and R8, which is slightly below the breakover voltage of the asymmetrical switch T4. Assuming the switch T4 is nonconductive below a 7-volt differential across the switch, the capacitor C3 could establish a negative voltage on the order of 6.5 volts at the switch T4.

Triggering of the asymmetrical switch T4 is controlled by a silicon controlled rectifier T5 which is connected to the conductor 56 leading from the transformer secondary. The SCR T5 is normally nonconductive and is in circuit with heater 48 for the safety switch

contacts 47. When the SCR T5 is triggered, the cathode voltage appears across a resistance R15 and a potentiometer R13. The wiper arm of the potentiometer R13 couples part of the rising cathode voltage across one terminal of the asymmetrical switch T4. The other terminal of the switch T4 is held at negative supply voltage established by capacitor C3 during negative half-cycle excursions of the transformer. When the combination of these two voltages exceeds the break-over voltage of switch T4, it switches from the normally "off" mode to its "on" or conducting state. Thus, at least one cycle of both positive and negative transformer voltage is necessary to cause T4 to conduct, eliminating the transient effects of thermostat contact closures. A capacitor C4 is connected across the asymmetrical switch T4 and the resistance R10, and a capacitor C7 is connected across the SCR T5 and the heater 48, to eliminate noise spikes and false triggering of the asymmetrical switch T4.

When the thermostat 40 closes, and there is no flame yet established at the burner 43, the cad cell 42 remains in its "dark" or high-resistance state. On positive half-cycle swings of the transformer secondary winding, the high resistance of the cell 42 causes the gate-cathode junction of SCR T5 to be forward biased by a bias network including resistor R6, resistor R5 and diode D4. Enough gate current and voltage appear at SCR T5 to trigger T5 to conduct sufficient holding current through the safety switch heating element 48 so that the SCR remains conducting for the duration of the positive half-cycle transformer voltage swing.

When the SCR T5 is triggered, it produces three results. (1) It supplies heating current to the safety switch heater element 48 which ultimately will cause opening of the safety switch contacts 47 if a flame is not established at the burner 43 within a period of time on the order of 15 to 45 seconds depending upon the proximity of the cell 42 to the burner 43. (2) The rising cathode voltage supplied to asymmetrical switch T4 through resistances R15 and R13 cause T4 to "break-over" and conduct current through the light emitting diode D3 and resistor R10, thus calling for energization of the burner motor 24 and igniter 28. (3) The rising cathode voltage causes the cathode-gate junction of T5 to go into "reverse breakdown" dumping a limited amount of current into the resistor R9 and the light emitting diode D4, causing the diode D4 to emit visible light indicating that a flame condition has not yet been established and that the control is operating in the trial period, with the safety switch heater 48 energized.

The resistive heating element 48 in the safety switch, upon receiving current from SCR T5, heats a bi-metallic element in the safety switch which serves to open the safety switch contacts after a predetermined time period. The switch is usually adjusted such that it will open the safety contacts 47 after 15 to 45 seconds of continuous heating by the element 48. If no flame is established in such time period, while the thermostat 40 remains closed, calling for heat, the contacts 47 open to remove power from the low voltage control, thereby shutting down the entire burner control system. Once the safety switch contacts open, they remain open, and it is necessary to manually reset the safety switch.

Once triggered into the conducting state, the asymmetrical switch T4 will remain in its conducting state, causing current to flow through the light emitting diode

D3 and the current limiting resistor R10, until the commercial power is shut off, or the safety switch contacts 47 open, or the thermostat contacts 40 open. As long as T4 conducts, the light emitting diode D3 conducts, and emits light to the base region of the phototransistor T2 for energizing the burner motor 24 and the igniter 28. The wiper arm of the potentiometer R13 is adjusted preferably so that the asymmetrical switch T4 will not "breakover" and conduct for line voltages less than approximately 90 volts. Thus, it is not possible to energize the low voltage control when the line voltage is less than that which is suitable for operating the burner motor 24 and the igniter 28. Prior to adjustment of the potentiometer R13, the resistor R15 serves to protect the asymmetrical switch T4 from receiving excessive current in case the wiper arm of the potentiometer R13 is randomly set, touching one of the extreme ends of the potentiometer.

If a flame is established at the burner 43 during the 15 to 45 second trial period before the safety switch contacts 47 open, as will normally occur if the control system functions properly, the resistance in the flame detector cell 42 will be reduced to a low volume between 300 and 2,000 ohms, depending upon the proximity of the cell to the flame. The low resistance in the flame detector cell reverse biases the gate-cathode junction of the SCR T5, thereby turning off the SCR T5. When the switch T5 is not conducting, no power is consumed by the heater element 48 in the safety switch, so that it cools and the contacts 47 remain in the normally closed position. As a result, the burner will continue to operate as long as the thermostat calls for heat and the flame detector cell reads flame condition.

The diagnostic indicator, light emitting diode D4 remains energized while the heater 48 is energized. The flame detection circuitry is thus monitored during such time period. Energization of the diode D4 indicates that the safety switch heater 48 is energized and timing out the trial period. During such trial period, if the diode D3 is not energized, the absence of the light indicates that no flame has been established, or insufficient light is reaching the flame detector cell 42, or the flame detection circuitry is open. Thus, at the time of the trial period, a service man is able to immediately ascertain what is happening in the flame detection circuitry. When a flame is appropriately established at the burner 43 within the trial period, the light emitting diode D4 is deenergized when the safety switch heater 48 is deenergized.

Preferably, the light emitting diode D3 and the phototransistor T2 are combined in a single commercially available integrated circuit such as Monsanto Company's photocoupler MCT26.

The switching devices T1 and T3-T5 may be of the type identified by various manufacturers as follows:

T1 — 64149 SPECIAL

T3 — 2N5305

T4 — ST-4

T5 — C103Y, TIC-44

The diodes D1, D2 and D4 may be of the type identified by manufacturers as follows:

D1 — 1N4002

D2 — 1N4148

D4 — RL-50

The capacitors C1-C7 have values generally as follows:

C1 — 0.1 MF, 400V
 C2 — 220 MF, 25V
 C3 — 220 MF, 16V
 C4 — 0.1 MF, 25V
 C5 — 270PF to 390 PF, 25V
 C6 — 270PF to 390 PF, 25V
 C7 — 0.1 MF, 50V

The resistances R1-R15 have values approximately as follows:

R1 — 100 ohm $\frac{1}{2}$ W
 R2 — 820 ohm $\frac{1}{2}$ W
 R3 — 68 ohm 1W
 R4 — 1.8K ohm $\frac{1}{2}$ W
 R5 — 33K ohm $\frac{1}{2}$ W
 R6 — 18K ohm $\frac{1}{2}$ W
 R7 — 22 ohm 3W, 5 percent
 R8 — 40 ohm 3W, 5 percent
 R9 — 390 ohm $\frac{1}{2}$ W
 R10 — 150 ohm $\frac{1}{2}$ W
 R11 — 820 ohm $\frac{1}{2}$ W
 R12 — 820 ohm $\frac{1}{2}$ W
 R13 — 100K ohm POT
 R14 — 33K ohm $\frac{1}{2}$ W
 R15 — 4.7K ohm $\frac{1}{2}$ W

To summarize the operation, when there is no call for heat, the thermostatic switch contacts 40 are normally open, and the components of the system are at rest. When the thermostatic switch is closed, a circuit is completed to the gate for the SCR T5. If the flame detector cell 42 is functioning properly, and there is no flame, the high resistance at the cell causes the SCR T5 to conduct. When the SCR T5 conducts, a circuit is completed through the safety switch heater 48 to start the trial period. At the same time, the indicator diode D4 is energized. Conduction in the SCR T5 results in triggering the asymmetrical switch T4, completing a circuit to energize the light emitting diode D3 to transmit light to the phototransistor T2. The emitted current from the phototransistor T2 causes the transistor T3 to conduct. The collector current from the transistor T3 biases the gate G of the triac T1 so that the latter is rendered conducting, to energize the burner motor 24 and the igniter 28. The motor drives a pump for supplying fuel oil to the burner 43 and the igniter causes ignition of such fuel. The existence of a flame reduces the resistance in the flame detector cell 42, rendering the SCR T5 nonconducting. The indicator diode D4 is deenergized. The heater coil 48 is deenergized, and the safety switch contacts 47 remain closed.

If, for some reason, the normally expected cycle of operation described above is not completed, no flame is established at the burner 43, the high resistance in the unlighted flame detector cell 42 will maintain the SCR T5 conducting until the heater element 48 opens the safety switch contacts 47, thereby shutting the system down until it receives manual attention.

The arrangement provides for safe failure. If a malfunction condition exists such that the thermostat terminals T are shorted, and the flame sensor terminals F are open, the burner control may turn on, but it will not operate longer than the time required for the heater to open the safety switch contacts 47, because there will be no reduction of resistance to render the SCR T5 nonconducting. If the flame sensor terminals F are shorted, the burner control will never start, because the SCR T5 will be nonconducting. If the safety switch heater element 48 is open circuited, the SCR T5 will

not receive sufficient holding current to conduct, as a result of which the asymmetrical switch T4 will remain off and the control will not start.

We claim:

1. A burner control system comprising:
 - a. means providing a source of low voltage including a normally closed safety switch,
 - b. a controlling relay element in circuit with the low voltage source,
 - c. a thermostatic switch in circuit with said controlling relay element adapted to close for conditioning the circuit responsive to a call for heat,
 - d. a heater for the safety switch,
 - e. a normally nonconductive electronic switch in circuit with the low voltage source and with the safety switch heater,
 - f. a circuit for triggering said electronic switch in circuit with said low voltage source and said thermostatic switch,
 - g. a light-sensitive flame detector in the triggering circuit for the electronic switch normally providing a relatively high resistance to bias said switch to conduct in the absence of a burner flame when the thermostatic switch is closed, and provide a relatively low resistance in the presence of a burner flame to reversely bias the switch to a nonconductive state when the burner is lighted, and
 - h. an indicator energizable responsive to the triggering circuit for the electronic switch during energization of the safety switch heater.
2. A burner control system comprising:
 - a. means providing a source of low voltage including a normally closed safety switch,
 - b. a controlling relay element in circuit with the low voltage source,
 - c. a thermostatic switch in circuit with said controlling relay element adapted to close for conditioning the circuit responsive to a call for heat,
 - d. a first normally nonconductive electronic switch in circuit with said controlling relay element and thermostatic switch for energizing said controlling relay element,
 - e. a circuit for triggering said first electronic switch including a second normally nonconductive electronic switch in circuit with the low voltage source,
 - f. a heater for said safety switch in circuit with said second electronic switch,
 - g. a circuit for triggering said second electronic switch in circuit with said low voltage source and said thermostatic switch,
 - h. a light-sensitive flame detector in the triggering circuit for the second electronic switch normally providing a relatively high resistance to bias said second electronic switch to conduct in the absence of a burner flame when the thermostatic switch is closed thereby to energize the safety switch heater and provide a relatively low resistance in the presence of a burner flame to reversely bias the second switch to a nonconductive state when the burner is lighted, thereby to deenergize the heater, and
 - i. a visible indicator energizable responsive to the triggering circuit for the second electronic switch during energization of the safety switch heater.
3. A burner control system as defined in claim 2, wherein the visible indicator comprises a light emitting diode.

4. A burner control system as defined in claim 2, wherein the second electronic switch comprises an asymmetrical switch rendered conductive responsive only to a minimum breakover voltage.

5. A burner control system as defined in claim 2, wherein the asymmetrical switch comprises a silicon asymmetrical trigger.

6. A burner control system comprising:

- a. means providing a source of low voltage including a normally closed safety switch,
- b. a controlling relay element in circuit with the low voltage source,
- c. a thermostatic switch in circuit with said controlling relay element adapted to close for conditioning the circuit responsive to a call for heat,
- d. an asymmetrical switch in circuit with said controlling relay element and thermostatic switch for energizing said controlling relay element responsive to a predetermined breakover voltage,
- e. an operator for said safety switch,
- f. a circuit for energizing said operator upon closure of said thermostatic switch, and
- g. a flame detector in the operator circuit for deenergizing the operator on the establishment of a burner flame.

7. A burner control system comprising:

- a. means providing a source of low voltage including a normally closed safety switch,
- b. a controlling relay element in circuit with the low voltage source,
- c. a thermostatic switch in circuit with said controlling relay element adapted to close for conditioning the circuit responsive to a call for heat,
- d. a forward breakover switch in circuit with said controlling relay element and thermostatic switch for energizing said controlling relay element responsive only to a predetermined minimum breakover voltage,
- e. a circuit for triggering said breakover switch including a second normally nonconductive electronic switch in circuit with the low voltage source,
- f. a heater for said safety switch in circuit with said second electronic switch,
- g. a circuit for triggering said second electronic switch in circuit with said low voltage source and said thermostatic switch, and
- h. a light-sensitive flame detector in the triggering circuit for the second electronic switch normally providing a relatively high resistance to bias said second switch to conduct in the absence of a burner flame when the thermostatic switch is closed, and provide a relatively low resistance in the presence of a burner flame to reversely bias the second switch to a nonconductive state when the burner is lighted.

8. A burner control system as defined in claim 7, wherein the breakover switch comprises a silicon asymmetrical trigger.

9. A burner control system as defined in claim 7, including an indicator energizable responsive to the triggering circuit for the second electronic switch during energization of the safety switch heater.

10. A burner control system comprising:

- a. means providing a line voltage circuit including selectively energizable burner means,

- b. a first electronic switch in circuit with the burner means including a gate for triggering said switch,
- c. a light-sensitive element in circuit with the gate for rendering the gate conductive,
- d. means providing a source of low voltage,
- e. a light emitting element for transmitting light to said light-sensitive element,
- f. a thermostat in circuit with said low voltage source and said light emitting element for conditioning the circuit responsive to a call for heat,
- g. a forward breakover device in the circuit with said light emitting element and thermostat for energizing said light emitting element responsive to a predetermined breakover voltage,
- h. a third normally nonconductive electronic switch in circuit with the low voltage source for rendering the forward breakover device conductive,
- i. a circuit for triggering said third electronic switch in circuit with said low voltage source and said thermostat, and
- j. a light-sensitive flame detecting cell in circuit with the triggering circuit for the third electronic switch normally providing a relatively high resistance to trigger said third switch in the absence of a burner flame when the thermostat is closed, and provide a relatively low resistance in the presence of a burner flame to render the third switch nonconductive when the burner is lighted.

11. A burner control system as defined in claim 10, wherein the forward breakover diode comprises a silicon asymmetrical trigger.

12. A burner control system comprising:

- a. means providing a line voltage circuit including selectively energizable burner means,
- b. a first electronic switch in circuit with the burner means including a gate for triggering said switch,
- c. a light-sensitive element in circuit with the gate for rendering the gate conductive,
- d. means providing a source of low voltage including a normally closed safety switch,
- e. a light emitting element for transmitting light to said light-sensitive element,
- f. a thermostat in circuit with said low voltage source and said light emitting element for conditioning the circuit responsive to a call for heat,
- g. a second electronic switch in circuit with said light emitting element and thermostat for energizing said light emitting element including a gate for triggering said second electronic switch,
- h. a third normally nonconductive electronic switch in circuit with the low voltage source for rendering the last recited gate conductive,
- i. a heater for the safety switch in circuit with the third electronic switch,
- j. a gate for triggering said third electronic switch in circuit with said low voltage source and said thermostat,
- k. a light-sensitive flame detecting cell in circuit with the gate for the third electronic switch normally providing a relatively high resistance to trigger said third switch in the absence of a burner flame when the thermostat is closed, and provide a relatively low resistance in the presence of a burner flame to render the third switch nonconductive when the burner is lighted, and

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- l. a visible indicator energizable responsive to the gate circuit for the second electronic switch during conductivity of the third switch.
- 13. A burner control system comprising:
 - a. means providing a line voltage circuit, 5
 - b. burner means in the line voltage circuit adapted to be selectively energized,
 - c. a first electronic switch in circuit with the burner means,
 - d. a circuit for triggering said switch including a controlled relay element, 10
 - e. means providing a source of low voltage including a normally closed safety switch,
 - f. a controlling relay element in circuit with the low voltage source for controlling said controlled relay element, 15
 - g. a thermostat in circuit with said controlling relay element for conditioning the circuit responsive to a call for heat,
 - h. a forward breakover device in circuit with said 20 controlling relay element and thermostat for ener-

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- gizing said controlling relay element,
- i. a circuit for triggering said breakover device including a third electronic switch in circuit with the low voltage source,
- j. a heater for said safety switch in circuit with said third electronic switch,
- k. a gate circuit for triggering said third electronic switch in circuit with said low voltage source and said thermostat,
- l. a light-sensitive flame detector in the gate circuit for the third electronic switch normally providing a relatively high resistance to trigger said third switch and the heater in the absence of a burner flame when the thermostat is closed, and provide a relatively low resistance in the presence of a burner flame to render the third switch and the heater nonconductive when the burner is lighted, and
- m. a light emitting diode energizable during energization of the third switch.

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