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[54] **ELECTROTHERMAL FURNACE CONTROL**
19 Claims, 2 Drawing Figs.

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[51] **Int. Cl.** **F23n 5/00**
[50] **Field of Search** 431/66, 71, 72, 74, 254; 236/68, 10

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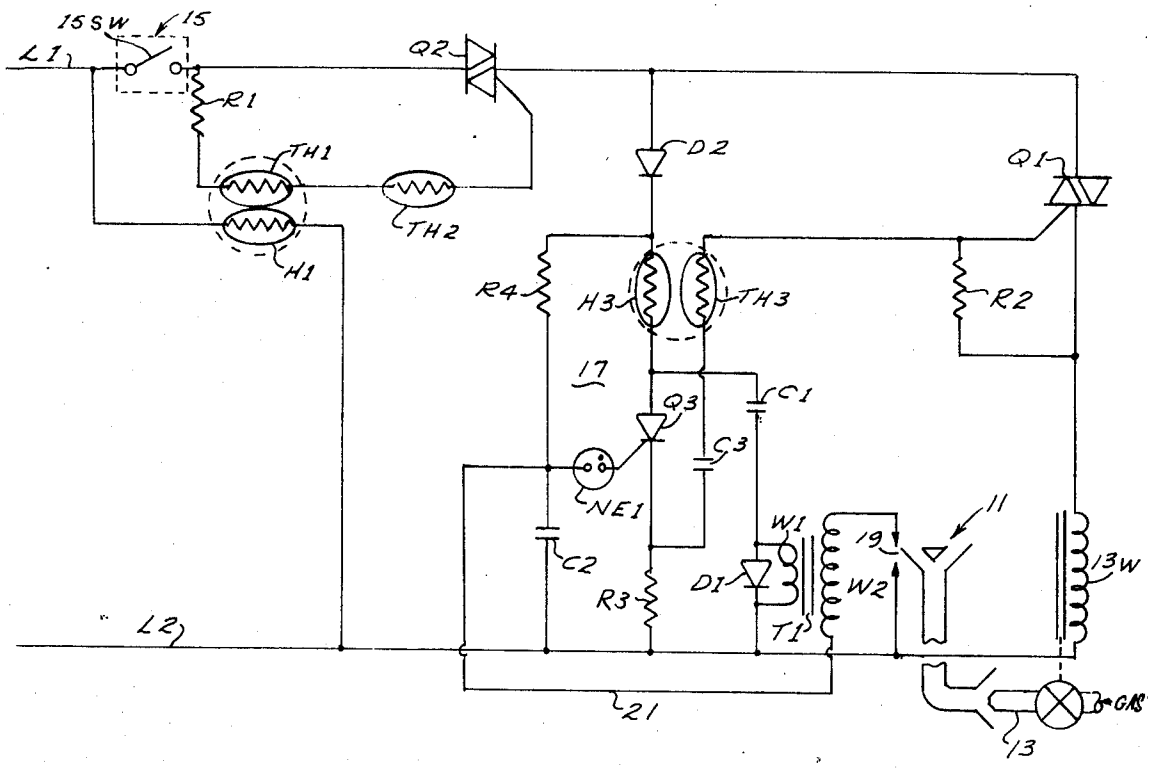
ABSTRACT: Apparatus for controlling the operation of a furnace having an electrically energizable fuel valve which, when energized, supplies fuel to the furnace burner. An ignition circuit generates recurrent sparking, when energized, upon the demand of a thermostat, and ceases to generate sparking after ignition of the fuel. A triac is connected for energizing the fuel valve and a triggering circuit for the triac causes initial triggering thereof upon energization of the ignition means and then supplies triggering current for continued triggering thereof after the ignition means ceases generating sparking. A thermistor prevents triggering current from being supplied to the triac if heated above a predetermined threshold. Means for heating the thermistor is energized to cause heating thereof when the ignition means generates sparking, the thermistor requiring a predetermined heating time interval to reach its threshold temperature such that, if the fuel is not ignited within this interval, triggering of the triac is terminated to prevent fuel from being further supplied to the burner.



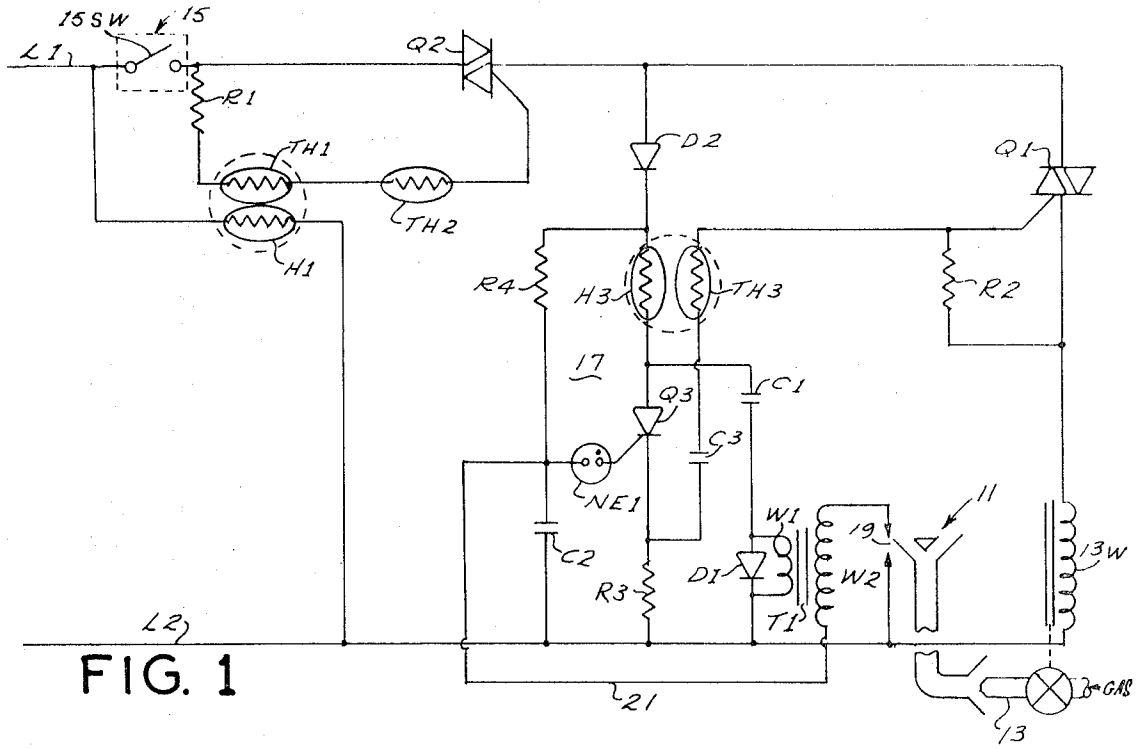


FIG. 1

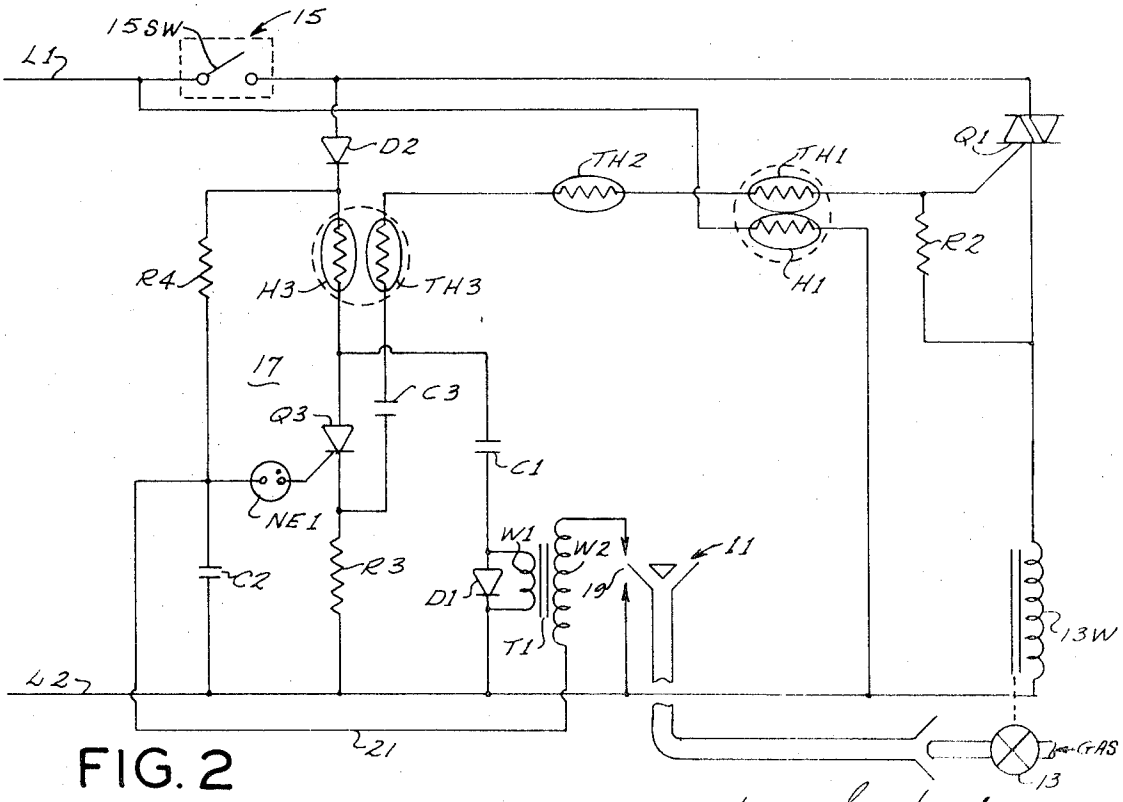


FIG. 2

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ELECTROTHERMAL FURNACE CONTROL

This invention relates to apparatus for controlling the operation of a furnace and, more particularly, to improved furnace control apparatus for carrying out various required furnace control and protective functions through the use of solid-state electrothermal circuitry.

This invention is an improvement of the electrothermal furnace control disclosed in application Ser. No. 822,901, filed May 8, 1969. An improvement of the latter electrothermal furnace control was the subject of application Ser. No. 822,902, filed May 8, 1969, which disclosed simplified furnace controls utilizing solid-state devices and electrothermal logic. While representing a simplification of the previously disclosed control, the aforesaid improved furnace controls required previously use of a magnetic contactor for supplying power to the circuit adapted to energize an electrically energizable fuel valve of the furnace and required both a semiconductor current-switching device for initially energizing the fuel valve and a separate means for maintaining energization of the fuel valve following initial energization thereof by the switching device. Certain of these requirements desirably can be eliminated in accordance with the teachings of the present disclosure, resulting in greatly simplified furnace control circuitry without compromising safety or reliability.

Accordingly, among the several objects of the present invention may be noted the provision of greatly simplified apparatus for carrying out required furnace control and protective functions employing solid-state devices and electrothermal logic; the provision of such apparatus which does not employ electromechanical devices; the provision of such apparatus for controlling a furnace with a high degree of safety and reliability; the provision of such apparatus which is fail-safe in operation; and the provision of such apparatus which is easily and economically manufactured. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, apparatus of the present invention is adapted to control the operation of a furnace in response to the demand of a thermostat sensing the temperature in a zone heated by a furnace. The furnace includes a burner and an electrically energizable fuel valve which, when energized, supplies fuel, e.g., gas, to the burner. The apparatus includes an ignition circuit which, upon energization, generates recurrent sparking to cause ignition of the fuel. This ignition circuit is energized when the thermostat demands heat and is operative to cease generating sparking after ignition of the fuel. Interconnected with the fuel valve is a triggerable semiconductor current-switching device which, when triggered, is conductive to cause energization of the fuel valve. A triggering circuit for this switching device is interconnected with the ignition means and is operative first to supply triggering current to the switching device for initial triggering thereof upon energization of the ignition means and then to supply triggering current to the switching device for continued triggering thereof after the ignition means ceases to generate sparking as long as the thermostat demands heat. A thermistor is connected to prevent this triggering current from being supplied to the switching device when the thermistor is heated above a predetermined threshold. Means is provided for heating the thermistor, this means being interconnected with the ignition means so that it is energized to cause heating of the thermistor when the ignition means generates sparking. Upon heating, the thermistor requires a predetermined heating time interval to reach its threshold temperature. If the fuel is not ignited within this predetermined interval, triggering of the switching device is terminated to prevent fuel from being further supplied to the burner. In other aspects of the invention, additional thermistors are employed for sensing the temperature in a plenum of the furnace and for sensing the presence of a forced-air draft to the burner to also control triggering of the switching device or to control another triggerable switching device and thus to also prevent fuel from being further supplied to the burner in the event of either a high plenum temperature or an insufficient forced-air draft.

In the accompanying drawings, in which are illustrated two of various possible embodiments of the invention,

FIG. 1 is a circuit schematic diagram of first embodiment of furnace control apparatus of the present invention; and

FIG. 2 is a schematic circuit diagram of a second embodiment of apparatus of this invention which is a simplification of the first embodiment.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Referring now to FIG. 1, there is illustrated a first embodiment of an electrothermal furnace control of the present invention which is adapted to control a furnace such as a gas-fired, forced-hot-air furnace of the type conventionally used for residential heating. The furnace has a burner, illustrated generally at 11, to which gas is supplied for combustion when a solenoid-operated gas valve 13 is opened by energization of its winding 13W. Combustion at burner 11 supplies heat to a plenum of the furnace. The furnace is of the type wherein a forced-air draft is provided to the burner, as by a conventional blower fan. A furnace of the present type is shown and described in the aforesaid application Ser. No. 822,901. The furnace is controlled by the present apparatus in response to the demand of the usual thermostat 15 which is suitably located for sensing the temperature in a zone heated by operation of the furnace, thermostat 15 including a switch 15SW which is closed to indicate a demand for heat. A pair of lines L1 and L2 are provided to supply power at a suitable voltage, e.g., line voltage of 115 v. AC, such that this potential will be supplied to the apparatus by the closing of switch 15SW when the thermostat demands heat.

Winding 13W of gas valve 13 is connected in a series circuit across lines L1 and L2, the circuit including the contacts of thermostat switch 15SW and the main terminals of a respective pair of triacs Q1 and Q2 which, as is known to those skilled in the art, are triggerable semiconductor current-switching devices. Such a device is conductive on successive half-cycles of the AC waveform applied across its main terminals when a triggering current of sufficient magnitude is supplied to its triggering or gate terminal.

A series triggering circuit for triac Q2 is connected between one of its main terminals and its gate terminal and includes a resistor R1 and a pair of thermistors TH1 and TH2. A heater thermistor H1 is thermally coupled to thermistor TH1 to provide means for heating the latter and is connected across lines L1 and L2 such that it is continually energized as long as lines L1 and L2 are connected to the AC supply. The pair of thermistors TH1 and H1 together constitute a draft sensor or air flow sensor. Thermistor TH1 has a positive temperature coefficient of resistivity (PTC) and preferably has a well-defined transition temperature, e.g., 80° C., above which the resistance thereof increases relatively abruptly. Preferably, thermistor H1 is the same type of thermistor having a transition temperature, for example, of 120° C. This pair is suitably mounted in a furnace air draft duct or in conjunction with a draft blower of the furnace such that thermistor TH1 is cooled by a forced-air draft provided to the burner. Thermistor H1 normally supplies insufficient heat to cause heating of thermistor TH1 above its transition temperature as long as there is sufficient forced-air draft. However, if there is insufficient forced-air draft H1 causes heating of thermistor TH1 above a predetermined threshold temperature corresponding to its transition temperature so that insufficient current is supplied to the gate terminal of triac Q2 to cause triggering of the latter. Consequently, energization of fuel valve winding 13W is prevented in the event that insufficient forced-air draft is supplied to burner 11.

Thermistor TH2 is also preferably a PTC thermistor having a well-defined transition temperature above which the resistance thereof increases relatively abruptly and is located in the plenum of the furnace for sensing the temperature therein.

When heated above a predetermined threshold temperature corresponding to the maximum permissible temperature in the plenum, thermistor TH2 also prevents triggering of triac Q2.

A triggering circuit for triac Q1 includes a resistor R2 connected between its gate terminal and the adjacent main terminal of the triac and further includes a connection from the gate terminal to an ignition circuit indicated generally at 17 which, upon energization, generates recurrent sparking for igniting the fuel supplied to burner 11. This ignition circuit includes a triggerable semiconductor current-switching device constituted by a silicon controlled rectifier (SCR) Q3 having its anode and cathode terminals connected in a circuit with a capacitor C1, a resistor R3 and the primary winding W1 of a conventional spark transformer T1. The winding W1 is shunted by a diode D1 to reduce the charging time constant of capacitor C1. Spark transformer T1 includes a high voltage winding W2 with which are interconnected a pair of electrodes 19 located at burner 11 such that ignition of the fuel is caused by recurrent sparking thereacross. Interconnected with the gate or triggering terminal of SCR Q3 are neon bulb NE1 and a capacitor C2, one side of capacitor C2 being connected to line L2. A connection 21 is provided from the junction of capacitor C2 and neon bulb NE1 to one side of high voltage winding W2 for a purpose to be explained. A resistor R4 is provided to supply current for charging capacitor C2 when power is supplied to ignition circuit 17 through a diode D2. Series-connected between the cathode of diode D3 and the anode of SCR Q3 is a heater thermistor H3 which is thermally coupled to a thermistor TH3 to provide means for heating the latter. One side of thermistor TH3 is connected to the gate terminal of triac Q1 and the other side is connected through a capacitor C3 to the junction of the cathode of SCR Q3 and resistor R3 and thus thermistor TH3 forms part of the triggering circuit for triac Q1.

Thermistor TH3 is a PTC thermistor and preferably has a well-defined transition temperature, e.g., 80° C., above which the resistance thereof increases relatively abruptly. Preferably also, thermistor H3 is a PTC thermistor and has a well-defined transition temperature, e.g., 120° C., above which its resistance increases relatively abruptly. As will be explained, if thermistor TH3 is heated above a predetermined threshold temperature corresponding with its transition temperature, triggering of triac Q1 is prevented. Upon being heated by thermistor H3, thermistor TH3 requires a predetermined heating time interval, e.g., 4—10 seconds, to reach this temperature. In effect, then, thermistors TH3 and H3 together constitute an electrothermal timer.

In the operation of the control of FIG. 1, it is assumed that lines L1 and L2 are connected to a source of power of appropriate voltage, e.g., 115 v. AC. Further, it is assumed that a sufficient forced-air draft is being satisfactorily provided to the burner and that the plenum of the furnace is not overheated, i.e., is not above a maximum permissible temperature. Thus, thermistors TH1 and TH2 are both relatively cool and, accordingly, exhibit a relatively low resistance. With respect to thermistor TH1, it should be understood that, since thermistor H1 is constantly energized by the voltage across lines L1 and 12, H1 self-heats due to internal resistive consumption of power, the increase of its resistance at the transition temperature causing a decrease in the power consumed to normally maintain the thermistor substantially at at its transition temperature. However, as long as there is sufficient forced-air draft, thermistor TH1 remains relatively cool. When the contacts of thermostat switch 15SW are closed, indicating a demand for heat, the voltage across lines L1 and L2 is provided across the circuit comprising gas valve winding 13W and triacs Q1 and Q2. Since the resistance of each of thermistors TH1 and TH2 is relatively low, triggering current is supplied through resistor R1 and these thermistors to the gate terminal of triac Q2 to cause triggering thereof on successive half-cycles of the applied AC waveform.

Upon triggering of triac Q2, power is supplied to triac Q1 and, through diode D2, to the ignition circuit 17. Thus SCR Q3 is forward biased on alternate half-cycles of the applied AC waveform. Current supplied through the resistance constituted by heater thermistor H3 quickly charges capacitor C1 to peak voltage. Simultaneously, current is supplied through resistor R4 to charge capacitor C2. When the voltage across capacitor C2 reaches the break down potential of neon bulb NE1, the latter conducts to supply a triggering current to the gate terminal of SCR Q3 to cause triggering thereof. When SCR Q3 conducts, capacitor C1 is discharged through primary winding W1 of transformer T1. Secondary winding W2 steps up the voltage across winding W1 to cause sparking across electrodes 19. Resistor R4 limits the current which can flow to charge capacitor C2 so that it charges in somewhat more time than capacitor C1 and thus capacitor C1 is ready for discharge when capacitor C2 reaches the breakdown voltage of neon bulb NE1. Capacitor C2 reaches this breakdown voltage many times per second, causing repetitive triggering of SCR Q3 and thus providing recurrent sparking across electrodes 19.

Upon triggering of SCR Q3, the voltage across resistor R3 is supplied through capacitor C3 and thermistor TH3 to the gate terminal of triac Q1 to cause initial triggering of the latter. Triggering of triac Q1 energizes gas valve winding 13W to supply gas to burner 11. The recurrent sparking across electrodes 19 ignites the gas and the presence of flame at electrodes 19 provides a conductive path thereacross. Because of connection 21, this conductive path discharges capacitor C2 and causes it to remain discharged so long as combustion continues. Accordingly, when ignition occurs, SCR Q3 ceases to be triggered and ignition circuit 17 ceases to generate sparking.

When triggering of SCR Q3 ceases, the potential across resistor R3 drops essentially to the potential of line L2. Because of the inductive reactance of gas valve winding 13W, there is a sudden change of voltage across this winding each time triac Q1 ceases to conduct; this voltage change is applied to the gate terminal of Q1 through capacitor C3 and causes triac Q1 to be triggered after triggering of SCR Q3 ceases. Thus it may be seen that the triggering circuit for triac Q1 operates first to initially trigger triac Q1 and then to maintain triggering of triac Q1 after the ignition circuit ceases generating sparking. Energization of gas valve winding 13W thus continues until thermostat 15 senses that the temperature in the heated zone has risen sufficiently and accordingly opens switch 15SW to deenergize gas valve winding 13W.

From the above it will have been observed that, by virtue of the series connection of heater thermistor H3 with the cathode and anode terminals of SCR Q3, thermistor H3 is energized concomitantly with energization of the ignition circuit and thus begins to heat thermistor TH3. If ignition does not occur, and thus triggering of SCR Q3 continues, thermistor TH3 continues to be heated by thermistor H3. After the predetermined heating time interval to reach its threshold temperature, e.g., 4 to 10 sec., the resistance of thermistor TH3 is increased sufficiently to prevent further triggering of triac Q1. When triggering of triac Q1 ceases, fuel valve winding 13W is deenergized to prevent fuel from being further supplied to the burner. Ignition circuit 17, however, remains energized and thus sparking continues at electrode 19 to insure that any gas which might be present at burner 11 will be ignited and burned rather than being permitted to dangerously accumulate. The continued triggering of SCR Q3 causes continued energization of heater thermistor H3. Self-heating of thermistor H3 causes its resistance to increase until it is maintained substantially at its transition temperature. This increased resistance reduces the level of energization of the ignition circuit and causes capacitor C1 to charge at a somewhat lower rate. Accordingly, SCR Q3 is triggered somewhat less frequently and thus sparking across electrodes 19 continues to be generated but at a reduced sparking rate. This advantageously prevents erosion of the electrodes 19 and yet permits thermistor TH3 to remain heated for preventing triggering of triac Q1. Gas valve winding 13W therefore remains deenergized if ignition does not occur.

From the above, it may be seen that the control remains "locked out" of operation following an unsuccessful ignition trial and may only be manually reset for a new ignition trial by disconnecting lines L1 and L2 from the source of power or by causing the thermostat switch 15SW to open.

Fuel valve winding 13W is also deenergized if the plenum of the furnace should overheat. Such overheating causes thermistor TH2 to be heated above the threshold temperature at which it will prevent sufficient current from being supplied to the gate terminal of triac Q2 to cause triggering thereof. If triac Q2 ceases to be triggered, the power circuit for fuel valve winding 13W is opened and thus the fuel valve winding is protectively deenergized to prevent further fuel from being supplied to the burner. Similarly, if there should be insufficient forced-air draft supplied to burner 19, thermistor TH1 will heat above its threshold temperature and will also cause triac Q2 to cease being triggered.

If heating of either thermistor TH1 or TH2 takes place such as to cause deenergization of fuel valve winding 13W in the manner just described it will be appreciated that, as long as thermostat switch 15SW remains closed indicating continued demand for heat, potential is still available for triggering of triac Q2. Thus, when the heated thermistor TH1 and TH2 cools sufficiently, triac Q2 is once more triggered. In other words, it may be seen that reset of the control is automatic if a shutdown should be caused by overheating of the furnace plenum or by insufficient forced-air draft, since triggering of triac Q2 will cause reenergization of ignition circuit 17 and the control will once more recycle.

FIG. 2 illustrates a second embodiment of the invention. While characterized by greater simplicity, in principle the control of FIG. 2 is not greatly different from the control of FIG. 1. This second embodiment does not employ the triac Q2 utilized in the FIG. 1 circuit for supplying power to triac Q1 and gas valve winding 13W. Instead, the supply voltage on lines L1 and L2 is provided directly across triac Q1 and gas valve winding 13W upon the closing of thermostat switch 15SW. The air flow sensing thermistor TH1 and the plenum temperature sensing thermistor TH2 of this embodiment are located in the triggering circuit for triac Q1. Thus, thermistors TH1, TH2 and TH3 are connected in series such that heating of any one of the thermistors above a predetermined threshold temperature will prevent triggering current from being supplied to triac Q1 at the level required to cause triggering thereof.

In operation, the FIG. 2 circuit is not greatly different from the FIG. 1 circuit. Upon the closing of thermostat switch 15SW to indicate a demand for heat in the zone which is heated by operation of the furnace, power is supplied through diode D2 to ignition circuit 17. Its operation in this circuit is identical with that in the FIG. 1 circuit and thus recurrent sparking is generated across electrodes 19. Triggering of SCR Q3 causes a triggering current to be supplied through the series-connected thermistors TH1—TH3 to the gate terminal of triac Q1, it being assumed that none of these thermistors is heated above a threshold temperature which would prevent triggering of triac Q1. Because of the voltage provided across the main terminals of triac Q1 upon the closing of switch 15SW, the triac is triggered and energizes gas valve winding 13W to open gas valve 13 for supplying gas to burner 11. The sparking at electrodes 19 causes ignition of the fuel, and the resultant flame across the electrodes discharges capacitor C2 to terminate triggering of SCR Q3. When this occurs, capacitor C3, together with inductive gas valve winding 13W, permits continued triggering of triac Q1. Thus, gas will continue to be supplied to burner 11 and combustion will therefore continue until thermostat 15 senses no further demand for heat and accordingly opens switch 15SW, deenergizing gas valve winding 13W.

However, if ignition does not successfully take place, heating of thermistor TH3 results from the energization of heater thermistor H3 through continued operation of triggering circuit 17. When self-heating by thermistor H3 occurs, heating of thermistor TH3 takes place, such that, after a predetermined time interval to reach its threshold temperature, it prevents further triggering of triac Q1, deenergizing gas valve winding 13W to prevent gas from being further supplied to burner 11.

Similarly, if thermistor TH2 is heated above its threshold temperature because of excessive temperature in the furnace plenum, triggering of triac Q1 will cease. The air flow sensor thermistor TH1 also functions either to prevent triggering of triac Q1 or to terminate such triggering in the event that an insufficient forced-air draft is provided to burner 11. Such an insufficient draft would permit thermistor TH1 to be heated above its transition temperature by thermistor H1, it being noted that thermistor H1 is connected across lines L1 and L2 for continual energization, as in FIG. 1.

A significant difference between these two embodiments may be recognized by observing that, in the event either of thermistors TH1 and TH2 prevents triggering of triac Q1, triggering of SCR Q3 continues by virtue of the connection to line L1 through diode D2 and thus energization of heater thermistor H3 continues, causing thermistor TH3 to be heated above its transition temperature and thus above the threshold temperature at which thermistor TH3 per se will prevent triggering of triac Q1. In other words, the control is "locked out" of operation and may only be manually reset even though the thermistor, i.e., thermistor TH1 or thermistor TH2, which prevented triggering of triac Q1 in the first place, has recooled. The control is thus manually resettable only, in the event of a "lockout" caused by excessive plenum temperature or insufficient forced-air draft, rather than being automatically resettable as is the FIG. 1 control.

Each of the controls described is thus seen to be simple in design and safe and effective in operation. Further, the use of electrothermal and solid-state devices, rather than electromechanical devices, insures high reliability. Just as importantly, each of the circuits is fail-safe in operation. For example, if triggering of SCR Q3 does not take place, triggering current cannot be supplied to the gate terminal of triac Q1 and thus gas valve winding 13W cannot be energized. Also, if either of triacs Q1 or Q2 of the FIG. 1 circuit, or simply triac Q1 of the FIG. 2 circuit, should fail, energization of gas valve winding 13W is prevented. It will also be appreciated that in the event one of the thermistors TH1–TH3 fails in operation, resulting in an open triggering circuit, triggering current cannot be supplied to the gate terminal of the triac with which that thermistor is associated. Accordingly, energization of gas valve winding 13W is prevented or terminated.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What we claim is:

1. Apparatus for controlling the operation of a furnace in response to the demand of a thermostat sensing the temperature in a zone heated by the furnace, the furnace having a burner and an electrically energizable fuel valve which, when energized, supplies fuel to the burner, said apparatus comprising:

ignition means which, upon energization, generates recurrent sparking for igniting the fuel, said ignition means normally being energized when the thermostat demands heat and ceasing to generate sparking after ignition of the fuel;

a triggerable semiconductor current-switching device interconnected with the fuel valve and, when triggered, being conductive for energizing the fuel valve, said fuel valve includes an inductive winding, said switching device including main terminals serially connected with the winding;

a triggering circuit for said switching device interconnected with said ignition means and operative to supply triggering current to said switching device for initial triggering thereof upon energization of said ignition means and a capacitor in said triggering circuit cooperating with said inductive winding to supply triggering current to said switching device for continued triggering thereof after said ignition means ceases generating sparking as long as the thermostat demands heat;

a thermistor connected in said triggering circuit for preventing said triggering current from being supplied to said switching device when the thermistor is heated above a predetermined threshold temperature; and

means for heating said thermistor interconnected with said ignition means and being energized to cause heating of said thermistor when said ignition means generates sparking, said thermistor requiring a predetermined heating time interval to reach said threshold temperature, whereby if the fuel is not ignited within said predetermined interval, triggering of said switching device is terminated to prevent fuel from being further supplied to the burner.

2. Furnace control apparatus as set forth in claim 1 wherein said ignition means includes a further triggerable semiconductor current-switching device including a pair of main terminals and generates sparking when said further switching device is triggered, said capacitor being connected to one of the main terminals of said further switching device to supply said triggering current for initial triggering of the first-said switching device upon triggering of said further switching device.

3. Furnace control apparatus as set forth in claim 1 wherein said means for heating said thermistor comprises a further thermistor thermally coupled to the first-said thermistor.

4. Furnace control apparatus as set forth in claim 3 wherein each of said thermistors has a positive temperature coefficient and a transition temperature above which the resistance thereof increases relatively abruptly, said further thermistor having a higher transition temperature than that of the first-said thermistor, said thermistors together constituting an electrothermal timer.

5. Furnace control apparatus as set forth in claim 3 wherein said further thermistor is connected in a series circuit with said ignition means for concomitant energization therewith when said ignition means generates sparking, said further thermistor being deenergized when said ignition means ceases to generate sparking.

6. Furnace control apparatus as set forth in claim 5 wherein the resistance of said further thermistor is increased by energization thereof for said predetermined time interval, whereby energization of said ignition means is reduced for causing sparking to be generated at a reduced sparking rate.

7. Furnace control apparatus as set forth in claim 1 further comprising a second triggerable current-switching device which is conductive, when triggered, for causing power to be supplied to the first-said switching device, said second switching device normally being triggered when the thermostat demands heat.

8. Furnace control apparatus as set forth in claim 7 wherein said second switching device includes a triggering terminal and further comprising a second thermistor mounted for sending the temperature in a plenum of the furnace and connected to said triggering terminal of the said switching device for preventing further triggering thereof, thereby preventing further energization of the fuel valve, when heated above a predetermined threshold temperature corresponding to a predetermined maximum permissible temperature in said plenum.

9. Furnace control apparatus as set forth in claim 8 wherein said second thermistor has a positive temperature coefficient of resistivity and a transition temperature above which the resistance thereof increases relatively abruptly.

10. Furnace control apparatus as set forth in claim 8 for controlling the operation of a furnace normally having a forced-air draft supplying the burner and further comprising:

an additional thermistor mounted for being cooled by the forced draft and connected in a series circuit with said second thermistor and said triggering terminal for preventing triggering of said second switching device when said additional thermistor is heated above a predetermine threshold temperature; and

means for heating said additional thermistor, said means normally supplying insufficient heat to cause said fourth thermistor to be heated above said threshold temperature as long as there is sufficient forced-air draft, but causing heating of said additional thermistor above said threshold temperatures thereby preventing energization of the fuel valve if there is insufficient forced-air draft.

11. Furnace control apparatus as set forth in claim 10 wherein said additional thermistor has a positive temperature coefficient of resistivity and a transition temperature above which the resistance thereof increases relatively abruptly, and said means for heating said additional thermistor comprises another thermistor having a positive temperature coefficient of resistivity and a transition temperature higher than that of said additional thermistor and above which the resistance thereof increases relatively abruptly.

12. Furnace control apparatus as set forth in claim 7 wherein each of said switching devices comprises a triac.

13. Furnace control apparatus as set forth in claim 1 further comprising a second thermistor, said thermistor being mounted for sensing the temperature in a plenum of the furnace and in said triggering circuit for preventing said triggering current from being supplied to said switching device when said second thermistor is heated above a predetermined threshold temperature corresponding to a predetermined maximum permissible temperature in said plenum.

14. Furnace control apparatus as set forth in claim 13 wherein said second thermistor has a positive temperature coefficient and a transition temperature above which the resistance thereof increases relatively abruptly.

15. Apparatus for controlling the operation of a furnace in response to the demand of a thermostat sensing the temperature in a zone heated by the furnace, the furnace having a burner and an electrically energizable fuel valve which, when energized, supplies fuel to the burner, the burner normally being supplied with a forced-air draft, said apparatus comprising:

an ignition circuit connected for energization when the thermostat demands heat, said ignition circuit generating recurrent sparking for igniting the fuel and ceasing to generate sparking after ignition of the fuel;

a triggerable semiconductor current-switching device having a pair of main terminals and a triggering terminal, said main terminals being connected with the fuel valve for energization thereof when said switching device is triggered;

a triggering circuit interconnecting said triggering terminal and said ignition circuit for normally supplying current to said triggering terminal initially upon energization of said ignition circuit and then for as long as the thermostat demands heat, said triggering circuit including:

a first thermistor connected for preventing said triggering current from being supplied to said triggering terminal, thereby preventing further energization of the fuel valve, when said first thermistor is heated above a predetermined threshold temperature;

a second thermistor mounted for sensing the temperature in a plenum of the furnace and connected for preventing said triggering current from being supplied to said triggering terminal, thereby preventing further energization of the fuel valve, when said second thermistor is heated above a predetermined threshold temperature corresponding to a predetermined maximum permissible temperature in said plenum; and

a third thermistor mounted for being cooled by the forced draft and connected for preventing said triggering current from being supplied to said triggering terminal thereby preventing further energization of the fuel

valve when said third thermistor is heated above a predetermined threshold temperature;

means for heating said first thermistor interconnected with said ignition circuit for concomitant energization therewith to cause heating of said first thermistor when said ignition circuit generates sparking, said first thermistor requiring a predetermined heating time interval to reach said threshold temperature thereof, whereby if the fuel is not ignited within said predetermined interval, fuel is prevented from being further supplied to the burner; and

means for heating said third thermistor normally supplying insufficient heat to cause said thermistor to be heated above said threshold temperature thereof as long as there is sufficient forded-air draft, but causing heating of said third thermistor above said threshold temperature thereof, whereby fuel is prevented from being supplied to the burner, if there is insufficient forced-air draft.

16. Furnace control apparatus as set forth in claim 15 wherein said means for heating said first thermistor comprises a further thermistor thermally coupled to said first thermistor and said means for heating said third thermistor comprises another thermistor thermally coupled to said third thermistor.

17. Furnace control apparatus as set forth in claim 16 wherein each of said first, second and third thermistors has a positive temperature coefficient and a transition temperature above which the resistance thereof increases relatively abruptly.

18. Furnace control apparatus as set forth in claim 17 wherein each of said first, second and third thermistors is connected in a series circuit with said triggering terminal.

19. Furnace control apparatus as set forth in claim 16 wherein said switching device comprises a triac.