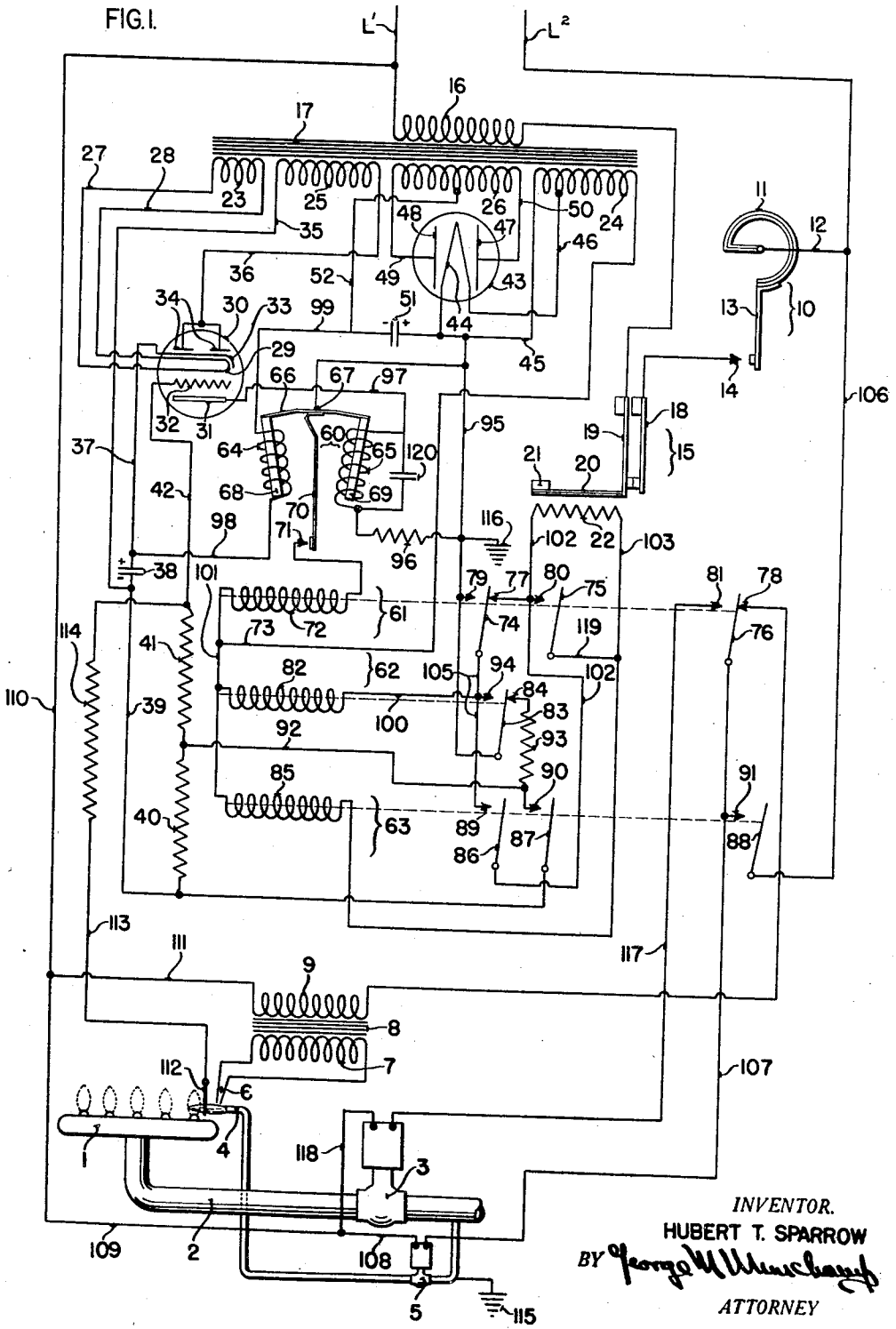
June 17, 1941. H. T. SPARROW 2,245,730

CONTROL SYSTEM

Filed May 12, 1937 3 Sheets-Sheet 1

FIG. 1.




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CONTROL SYSTEM

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FIG. 2.

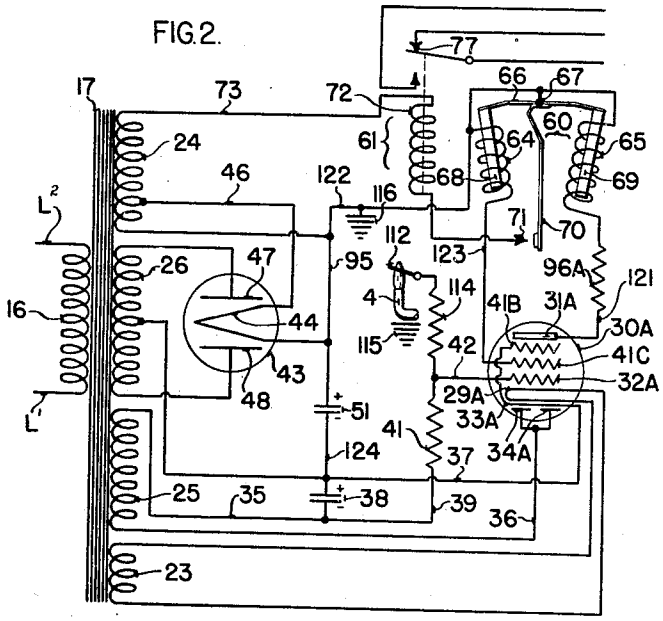



FIG. 4.

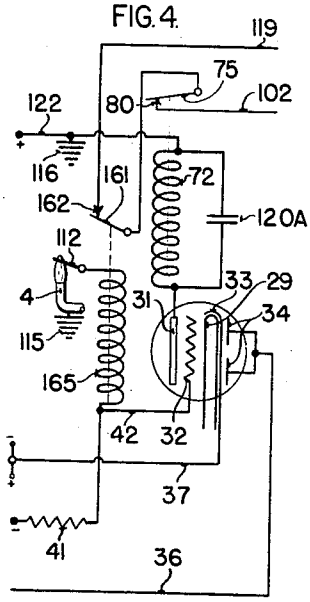



FIG. 3.

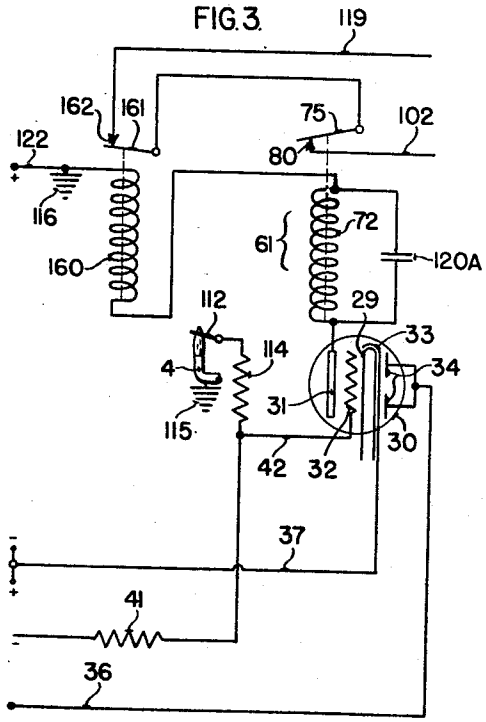
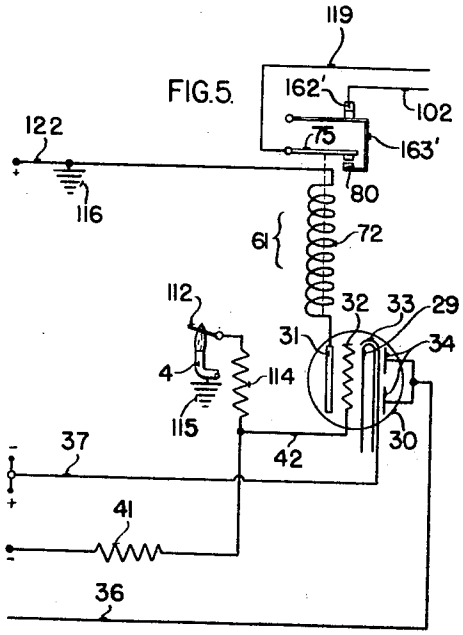



FIG. 5.




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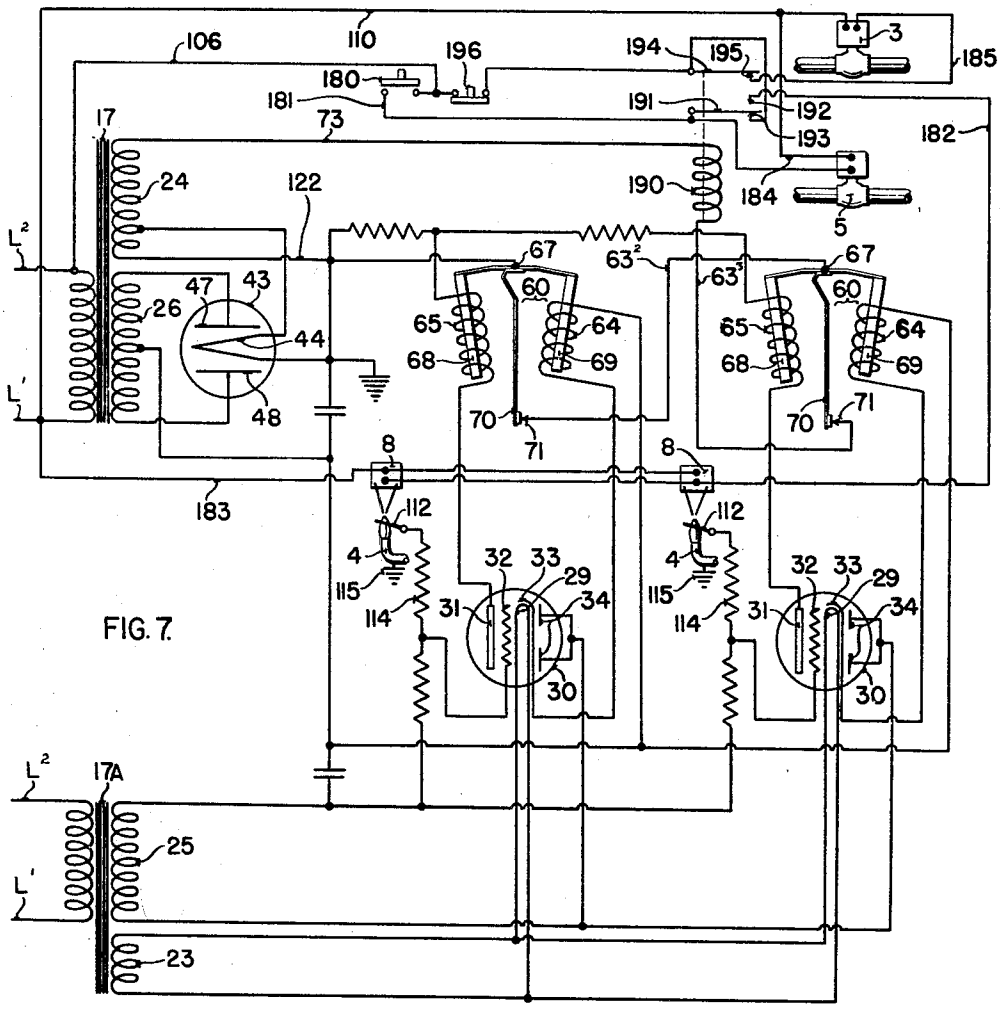



FIG. 7.

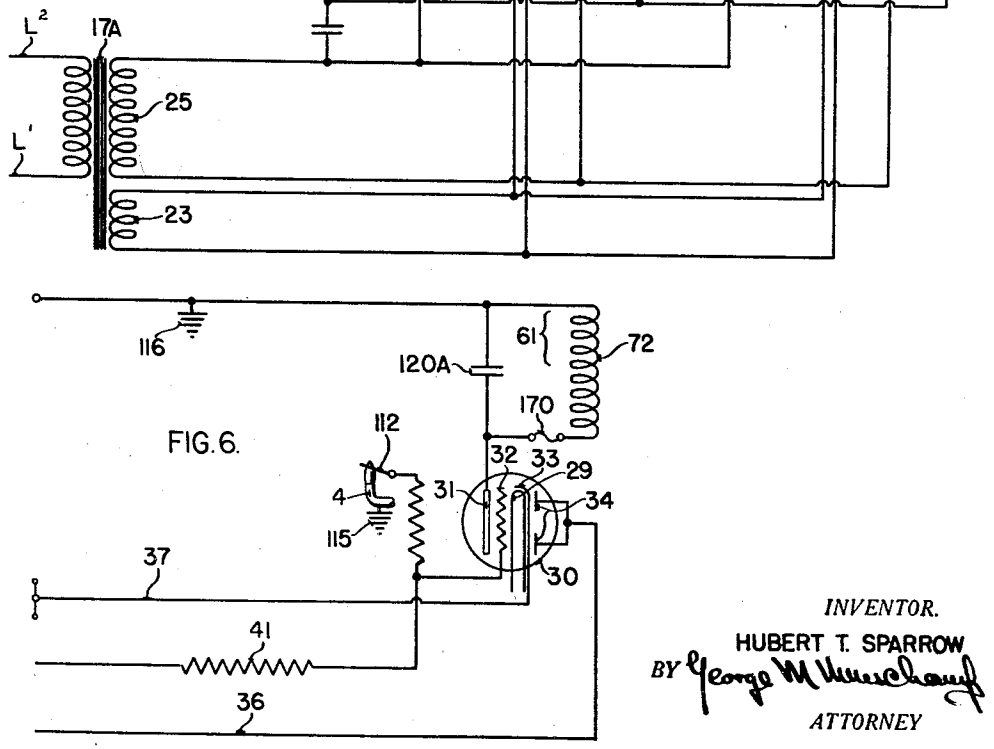



FIG. 6.

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Patented June 17, 1941 2,245,730

# UNITED STATES PATENT OFFICE

2,245,730

## CONTROL SYSTEM

Hubert T. Sparrow, Minneapolis, Minn., assignor to The Brown Instrument Company, Philadelphia, Pa., a corporation of Pennsylvania

Application May 12, 1937, Serial No. 142,115

31 Claims. (Cl. 158—28)

The present invention relates to an improved fuel combustion control system and more particularly to such a control system having safety means for distinguishing between normal conditions of combustion and abnormal conditions.

An object of the present invention is to provide a system of the class described wherein means are provided for distinguishing between an actual condition of combustion and a simulated condition of combustion.

A further object of the invention is to provide a fuel combustion control system having means for automatically supplying and igniting the fuel wherein further means are provided for preventing the operation of the fuel supplying and igniting means if abnormal conditions exist.

A further object of the invention is to provide such combustion checking means which operate upon the occurrence of an abnormal condition even after initial combustion has taken place to shut down the fuel supply means.

Another object of the invention is to provide a combustion control system of the class described in which the combustion conditions in a plurality of fuel fired furnaces may be controlled by means of a single control system.

In combustion control systems which have been proposed heretofore, various means have been employed for determining if combustion conditions are proper, and whether combustion actually takes place, one such means comprising an electrode which extends into the flame of the burner and which is so connected in the system as to provide a conductive path of relatively low resistance to ground through the flame. The variation in the electrical conductivity of this path to ground when a flame is present and when a flame is not present is commonly employed to change the bias on the control grid of an electronic device for controlling the thermal safety switch. Since there is a possibility that a low resistance path may be set up from the electrode to ground through other agencies than by means of the flame, for example, a low resistance path which may be established between the flame electrode and ground by reason of carbonization, by accidental touching of the electrode to ground, or by other abnormal conditions simulating combustion, provisions have been made in devices of the prior art for preventing the fuel supplying and ignition means from being turned on when such an abnormal condition exists.

An abnormal condition of this character simulating combustion may arise after the system is already in operation and, hence, it is desirable to provide means for distinguishing between this abnormal condition and actual combustion while the system is in operation. For example, in a thermostatically controlled house heating system, if the control system is insensitive to the presence of the flame after initial ignition of the latter, the fuel feeding means will be operated continuously as long as the room thermostat is closed. If the flame should then be extinguished, the furnace will be flooded with atomized fuel and a highly explosive mixture of the latter will be permitted to accumulate.

In a combustion system in which a plurality of burners operate together as for example, for heating in unison and supplied with a common fuel line, it is important that an abnormal or dangerous condition of any one of the burners is guarded against. In such a system failure of any one of the burners to ignite may result in an explosion.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, and the advantages possessed by it reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

Of the drawings:

Fig. 1 is a diagrammatic view illustrating one embodiment of the invention as adapted for use with a single furnace;

Fig. 2 illustrates a modification of a portion of the device of Fig. 1;

Figs. 3 to 6, inclusive, illustrate further modifications of the device of Fig. 1; and

Fig. 7 is a diagrammatic view illustrating the invention as employed for use with a plurality of furnaces.

In Fig. 1 of the drawings a gas burner 1 is shown as supplied with gas through conduit 2 and the flow of gas to the burner is controlled by an electrically operated or other suitable valve 3. A pilot burner 4 is provided which is controlled by an electrically operated or other suitable valve 5, and means are provided for igniting the pilot flame including a pair of electrodes 6 which are connected to the terminals of a secondary winding 7 of an ignition transformer 8 having a primary winding 9 which is adapted to be energized from the alternating current supply lines L' and $L^2$.

The fuel valve operating circuit of my control

system is controlled by means of the thermostat 10 which may be located in a room or space to be heated. The thermostat 10 may be of any suitable construction and includes a bimetallic element 11 connected by means of conductor 12 to line $L^2$, and a contact blade 13 adapted to engage a stationary contact 14 which is connected to line L' through thermal switch 15 and winding 16 of transformer 17.

The thermal switch 15 is preferably of the form disclosed in the Patent 1,958,081 issued to F. S. Dennison May 8, 1934. As shown more or less diagrammatically in the drawings, this switch comprises a stationary arm 18 and a movable arm 19 biased for movement away from arm 18 but normally held in engagement with the latter by means of a bimetallic element 20. Element 20 is rigidly secured at one end to a block 21 and is arranged to be heated by a coil 22 when the latter is energized through a circuit which will later be described. Upon energization of coil 22 for a predetermined period of time, element 20 will be warped sufficiently in the clockwise direction to permit arm 19 acting under spring or other bias to separate from switch arm 18 thereby interrupting the circuit including thermostat 10. The switch 15 will remain locked in this position until manually returned to its normal closed position.

The transformer 17 which supplies power for the control system is a combination step-up and step-down transformer and comprises the line voltage primary winding 16, low voltage secondary windings 23 and 24, and high voltage secondary windings 25 and 26. The low voltage secondary winding 23 is connected by conductors 27 and 28 to the heater filament 29 of an electronic valve 30 and supplies energizing current thereto. The electronic valve 30 is a duplex-diode-triode type and functions both as a rectifier to supply a source of direct current for grid biasing means and as an amplifier. The valve 30 includes an anode 31, a grid 32, a cathode 33, a pair of diodes 34, and the heater filament 29. The transformer secondary winding 25 is connected by conductors 35 and 36 in a circuit including the cathode 33 and the diodes 34 which may be connected together since it is not necessary in the present case to have full wave rectification. This circuit may be traced from the diodes 34, cathode 33, conductor 37, a condenser 38, conductor 35, through the secondary winding 25, and conductor 36 to the diodes 34. Since only half wave rectification is obtained with the diodes connected as shown in Fig. 1, pulsating direct current flows from the diodes 34 to the cathode 33 and this pulsating current is impressed across the terminals of the condenser 38 which operates to filter out the pulsations. It will be noted that the cathode 33 is connected to the positive side of the condenser, and that the negative side of the latter is connected through conductor 39, resistors 40 and 41, and conductor 42 to the grid 32. The tendency of the voltage produced through the rectifying action of the diodes 34 and cathode 33 is thus seen to bias the grid 32 negatively.

A second electronic valve 43 is provided, which valve may be a conventional full wave rectifier, having a filament cathode 44 connected by conductors 45 and 46 with a suitable portion of the transformer secondary winding 24 and receiving energizing current therefrom. The anodes 47 and 48 of the valve 43 are connected by conductors 49 and 50 with the terminals of the transformer secondary winding 26, and the rectified plate current of the valve 43 is connected across the terminals of a filtering condenser 51. A center tap on the secondary winding 26 is connected by a conductor 52 to one terminal of the condenser 51 and the other terminal of the latter is connected to the filament cathode 44 so that a direct current voltage is maintained across the condenser 51. The positive terminal of this condenser is connected, under certain conditions, through various relay arms and contacts, to be presently described, to the grid 32. When so connected, the tendency of the power supplied by secondary winding 26 and the rectifier valve 43 is to raise the potential of the grid 32 with respect to the cathode 33. It will thus be seen that two sources of direct current voltage are provided, one of which is connected so as to bias the grid negatively, and the other of which when connected to the grid, tends to reduce said bias.

As shown in Fig. 1, a plurality of relays designated as 60, 61, 62 and 63 are employed in the control system. The relay 60 is a sensitive differential relay which is employed primarily for distinguishing between normal conditions of combustion and conditions which simulate combustion. The main function of the relay 61, which is controlled by the relay 60, is to check the operation of the system before the fuel igniting and fuel feeding means are permitted to operate, and after combustion has been established, to bring about the desired operating conditions. Energization of the relay 61 will result in the closing of an energizing circuit to the relay 62 and, if only normal conditions of combustion are present, the relays 60 and 61 will be deenergized and an operating or combustion producing condition of the system may be established. De-energization of the relay 61 results in the closure of an energizing circuit to the relay 63 which functions to establish the conditions necessary for combustion.

The three relays 61, 62 and 63 are alternating current relays and are energized through a circuit from the transformer secondary winding 24. The relay 60 is a direct current relay and is included in the output circuit of the electronic valve 30. Relay 60 comprises two coils 64 and 65 which are operatively associated with a balanced armature 66. This armature is pivoted for rotation at 67, a point intermediate its ends, and carries iron cores 68 and 69 at each end which are adapted to move into and out of the coils 64 and 65, respectively. The armature 66 also carries a switch blade 70 which is adapted to engage a contact 71. The winding 64 is connected in the cathode circuit and the winding 65 is connected in the anode circuit of the electronic valve 30 so that, when the valve is conductive as it normally will be, the same current flows through both windings and the winding 65 is wound with more turns than the winding 64. In consequence, when normal operating current flows through both windings, the winding 65 will be stronger magnetically than the winding 64 and the armature 66 will be rotated in a clockwise direction. Under abnormal conditions, however, as later described in detail, additional current will be caused to flow through the winding 64 and the latter will become stronger magnetically than the winding 65.

As illustrated in Fig. 1 rotation of the armature 66 in a clockwise direction moves the armature switch blade 70 into engagement with the contact 71, which engagement results in the closure of an energizing circuit to the relay 61 from transformer winding 24 over conductor 45, switch arm

70, contact 71, a winding 72 of relay 61, conductor 73 to the opposite side of transformer winding 24. Winding 72 is operatively associated with three switch arms 74, 75 and 76 which are spring biased toward the right, and when the relay winding 72 is de-energized, the arms 74 and 76 engage contacts 77 and 78, respectively. When the relay winding 72 is energized, the arms 74, 75, and 76 move into engagement with contacts 79, 80, and 81, respectively.

The relay 62 comprises a winding 82 which is operatively associated with a switch arm 83. This arm is similarly biased toward the right and, when the winding 82 is de-energized, is in engagement with a contact 84.

The fourth relay 63 comprises a winding 85 which is operatively associated with three relay arms 86, 87 and 88. These arms are also biased towards the right and are adapted to be moved into engagement with contacts 89, 90 and 91 upon energization of the relay winding 85.

When the temperature of the room or space to be controlled falls below the value it is desired to maintain, the thermostat 10 operates to move the switch blade 13 into engagement with the contact 14 resulting in closure of an energizing circuit to the transformer primary winding and thereby energization of the transformer secondary windings. As soon as the cathode 33 of the tube 30 becomes heated, a direct current voltage appears across the terminals of the condenser 38 which, because of the connections previously described, causes a negative biasing voltage to be applied to the grid 32 of the tube 30. In a similar manner, as soon as the cathode 44 of the tube 43 becomes heated, a direct current voltage appears across the terminals of the condenser 51. As previously pointed out, the negative terminal of the condenser 51 is connected together with the positive terminal of condenser 38 to the cathode 33.

When the system is initially energized, the various relays are in the positions shown in Fig. 1, and the grid 32 is connected to the positive side of condenser 51 through a circuit including grid 32, conductor 42, resistance 41, conductor 92, resistance 93, contact 84, switch arm 83, and conductor 95 to the positive terminal of the condenser 51. The result of this connection of grid 32 to the positive terminal of the condenser 51, which has a voltage applied across it which greatly exceeds the voltage across the condenser 38, is that the grid 32 is subjected to a positive voltage which reduces the negative biasing action of the condenser 38 sufficiently to cause a current to flow between anode 31 and cathode 33. The circuit path through which such anode circuit flows may be traced from the positive terminal of the condenser 51, conductor 95, resistance 96, relay winding 65, conductor 97, anode 31, cathode 33, conductor 37, conductor 98, relay winding 64 and conductor 99 to the negative side of the condenser 51.

This flow of current through the anode circuit including the relay windings 64 and 65 is effective to cause the armature 66 to rotate in a clockwise direction and to move the switch blade 70 into engagement with the contact 71, and to thereby close the previously mentioned energizing circuit to the relay 61. The relay arms 74, 75 and 76 are then moved into engagement with the contacts 79, 80 and 81, respectively. The movement of arm 74 into engagement with contact 79 establishes an energizing circuit through the relay 62 which may be traced from the left end terminal of the transformer secondary winding 24, conductor 45, conductor 95, contact 79, switch blade 74, conductor 105, conductor 100, relay winding 82, conductor 101, and conductor 73, back to the other terminal of the transformer secondary winding 24. The establishment of this energizing circuit for relay 62 causes the switch blade 83 to be moved into engagement with the contact 94, and such engagement establishes a holding circuit for the relay 62 which may be traced from conductor 45, conductor 95, switch blade 83, contact 94, conductor 100, relay winding 82, conductor 101, conductor 73, and the transformer secondary winding 24 to the conductor 45.

At the same time that the switch blade 83 moves into engagement with the contact 94 it moves out of engagement with the contact 84, and since the previously traced connection between the grid 32 and the positive side of the condenser 51 depended upon the engagement of switch arm 83 with the contact 84, the grid 32 is now subjected only to the negative biasing voltage applied across condenser 38. The result is that the grid potential is now sufficiently negative to render the tube 30 non-conductive, and since no plate current flows through the relay windings 64 and 65, the latter are de-energized and the switch blade 70 moved out of engagement with the contact 71.

When the switch blade 70 is so moved out of engagement with the contact 71 the relay winding 72 is de-energized and the switch blade 74 again engages the contact 77 to close an energizing circuit to the relay winding 85. This circuit is energized only because the previously mentioned holding circuit for the relay winding 82 has been closed, and may be traced from the left hand end of transformer secondary winding 24, conductor 45, conductor 95, switch blade 83, contact 94, switch blade 74, contact 77, conductor 102, heating element 22, conductor 103, relay winding 85, conductor 101, and conductor 73 back to the other side of the transformer secondary winding 24. The energization of relay 63 causes the relay arms 86, 87 and 88 to be moved into engagement with the contacts 89, 90 and 91, respectively. The engagement of switch blade 86 with contact 89 closes a holding circuit for the relay winding 85 from one end of the transformer secondary winding 24, conductor 45, conductor 95, switch blade 83, contact 94, conductor 105, contact 89, switch blade 86, conductor 102, heating element 22, conductor 103, relay winding 85, and conductors 101 and 73 back to the other side of the transformer secondary winding 24. The establishment of the holding circuit just traced functions to render the energization of relay winding 85 independent of relay 61 so that when the relay 61 becomes re-energized, as subsequently takes place, the relay 63 will remain energized. It is pointed out, however, that the energizing and holding circuit for relay winding 85 includes the heating element 22 of the thermal safety switch 15 so that as soon as the relay winding 85 is energized the heating element of the thermal safety switch begins to heat the bimetallic element 20.

When the relay 85 is energized, the resulting movement of the switch blade 88 into engagement with the contact 91 results in the establishment of the following circuit through the operating means for the valve 5, which controls the supply of fuel to the pilot burner: from supply line $L^2$, conductor 106, switch blade 88, con-

tact 91, conductor 107, the pilot valve actuating means, and conductors 108, 109 and 110 to the supply line L'. The establishment of this circuit causes the valve controlling the pilot to be opened with the result that fuel is fed thereto. At the same time, the ignition transformer 8 is energized through a circuit including supply line $L^2$, conductor 106, switch blade 88, contact 91, conductor 107, switch blade 76, contact 78, the ignition transformer primary winding 9 and conductors 111 and 110 to the supply line L'. This energization of the primary winding of the ignition transformer 8 causes a high voltage to be induced across the terminals of the secondary winding 7 which is applied to produce a spark across the electrodes 6.

Combustion will now take place if conditions are proper and the control system will subsequently operate to open the main fuel valve and to de-energize the ignition transformer. As soon as a flame appears at the pilot, a circuit is established through the flame which operates to reduce the negative bias on the grid 32 to render the tube 30 conductive. The plate current conducted by the latter energizes the relay 60 which operates in the manner previously described to re-energize the relay 61. As will be described hereinafter, re-energization of the relay 61 results in operation of the main fuel valve and de-energization of the ignition means.

The means for reducing the negative bias on the grid 32 for rendering the tube 30 conductive and subsequently causing opening of the main gas valve 3 includes an electrode 112 which is insulated from the burner and extends into the pilot flame. This electrode is connected through conductor 113, protective resistance 114, and conductor 42 to the grid 32. The pilot supply pipe is connected to ground as indicated at 115 and the positive side of the condenser 51 is connected to ground as indicated at 116. When a flame of lower resistance than the air gap appears at the pilot by reason of the same being lighted, an electrically conductive path is established between the grid 32 and the positive side of the condenser 51. This path is of low enough resistance to drive the grid sufficiently positive to render the tube 30 conductive. The resistor 114 is of comparatively low value and is provided to prevent the grid from being subjected to too high a voltage if the electrode should accidentally be connected directly to ground, and functions to limit the flow of grid current in the electronic valve 30 to a safe value.

When the tube 30 is thus rendered conductive, the resulting energization of relay 60 and consequent energization of relay 61 operates to move the switch arms 74, 75 and 76 into engagement with the contacts 79, 80 and 81, respectively. Movement of the arm 76 out of engagement with the contact 78 causes the previously traced circuit through the primary of the ignition transformer to be interrupted with the result that the ignition means is de-energized. At the same time movement of the arm 76 into engagement with contact 81 establishes an energizing circuit to the valve actuating means 3 from supply line $L^2$, conductor 106, switch blade 88, contact 91, conductor 107, switch blade 76, contact 81, conductor 117, the control valve 3, conductor 118, conductor 109, and conductor 110 to the supply line L'. The main fuel valve 3 is then opened and fuel is admitted to the burner 1, which fuel is subsequently ignited by the pilot flame.

The system is not permitted to open the main fuel valve, however, until a check has been made on the insulation resistance of the system. Referring to Fig. 1 it will be noted that until the relay 63 is energized, the connection between the grid 32 and the negative side of the condenser 38 includes resistances 40 and 41. As soon as the relay 63 is energized, however, with the resultant moving into engagement of switch arm 87 with contact 90, the resistance 40 is shunted out through a circuit from one end of resistance 40, conductor 92, contact 90, switch blade 87 to the opposite side of the resistor. It is thus seen that until relay 63 is energized, the resistance between the grid and the negative side of the condenser 38 is much greater than after energization of this relay so that during the initial stages of operation of the system the grid is biased less negatively.

The advantage obtained in so biasing the grid less negatively during the initial stages of operation and increasing this bias later on is that if, through insulation leakage or due to a low resistance between the electrode 112 and the pilot burner 4, there is a path of comparatively low resistance between the grid and the positive side of the condenser 51, which side is the grounded side, the grid bias will remain sufficiently low so that the tube 30 will be conductive. Since it is necessary for the tube 30 to be non-conductive before the relay 63 can be energized, the latter will not be energized in the event of excessive insulation leakage. As soon as the resistance 40 is shunted out, however, the negative bias on the grid 32 is increased so that in order to again reduce the grid bias sufficiently to render the tube 30 conductive, a substantial decrease in resistance between the grid and the positive side of the condenser 51 is required.

In this manner a check is made on the insulation resistance of the system while at the same time provision is made against a faulty check of the presence of a flame being made by virtue of the grid bias not being sufficiently negative that the system is too sensitive. By cutting out resistor 40 it is necessary that there be a material reduction in the resistance in the circuit between the grid 32 and the positive side of the condenser 51 such as in the event of a flame bridging the gap between the pilot and the electrode 112. Moreover, this insures recycling in the event of pilot flame failure, that is, immediate closure of the main fuel valve 3 and re-energization of the ignition transformer 8 to re-light the pilot flame and to subsequently open the main fuel valve. This insurance is had since even though the electrode may have become somewhat carbonized in use, the resistance between the electrode and ground by virtue of the carbonization will ordinarily be too high to maintain the bias sufficiently low to permit the tube 30 to become conductive.

It will be noted that the connection between the grid 32 and the positive side of the condenser 51 includes the resistance 41. The grid is connected through this resistance to relay contact 90, and since it is extremely difficult to adequately insulate parts of a relay without impeding their proper function, it is desirable that the resistance 41 be of rather large value, for example, of the order of 50 megohms. There is then assurance that any path between the grid and the grounded high potential side of the system, other than through the electrode 112, will be of such high resistance as to not appreciably raise the potential of the grid.

The re-energization of relay 61 with the resultant movement of arms 74 and 75 into engagement with contacts 79 and 80, respectively, establishes a new holding circuit for relay winding 85 which does not include the resistance 22 of the thermal safety switch 15 but shunts that resistance. This circuit may be traced from one end of the secondary winding 24, through conductors 45 and 95, contact 79, switch blade 74, conductor 105, contact 89, switch blade 86, conductor 102, contact 80, switch blade 75, conductors 119 and 103, winding 85, and conductors 101 and 73 to the other end of secondary winding 24. Short circuiting of the resistance 22 in this manner operates to render the thermal safety switch 15 inoperative and the system will then remain in operation as long as normal combustion conditions exist and the thermostat 10 is in closed position.

As illustrated in Fig. 1, an additional safety feature has been provided for delaying the action of the ignition cut-off means until there is a certainty that a steady pilot flame is burning. The condenser 120, shown connected across the relay winding 65, is provided for this purpose. When the tube 30 is conductive and energizing current flows through the winding 65, the latter will not become magnetically strong enough to cause clockwise rotation of the armature 66 until the condenser 120 becomes charged. The relay 61, therefore, will not become re-energized immediately upon the appearance of a flame at the pilot and consequently delay in de-energizing the ignition circuit will be introduced. After a predetermined period of time, depending upon the capacity of condenser 120, the condenser will become charged and sufficient energizing current will flow through the winding 65 to cause clockwise rotation of the armature 66 and subsequent energization of the relay 61, and thereby de-energization of the ignition circuit. By choosing a condenser of suitable capacity any desired time delay can be obtained and the action of the ignition interrupting means can be delayed until there is a certainty that the pilot flame is burning steadily.

If, for any reason, the pilot burner should not become lighted, the potential of grid 32 will not be raised sufficiently to cause energization of relays 60 and 61. The result will be that the last traced holding circuit for relay coil 85 will not be established and the current flowing therethrough must pass through the heater winding 22. After a predetermined period of time, this will cause the bimetallic element 20 to be heated sufficiently to result in a separation of switch arms 18 and 19. The separation of the switch arms opens the circuit to the primary winding 16 of transformer 17 and de-energizes the entire system. As was previously noted, the switch arms 18 and 19 cannot be automatically reset so that it is necessary for an attendant to investigate the condition which prevents ignition of the pilot burner before the system can again be put into operation.

Moreover, since it is necessary for the relay 61 to be energized and de-energized, before the relay 63 can be energized, which last mentioned relay controls the ignition of the pilot fuel supply, there is assurance that there will be no faulty check of the presence of combustion due to the presence of a low resistance path between electrode 112 and the pilot burner 4. If such a condition should exist, the relay 61 would not be de-energized, so that relay 63 would not be energized and the fuel supply and ignition means would not be brought into operation.

As was mentioned previously, if a condition simulating combustion should be established after the system is in operation, the system will operate to close the main fuel supply valve. If a low resistance path is established between electrode 112 and the pilot burner 4 after the system is already in operation, the potential on the grid 32 will be increased sufficiently in the positive direction to cause the flow of current between the grid and cathode of the tube 30. This grid current will flow through the winding 64 of the relay 60 but will not flow through the winding 65 so that the former will be made stronger magnetically than the latter and the armature 66 will be rotated in a counter-clockwise direction, resulting in separation of the switch arm 70 and contact 71. The relay 61 will then be de-energized and the thermal safety switch 15 will subsequently operate to de-energize the system.

The circuit through which grid current flows when the electrode 112 is connected through a low resistance path to ground, may be traced from the positive side of condenser 51, conductor 95, ground connection 116, ground connection 115, electrode 112, conductor 113, resistor 114, conductor 42, grid 32, cathode 33, conductor 37, conductor 98, relay winding 64, and conductor 99 to the negative side of condenser 51. In the use of the present invention, under certain conditions, it has been found desirable to so establish the circuit constants of the system such that when the resistance between the flame electrode 112 and ground is 10,000 ohms or less, grid current will flow and the relay 60 will be operated to de-energize the relay 61. When the system is so operated, the resistance 114 should have a value of at least 25,000 ohms in order to limit the flow of grid current in the tube 30 to prevent damage thereto. It is also desirable from a circuit operating standpoint that the grid current flow between the grid 32 and cathode 33 be limited because if this is not done, the grid will become hot and will become an emitter of electrons. These electrons will travel to the anode 31 and additional current will thereby flow in the relay winding 65. The result will be that additional current will flow in both of the windings 64 and 65 and the operation of the relay 60 will be unstable. By limiting the flow of grid current in the tube 30, however, this condition is obviated and the system is extremely stable in operation.

It will be noted that means have been provided for thoroughly testing the operation of the combustion control system before the establishment of combustion producing conditions, and after combustion has been established. Thus, if, as a result of carbonization of the electrodes, or direct connection of the electrodes to ground, an abnormal condition exists before the main fuel valve is open, the main fuel valve will not be opened and the system will be rendered inoperative. If the electrode is connected to ground through direct connection or because of excessive carbonization after the system is already in operation, the system will immediately detect this abnormal condition and operate to close the main and pilot fuel valves.

Moreover, assurance is had that there will be no delay in checking the presence of a flame preparatory to shunting of the thermal safety switch, by reason of the time required to heat the filaments in tubes 30 and 43. Before the re-

lay 62 can be energized, it is necessary for relay 61 to be energized and this cannot take place until the filaments are heated. By thus requiring energization and de-energization of the relay 61 which ultimately is energized to shunt out the thermal safety switch, means have been provided for guarding against a condition which might arise through a shorted electrode wherein the thermal safety switch would be shunted out even though there was no combustion with the result that the ignition and fuel supply means would continue in operation without combustion of the fuel being supplied taking place. Moreover, means have been provided for checking the operation of a component part of the system. If the tubes 30 and 43 are not functioning properly, for example, if the filaments burn out, the relay 61 will not be energized. If the tubes 30 and 43 should be functioning properly, but the resistance across the flame gap should be sufficiently low that the flame checking means might otherwise work even in the absence of a flame, the relay 61 will not be initially de-energized so that it is impossible for the relay 63 to be energized so as to establish combustion under these conditions.

Furthermore, means have been provided for avoiding the disadvantages of certain devices of the prior art wherein the establishment of a low resistance path between the electrode 112 and ground while the system is in operation remains undetected. It will be noted that if carbonization of the electrode 112 occurs to a sufficient degree to reduce the resistance between the electrode and ground to a value of approximately 10,000 ohms that the system will operate to close the main fuel supply valve. The presence of other abnormal conditions producing the same low resistance path from the flame electrode will operate in a similar manner to de-energize the system. It is thus seen that the system may be proportioned so that slight variations in the conductivity of the flame will not cause the system to be de-energized, but if the resistance from the electrode to ground decreases to an abnormally small value the system will be de-energized.

In Fig. 2, I have illustrated, more or less diagrammatically, a modification of a portion of the device of Fig. 1. In this modification, the relay 60 is not actuated in response to an abnormal condition by virtue of the flow of grid current, as in Fig. 1, but in other respects the operation of this device may be identical with the operation of the device of Fig. 1. For purposes of simplification, only the relay 61 has been shown in Fig. 2 and the resistance 40 of Fig. 1 and the circuit for shunting out the latter has been omitted. It will be understood, however, that the detection unit shown in Fig. 2 may be connected in the control circuit of Fig. 1 and operated in the identical manner in which the detection unit of Fig. 1 is operated.

Referring to Fig. 2, it will be noted that the duplex-diode-triode 30 of Fig. 1 has been replaced by a duplex-diode-pentode type tube 30A. Tube 30A includes an anode 31A, a cathode 33A, a grid 32A, a screen 41C, and a suppressor grid 41B. The tube also includes a cathode heater 29A and a pair of diode anodes 34A. Since only half-wave rectification is required, the anode diodes 34A may be connected to each other as in Fig. 1. The suppressor grid 41B is connected to the cathode 33A in the usual manner, and functions to prevent the flow of secondary electrons from the anode 31A to the screen 41B. The relay winding 65 is connected from the positive side of the condenser 51 to the anode 31A through the conductor 121 which has a resistor 96A inserted therein. The purpose of the resistor 96A is to limit the flow of plate current in the tube 30A. The relay winding 64 is connected over conductor 122 from the positive side of the condenser 51 over conductor 123 to the screen 41C. The diodes 34A are connected to conductor 36 to one terminal of the transformer secondary winding 25 and the other terminal of the winding 25 is connected by the conductor 35 to one terminal of the condenser 38. The other terminal of the condenser is connected to conductor 37 to the cathode 33A. The condenser 38 has impressed across its terminals a pulsating direct current voltage produced by the diode unit, the pulsations of which are filtered out by the condenser. The grid 32A is connected through resistor 41 to the negative terminal of condenser 38 by the conductors 39 and 42 so that the tendency of the voltage produced by the rectifying action of the diodes 34A is to bias the grid 32A negatively.

The rectifier 43 of Fig. 2 is identical with the correspondingly identified rectifier tube of Fig. 1 and is connected in an identical manner through the transformer secondary winding 26 to the opposite terminals of the condenser 51. Thus a pulsating direct current voltage is maintained across the condenser 51, the pulsations of which are filtered out by the condenser. The two power supplies are connected in series, as in Fig. 1, through a conductor 124 which connects the negative terminal of condenser 51 with the positive terminal of condenser 38. The grid 32A is connected through resistor 114 and the flame resistance to the positive terminal of the condenser 51 by conductor 95 so that the tendency of the voltage across the condenser 51 is to reduce the negative bias on the grid 32A which is applied thereon by the condenser 38. As in Fig. 1 a further connection may be provided between the grid 32A and the positive side of condenser 51 through switch blade 83 and resistor 93.

The checking operations of the device of Fig. 2 preparatory to combustion may be identical with those described in connection with Fig. 1, and hence, require no further description. If an abnormal condition should occur after the system is already in operation, the device of Fig. 2 will operate to de-energize the combustion system. When a normal flame bridges the gap between the pilot 4 and electrode 112, the negative potential maintained on the grid 32A by the condenser 38 will be reduced and space current will be conducted by the tube 30A. With this potential maintained on the grid 32A, most of the space current will flow to the anode 31A so that greater current will flow in the winding 65 of the relay 60 than in the winding 64, and energize the relay 60 for clockwise rotation. The switch blade 70 will then engage the contact 71 to close an energizing circuit to the relay 61. The area of the anode 31A is much greater than the area of the screen 41C, and the suppressor grid 41B prevents the flow of secondary electrons from the anode 31A to the screen 41C so that normally most of the space current will flow to the anode and thereby to the winding 65.

If the resistance of the path from the electrode 112 to ground, however, should decrease to a value approximating 10,000 ohms as a result of carbonization of the electrode 112 or any other abnormal condition, the grid 32A will be connected through a much lower resistance to the

positive side of the condenser 51 and accordingly the potential thereon will be driven in the positive direction. Because of the presence of the current limiting resistor 96A in the anode circuit, the resulting increase in space current will not materially increase the flow of current through the winding 65, but will flow in the screen circuit through the relay winding 64. The relay winding 64 will then become stronger magnetically than the winding 65 and the switch blade 70 accordingly will be rotated out of engagement with the contact 71, de-energizing the relay 61. When employed in conjunction with the device of Fig. 1, the detection unit of Fig. 2 will then operate to remove the shunt across the heating resistance 22, and the latter will subsequently operate to de-energize the thermal safety switch 15 and to thereby render the system inoperative.

In Figs. 3 to 6, I have illustrated, more or less diagrammatically, alternative forms of flame detection units which will operate upon the establishment of a low resistance path from the flame electrode 112 to ground to render the system inoperative, and to thereby prevent atomized fuel from being supplied to the furnace when the conditions of combustion are not proper. The combustion responsive units disclosed in Figs. 3 to 6 may be connected in the control circuit of Fig. 1 and will function in a similar manner to that in which the flame detection unit in Fig. 1 functions, to check the conditions of combustion before permitting the fuel valve to be opened and after the conditions of combustion have been established to continuously check the resistance from the flame electrode 112 to ground, and upon the occurrence of an abnormally low resistance therebetween to render the system inoperative.

In Fig. 3, I have shown the relay 61 connected in the anode circuit of an electronic valve 30, which may be identical with the correspondingly identified valve 30 of Fig. 1, and have provided an additional relay 160 in series with the relay 61 which operates upon the establishment of an abnormally low resistance from the flame electrode to ground to de-energize the system. The relay 160 is a sub-sensitive relay and in the normal operation of the system sufficient current does not flow therethrough to cause it to be energized. The relay 160 is operatively associated with a switch blade 161 which is biased in any suitable manner when the relay is de-energized, into engagement with a contact 162. The switch blade 161 and contact 162 are preferably connected in series circuit relation with the switch blade 75 and contact 80 of the relay 61 of Fig. 1. Referring to Fig. 1 it will be seen that closure of the switch arm 75 and contact 80 establishes a shunt circuit across the heater winding 22 of the thermal safety switch 15, and prevents energization of the latter in normal operation. By employing the flame responsive unit of Fig. 3 in conjunction with the control relay circuit of Fig. 1, it will be noted that the occurrence of a path of a predetermined low resistance between the electrode 112 and ground will result in separation of the switch blade 161 and contact 162 and thereby removal of the shunt across the thermal safety switch heater winding 22.

When normal flame resistance exists from electrode 112 to ground, the flow of space current in the tube 30 will be sufficient to cause energization of the relay 61, but will be insufficient to cause energization of the relay 160. If an abnormal condition occurs, however, resulting in the resistance of the path from the flame electrode to ground decreasing to a certain predetermined low value, the increased positive potential on the grid 32 will result in increased space current being conducted by the tube 30. This increased space current will cause energization of the relay 160 and the latter will operate to move the switch blade 161 out of engagement with the contact 162, and to thereby open the circuit initially closed by engagement of the switch blade 75 and contact 80. Opening of the circuit through contact 80 and switch blade 75 removes the shunt connection from the heater winding 22, and subsequent heating of the latter operates to separate the switch members 18 and 19 of the thermal safety switch 15 and to thereby render the system inoperative, simultaneously closing the pilot and main fuel valves.

In Fig. 3, a condenser 120A is shown connected across the terminals of the relay winding 72, the function of this condenser being identical with that of condenser 120 connected across relay winding 65 in Fig. 1. After the conditions necessary for combustion have been established and a flame appears at the pilot, the negative potential on the grid 32 will be reduced and the tube 30 will be rendered conductive. Due to the presence of condenser 120A the relay winding 61 will not be energized immediately, but a delay depending upon the capacity of the condenser will be introduced. The extent of this delay is directly dependent upon the time required to charge the condenser 120A. As soon as the condenser becomes charged, the relay 61 will be energized and will operate in the desired manner.

In Fig. 4 an alternative circuit has been disclosed for rendering the combustion system inoperative when the resistance of the path from the flame electrode to ground reaches a predetermined low value. For simplification only, the flame detection circuit is shown in Fig. 3, but it will be understood that this circuit may be connected in the circuit of Fig. 1 and made to perform the combustion checking operations performed by the corresponding flame detection unit of Fig. 1.

Referring to Fig. 4, a sensitive relay 165 is connected in circuit between the grid 32 and the flame electrode 112. Upon the occurrence of an abnormally low resistance path between the flame electrode and ground, a high positive voltage will be applied to the grid 32, resulting in the flow of grid current in the tube 30. This grid current will flow through the sensitive relay winding 165 and energize the latter. As shown in Fig. 4, the relay 165 is operatively associated with a switch arm 161 which is biased into engagement with a contact 162 when the relay is de-energized. The switch blade 161 and contact 162 are connected in series with the switch blade 75 and contact 80, as are the correspondingly identified parts of Fig. 3, so that energization of the relay 165 and consequent separation of the switch blade 161 and contact 162 results in removal of the shunt across the thermal safety switch heater winding 22 and thereby de-energization of the system.

In Fig. 4, the resistance 114 of Fig. 1 has been omitted, the winding 165 of the sensitive relay being substituted therefor. When an auxiliary resistance such as the resistance 114 is not used in conjunction therewith, the resistance of the winding 165 is preferably made sufficiently high to limit the flow of grid current through the tube 30. If desired, however, an auxiliary resistance, preferably lower in value than the resistance

114 since the relay winding 165 necessarily comprises a resistance, may be connected in series with the relay winding 165, the combined resistance being employed to limit the flow of grid current.

In Fig. 5, I have illustrated another form of the invention in which means are provided for rendering the system inoperative upon the occurrence of an abnormal condition at the flame electrode. By the utilization of a novel switching arrangement, a material reduction in equipment necessary for detecting the presence of an abnormally low resistance path from the flame electrode to ground may be effected. Referring to Fig. 5 it will be noted that only a single relay, which may be the relay 61, is required. The relay 61 is operatively associated with switch arms 74, 75, and 76 which may be identical with the correspondingly identified parts in Fig. 1. For purposes of simplification only the relay arm 75 has been shown in Fig. 5, the circuit de-energizing means being effected by separation of this arm from its respective contact 80 as in the previously described forms.

The novel switching arrangement referred to includes two switch blades 75 and 163'. The switch blade 75 is operatively associated with the relay winding 72, and is adapted upon energization of the latter to be moved into engagement with the contact 80. When the relay winding 72 is de-energized the switch blade 75 is biased out of engagement with the contact 80.

The contact 80 is carried by the second mentioned switch blade 163' and the latter is biased in any suitable manner into engagement with a contact 162'. Before combustion has taken place and a flame has appeared at the pilot, a high negative potential will be applied to the grid 32 and negligible current will be conducted by the tube 30. The switch arm 75 will then be biased out of engagement with the contact 80. Upon the appearance of a flame, however, the negative potential on the grid 32 will be reduced and space current of a predetermined normal value will be conducted by the tube 30. The switch arm 75 will then be moved into engagement with the contact 80. The bias urging the switch blade 163' into engagement with the aforementioned contact 162' is preferably of such value that the force exerted on the contact 80 by the switch arm 75, with normal flow of current through the relay winding 72, is insufficient to pull switch blade 163' out of engagement with the contact 162' but upon an abnormally large current in winding 72 blade 163' will be separated from contact 162'.

It is thus seen that with proper conditions of combustion that a circuit is closed from conductor 102 to conductor 119, and by reference to Fig. 1 it will be seen that the closure of this circuit effectively shunts the thermal safety switch heater winding 22. The latter is thereby prevented from operating to de-energize the system and normal operating conditions have been established.

If a high positive potential is applied to the grid 32, as a result of the presence of an abnormally low resistance path from the flame electrode to ground, however, increased space current will be conducted by the tube 30, and this increase in current in winding 72 will result in the latter becoming stronger magnetically. The switch blade 75 will then be urged with greater force into engagement with the contact 80 and when the pull exerted by relay winding 72 becomes greater than the bias urging the switch blade 163' into engagement with the contact 162', the latter mentioned parts will be separated. By properly designing the switch blade 163' and the means biasing it into engagement with the contact 162', it is thus seen that the relay 61 may be made to operate to open this contact when a predetermined value of current is flowing in the winding 72, and thereby when a path of predetermined low resistance has been established from the flame electrode 112 to ground.

As in the previously described forms of my invention, opening of the circuit shunting the heater winding 22 results in the latter operating to separate the contacts 18 and 19, and thereby to de-energize the system.

It will be clear therefore that with a current value in the anode circuit of valve 30 which is above a predetermined value and below a predetermined higher value the fuel supply to the burner will be permitted, but upon a rise in the anode current above the higher predetermined value or a fall of the anode current below the lower predetermined value the fuel supply will be cut off. Relay 61 is thereby operated to one position on a low anode current value, to a second position on an intermediate current value and to the first position on a higher plate current value. Such relay operation is useful in various connections including those illustrated herein. Thus there is a range of current flow in the anode circuit of valve 30 or in other words a band of predetermined width which is directly dependent upon the relative forces biasing the switch arms 75 and 163' in an upward direction wherein the fuel supply to the furnace is permitted and upon any departure of the anode current flow from this predetermined range the relay 61 is caused to operate in a sense to cut off the supply of fuel to the furnace.

In Fig. 6, a further modification of my invention has been illustrated in which the increased flow of space current conducted by the tube 30 as a result of the presense of an abnormally low resistance path from the flame electrode to ground is utilized to blow a fuse which may be connected in the anode, cathode, or grid circuit of the tube 30 as desired, and to thereby cause de-energization of the system. For purposes of explaining the operation of this modification of my invention, I have shown the fuse connected in the anode circuit of the tube 30.

Referring to Fig. 6, the above mentioned fuse is shown designated by the reference character 170 and is connected in series with the relay winding 72. When normal conditions of combustion are prevailing and a flame is present at the pilot, the space current conducted by the tube 30 will be a predetermined value which is sufficient for the normal operation of the relay 61. The fuse 170 is of such rating that it is adapted to easily withstand this flow of anode current.

If a high positive potential is applied to the grid 32, however, causing a substantial increase in space current conducted by the tube 30, the fuse 170 will be blown and the flow of anode current will thereby be interrupted, resulting in de-energization of the relay 61. The consequent separation of the switch blade 75 and the contact 80 removes the shunt from across the heater winding 22 as previously described, causing the thermal safety switch 15 to operate to render the system inoperative.

The required rating for the fuse 170 will nec-

essarily depend upon its location in the circuit as seen in Fig. 6. The anode current conducted by the tube 30 may be different from the current in the cathode circuit, depending upon whether or not grid current is flowing in the tube, and hence the current ratings of a fuse for each of these circuits should be of corresponding values. The current which it is desirable to permit to flow in the grid circuit of the tube is necessarily much less than the anode or cathode current, and hence, if a fuse is placed in the grid circuit, it must be so designed as to blow at a correspondingly low value of current therethrough.

In Fig. 7, I have illustrated, more or less diagrammatically, another modification of my invention which may be employed in checking the combustion conditions of a plurality of fuel fired furnaces simultaneously. Although it will be understood that the flame responsive units of Fig. 7 may be employed in conjunction with the control relay system of Fig. 1, I have, for purposes of simplification, shown this form of my invention as adapted to be employed in conjunction with manually lighted furnaces. When so employed, the circuit of Fig. 7 will operate upon flame failure, or upon the occurrence of an abnormally low resistance path to ground, from any one of the flame electrodes associated with the respective burners, due to accidental shorting or carbonization or for any other reason, to close the main fuel supply valve or to maintain said fuel valve closed if any one of the burners fails to ignite.

In Fig. 7, in order to avoid confusion of the drawings, I have shown a circuit responsive to the combustion conditions of only two fuel fired furnaces, but it will be understood that four or five fuel fired furnaces may be so controlled from a single control unit, the only limit as to the actual number of furnaces which may be so controlled being the load that the transformer 17 can safely handle.

While any suitable means may be employed for lighting the burners, for example, the control system described in connection with Fig. 1, for clearness and definiteness of illustration, I have shown an arrangement in Fig. 7 wherein the pilot and main flames may be lighted as the result of a manual operation, and after combustion has taken place the system will operate so as to maintain the pilot and main fuel valves in open position.

The arrangement referred to above includes a plurality of ignition transformers 8, each associated with a respective pilot burner, and adapted to be energized together with the pilot valve actuating means upon closure of a normally open push button 180. The energizing circuit for the pilot valve actuating means may be traced from the supply line $L^2$, conductor 106, push button 180, conductor 181, the pilot valve actuating means and conductors 184 and 110 to the supply line $L^1$, and the energizing circuit for the ignition transformers may be traced from the supply line $L^2$, conductor 106, pushbutton 180, conductor 181, a switch blade 191, contact 192, conductor 182, the primary windings of the ignition transformers 8, which may desirably be connected in parallel, and conductor 183 to the supply line $L^1$.

As soon as a pilot flame appears at one of the burners the negative bias on the grid 32 of the respective tube 30 is reduced and the tube is rendered conductive. The tubes 30 are each operatively associated with a respective relay 60 and the individual flame detection units operate in the manner described in connection with Fig. 1 so that the space current conducted by the tube 30 upon the appearance of a flame at the pilot results in actuation of the corresponding relay 60 and thereby movement of the switch blade 70 into engagement with the contact 71. All the contacts 70—71 are in series so that when a pilot flame has appeared at each of the burners and each of the relays 60 has operated to close its respective contact 71, a circuit will have been completed, through the switch blades 70 and contacts 71, to a relay 190. This circuit may be traced from one end of the transformer secondary winding 24, conductor 122, switch blade 70 and contact 71 of the first relay, conductor $63^2$, switch blade 70 and contact 71 of the next relay, conductor $63^3$, relay winding 190, and conductor 73 to the other end of the transformer secondary winding 24. The relay winding 190 is operatively associated with a pair of switch arms 191 and 194 which are adapted upon energization of the relay winding to be moved into engagement with contacts 193 and 195, respectively, but when the relay winding is deenergized, are held out of engagement therewith, and the switch blade 191 is then held into engagement with contact 192.

The switch arm 194 and contact 195 are included in an energizing circuit to the main valve actuating means so that energization of the relay winding 190 results in the establishment of a circuit for actuating the main fuel valve to its open position. This circuit may be traced from the supply line $L^2$, conductor 106, switch blade 194, contact 195, conductor 185, the main fuel valve actuating means, and conductor 110 to the supply line $L^1$. The switch blade 191 and contact 193 are included in an energizing circuit to the pilot valve actuating means, independent of the push button energizing circuit, so that energization of the relay winding 190 results in the establishment of a holding circuit for the pilot valve actuating means which may be traced from the supply line $L^2$, conductor 106, contact 193, switch blade 191, the pilot valve actuating means and conductors 184 and 110 to the supply line $L^1$. Furthermore, it will be noted that when the relay winding 190 is energized, the energizing circuit to the ignition transformers 8 is interrupted, and thereby the ignition transformers are deenergized, as a result of separation of the switch blade 191 and contact 192. The operating condition of the circuit having thus been established, the push button 180 may subsequently be released.

The system will then continue to operate, as long as the conditions of combustion are proper, so long as it is desired to maintain the burners in operation. For interrupting the energizing circuit to the pilot and main fuel valve actuating means when it is desired to shut down the system, means have been provided in the form of a normally closed push button 196. The latter may be inserted in the energizing conductor 106 and operates when actuated so as to result in closure of the pilot and main fuel valves and thereby the shutting off of the fuel supply to the various burners. As soon as one of the pilot flames is extinguished, the corresponding tube 30 becomes non-conductive and the relay 60 which cooperates therewith is de-energized. This results in interruption of the energizing circuit to the relay winding 190 and thereby separation of the switch blades 191 and 194 and their respective contacts 193 and 195. If thereafter, the push button 196 is released and later closed the system will remain de-energized until switch 180 is closed.

If, while the system is in operation, one of the electrodes 112 should be accidentally connected to ground or should be connected to ground through an abnormally low resistance by reason of carbonization or for any other reason, the detection unit individual thereto will immediately detect this condition and operate to cause de-energization of the entire system. The operation of each of the detection units upon the ocurrence of such an abnormal condition may be identical with that described in connection with Fig. 1, and hence, need not be described again in detail. Briefly, the connection of the grid 32 of one of the tubes 30 to ground through a resistance path of predetermined low value results in the application to the grid of a high positive voltage which results in the flow of grid current through the tube. This grid current flows in the cathode circuit of the tube 30, but not in the anode circuit thereof, resulting in greater current flow through the winding 64 than through the winding 65 of the corresponding relay 60. The result is that the armature 66 is so rotated as to move the switch blade 70 out of engagement with the contact 71 and the energizing circuit to the relay winding 190 is interrupted, causing the pilot and main fuel valves to be closed.

In Fig. 7 two individual power supply transformers 17 and 17A have been shown, the primary windings of which are energized from the supply lines $L'$ and $L^2$. If desired, however, the secondary windings of these transformers may be wound on the same core, only one primary winding being employed. It will be readily understood that by employing separate transformers for the various energizing circuits of Fig. 7 that the number of burners which may be operated from a single control unit may be increased.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a burner control system, a burner, burner fuel control means, an electronic valve including a cathode, an anode and a control grid, energizing means, an electrode located near said burner but separated therefrom by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, relay means connected in circuit with said cathode and anode and said energizing means adapted to cause said burner fuel control means to assume a fuel feeding position when said gap is bridged by the burner flame, and relay means connected in circuit with said cathode and control grid and said energizing means adapted to cause said burner fuel control means to assume a position preventing the supply of fuel when an abnormal leakage path has been established between said electrode and ground.

2. In a burner control system, a burner, burner fuel control means, an electronic valve including a cathode, an anode and a control grid, a source of energizing current, an electrode located near said burner but separated therefrom by a gap adapted to be bridged by the burner flame, a relay having a normally open contact connected in circuit with said cathode, anode, and said source of energizing current, a second relay having a normally closed contact connected in circuit with said cathode, control grid, flame electrode and said source of energizing current, circuit means including said relay contacts adapted upon closure of said first mentioned contact to cause said burner fuel control means to assume a fuel feeding position, and adapted upon opening of said second mentioned contact to cause said burner fuel control means to assume a position preventing the supply of fuel.

3. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, circuit control means including said cathode and anode adapted to cause said burner fuel control means to assume a fuel feeding position, and circuit control means opposing said first mentioned circuit control means and including said cathode and control grid adapted to cause said burner fuel control means to assume a position preventing the supply of fuel.

4. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, circuit means including said cathode and anode adapted to cause said burner fuel control means to assume a fuel feeding position in response to the increased conductivity of the gap between said electrode and said burner by reason of the burner flame bridging said gap, and circuit means opposing said first mentioned circuit means and including said cathode and said control grid adapted to cause said burner fuel control means to assume a position preventing the supply of fuel in response to the conductivity of the gap between said flame electrode and burner becoming abnormally high.

5. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including a current limiting resistor in series with said cathode and anode and both of said opposed windings for actuating said relay to energize said burner fuel feeding means, and circuit means including said cathode and control grid and the relay winding wound with the fewer turns for actuating said relay to de-energize said burner fuel feeding means.

6. In a burner control system, a burner, burner fuel control means, an electronic valve having a plurality of elements, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and one of the elements of said valve, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including two other elements of said valve and both of said opposed windings

for actuating said relay to energize said burner fuel feeding means, and circuit means including at least one of the last mentioned elements of said valve and another element and the relay winding wound with the fewer turns for actuating said relay to de-energize said burner fuel feeding means.

7. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including said cathode and anode and both of said opposed windings for actuating said relay to energize said burner fuel feeding means, and circuit means including said cathode and control grid and the relay winding wound with the fewer turns for actuating said relay to de-energize said burner fuel feeding means.

8. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, circuit means including said cathode and anode and a current limiting resistor adapted to cause said burner fuel control means to assume a fuel feeding position, and circuit means opposing said first mentioned circuit means and including said cathode and control grid, and said electrode adapted to cause said burner fuel control means to assume a position preventing the supply of fuel.

9. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a relay having an open position and a closed position and adapted to control said burner fuel control means in one sense when in said open position and in an opposite sense when in said closed position, circuit means for actuating said relay to said closed position including said cathode and anode, and circuit means opposing said first mentioned circuit means for actuating said relay to said open position and including said cathode, control grid and said electrode.

10. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, an electronic valve including an anode, a cathode, and a control grid, a device responsive to said variable condition, a connection between said device and said control grid, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including a current limiting resistor in series with said cathode and anode and both of said opposed windings for actuating said relay to control said control means in said one sense, and circuit means including said cathode and control grid and the relay winding wound with the fewer turns for actuating said relay to control said control means in said another sense.

11. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, an electronic valve including an anode, a cathode, and a control grid, a device responsive to said variable condition, a connection between said device and said control grid, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including said cathode and anode and both of said opposed windings for actuating said relay to control said control means in said one sense, and circuit means including said cathode and control grid and the relay winding wound with the fewer turns for actuating said relay to control said control means in said another sense.

12. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, an electronic valve including an anode, a cathode, and a control grid, a device responsive to said variable condition, a connection between said device and said control grid, a circuit including said cathode and anode, a circuit including said cathode and control grid, and means independently controlled by each of said circuits for controlling said control means.

13. In a burner control system, a burner, burner fuel control means, an electronic valve including a cathode, an anode, a screen grid, and a control grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, circuit control means including said cathode and anode adapted to cause said burner fuel control means to assume a fuel feeding position, and circuit control means including said cathode and said screen grid adapted to cause said burner fuel control means to assume a position preventing the supply of fuel.

14. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, a cathode, a control grid, and a screen grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including said cathode and anode and a current limiting resistor in series with both of said opposed windings, circuit means including said cathode and said screen grid and the relay winding wound with the fewer turns, energizing means, means adapted when the first mentioned circuit is energized to a greater degree than the second mentioned circuit to cause said burner fuel control

means to assume a fuel feeding position, and means adapted when the second mentioned circuit is energized to a greater degree than the first mentioned circuit to cause said burner fuel control means to assume a position preventing the supply of fuel.

15. In a burner control system, a burner, burner fuel control means, an electronic valve including a cathode, an anode, a control grid, and a screen grid, an electrode located near but separated from said burner by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, circuit control means including said cathode and anode adapted to cause said burner fuel control means to assume a fuel feeding position, and circuit control means including said cathode and said screen grid adapted to cause said burner fuel control means to assume a position preventing the supply of fuel.

16. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, an electronic valve including an anode, a cathode, a control grid and a second grid, a device responsive to said variable condition, a connection between said device and said control grid, a circuit including said cathode and anode, a circuit including said cathode and the second one of said grids, and means jointly controlled by said circuits for controlling said control means.

17. In a burner control system, a burner, burner fuel control means, an electronic valve including an anode, cathode, and a control grid, an electrode located near the burner but separated therefrom by a gap adapted to be bridged by the burner flame, a connection between said electrode and said control grid, energizing means, a relay adapted to control said burner fuel control means and energized by said energizing means under control of said electronic valve, said relay having a normally open contact and a normally closed contact and adapted when normally energized to close said open contact and when abnormally energized to close said open contact and to open said closed contact, circuit means connected in series with both of said contacts adapted upon closure of said open contact to cause said burner fuel control means to assume a fuel feeding position and adapted upon opening of said normally closed contact to cause said burner fuel control means to assume a position preventing the supply of fuel.

18. In a combustion control system, means for producing combustion, a relay to control said means, an electronic valve having a cathode, anode and a control grid, means in circuit with said anode and cathode for controlling said relay and adapted to control the adjustment of the latter to one position in response to a predetermined current value through said valve, to a second position in response to another value of said current and to a third position in response to a third value of said current, and means responsive to combustion for controlling said grid.

19. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, a device responsive to said condition, an electronic valve including an anode, cathode and control electrode, a source of energizing current, a relay having a normally open contact connected in circuit with said source of energizing current and said anode and cathode, a relay, having a normally closed contact, connected in circuit with said source of energizing current, said device responsive to said condition, said cathode and said control electrode, and means jointly controlled by said relays for controlling said control means.

20. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, circuits including an electronic valve including an anode, cathode and a control electrode, means responsive to said variable condition for controlling said electrode to thereby control the anode current, a relay to control said control means, said relay having a winding included in said anode circuit and having a pair of normally open contacts and a pair of normally closed contacts and operating when both pairs of contacts are closed to produce operation of said control means in said one sense and operating when one of said pairs of contacts is open to produce operation of said control means in said another sense, biasing means tending to open the first mentioned contacts, biasing means tending to close the second pair of contacts, and means responsive to a predetermined current of one value in said winding to overcome said first biasing means and close said first contacts and responsive to a predetermined current of another value in said winding to overcome said second biasing means and open said second contacts.

21. In a fuel burner system, a plurality of burners, burner fuel control means, an electrode individual to each of said burners and separated therefrom by a gap adapted to be bridged by the individual burner flames, an electronic amplifier including an electronic valve individual to each of said electrodes, each of said electronic valves including an anode, cathode, and a control grid, connections between each of said electrodes and the control grids of the electronic valve individual thereto, circuit means including said anodes and cathodes of said electronic valves adapted when the burner flames bridge said gaps to cause said burner fuel control means to assume a fuel feeding position and circuit means opposing said first mentioned circuit means and including said cathodes and control grids and adapted when an abnormal leakage path has been established between one of said electrodes and ground to cause said burner fuel control means to assume a position preventing the supply of fuel.

22. In a control system, burner means adapted to cooperate with a plurality of variable conditions, each condition adapted to be modified by a respective one of said burner means, each of said conditions normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said conditions within said predetermined range of values and in another sense upon the occurrence of said conditions assuming one of said widely displaced values, a device individual to and responsive to each of said conditions, an electronic valve individual to each of said devices, each of said electronic valves including an anode, cathode, and a control grid, connections between each of said control grids and the device individual thereto, circuit means including said anodes and cathodes of said electronic valves, circuit means including said cathodes and control grids, and means jointly controlled by said circuits for controlling said control means.

23. In a control system, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, means for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, an electronic valve including an anode, a cathode, a control grid and a second grid, a device responsive to said condition, a connection between said device and said control grid, a relay having two opposed windings, one of which is wound with more turns than the other, circuit means including said cathode and anode in series with both of said windings, circuit means including said cathode and one of said grids and the relay winding wound with the fewer turns, energizing means, means adapted when the first mentioned circuit is energized to a greater degree than the second mentioned circuit to cause said control means to operate in said one sense and means adapted when the second mentioned circuit is energized to a greater degree than the first mentioned circuit to cause said control means to operate in said another sense.

24. In a safety control device, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, a motor for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, a device responsive to variations in the value of said condition, a connection between said motor and a source of energy, apparatus for controlling said motor including a member actuable in one direction for controlling said motor in one sense and actuable in the opposite direction for controlling said motor in the opposite sense, said device being responsive to three successive values of said condition, means connected to said device for controlling said member and including an electronic device having an input circuit and an output circuit, first energizing means for said member, second energizing means for said member, a connection to be energized responsively to the intermediate one of said values and to be deenergized responsively to another of said values and including said first mentioned energizing means and said output circuit, and a second connection to be energized responsively to the third mentioned value and including said second mentioned energizing means and said input circuit.

25. In a safety control device, burner means adapted to cooperate with a variable condition which is adapted to be modified by said burner means, said condition normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced values, a motor for controlling said first mentioned means in one sense to maintain said condition within said predetermined range of values and in another sense upon the occurrence of said condition assuming one of said widely displaced values, a device responsive to variations in the value of said condition, a connection between said motor and a source of energy, apparatus for controlling said motor including a member actuable in one direction for controlling said motor in one sense and actuable in the opposite direction for controlling said motor in the opposite sense, said device being responsive to three successive values of said condition, means connected to said device for controlling said member and including an electronic valve having an anode, a cathode, and a control grid, first energizing means for said member, second energizing means for said member, a connection to be energized responsively to the intermediate one of said values and to be deenergized responsively to another of said values and including said first mentioned energizing means and the anode and cathode of said valve, and a second connection to be energized responsively to the third mentioned value and including said second mentioned energizing means and the cathode and control grid of said valve.

26. Safety control apparatus for a fuel burner including an electrode associated with the burner flame, relay means controlling said burner in one sense to supply fuel thereto and in the opposite sense to interrupt said fuel supply, an impedance responsive device to control said relay means in said one sense when the value of the impedance to which said device is responsive is within a predetermined range of values and in said opposite sense when the value of the impedance to which said device is responsive is higher or lower than said predetermined range, a connection between said electrode and said device, said impedance including the impedance between said burner and said electrode, an additional impedance to control the response of said impedance responsive device to said first mentioned impedance, a connection between said additional impedance and said device, and switching means associated with said device and actuated when said relay means is actuated in said one sense to render said additional impedance ineffective.

27. The combination of claim 26 in which said additional impedance is initially effective to control the sensitivity of said impedance responsive device and thereby to make said impedance responsive device control said relay means in said one sense on the occurrence of an impedance path between said electrode and ground higher than a predetermined value and on actuation of said switching means is thereafter ineffective to con-

trol the sensitivity of said impedance responsive device whereby said impedance responsive device controls said relay means in said one sense when the impedance of said path is lower than said predetermined value and is higher than a predetermined value lower than the first mentioned value.

28. In a safety control system of the class wherein means are provided to supply a combustible agent to produce a combustion condition and said means are operated to continue the supply of said agent as long as the value of said condition lies within a predetermined safe range of values and said means are operated when said condition assumes a value without said predetermined range of values to discontinue the supply of said agent, the combination with said means of an electronic valve having an anode, a cathode, and a control grid, a device responsive to the value of said condition, a connection between said device and said control grid, a circuit including said cathode and anode, a circuit including said cathode and control grid, and means independently controlled by each of said circuits for controlling said first mentioned means, said controlling means operating said first mentioned means in the sense to supply said agent when the control effect on said controlling means of said first mentioned circuit predominates over that of the second mentioned circuit and operating said first mentioned means in the sense to discontinue the supply of said agent when the control effect on said controlling means of said second mentioned circuit predominates over that of the first mentioned circuit.

29. In a safety control system of the class wherein means are provided to supply a combustible agent to produce a combustion condition and said means are operated to continue the supply of said agent as long as the value of said condition lies within a predetermined safe range of values and said means are operated when said condition assumes a value without said predetermined range of values to discontinue the supply of said agent, the combination with said means of an electronic valve having an anode, a cathode, and a control grid, a single device responsive to the value of said condition, a connection between said device and said control grid, a circuit including said cathode and anode, a circuit including said cathode and control grid, and means jointly controlled by said circuits for controlling said first mentioned means, said controlling means operating said first mentioned means in the sense to supply said agent when the control effect on said controlling means of said first mentioned circuit predominates over that of the second mentioned circuit and operating said first mentioned means in the sense to discontinue the supply of said agent when the control effect on said controlling means of said second mentioned circuit predominates over that of the first mentioned circuit.

30. In a safety control system of the class wherein means are provided to supply a combustible agent to produce a combustion condition and said means are operated to continue the supply of said agent as long as the value of said condition lies within a predetermined safe range of values and said means are operated when said condition assumes a value without said predetermined range of values to discontinue the supply of said agent, the combination with said means of an electronic valve having an anode, a cathode, and a control grid, a device responsive to the value of said condition, a connection between said device and said control grid, a relay having two opposed windings one of which is wound with more turns than the other to control said means, circuit means including said cathode and anode and both of said windings for actuating said relay to control said means in one sense to permit the supply of said agent, and circuit means including said cathode and control grid and the relay winding wound with fewer turns for actuating said relay to control said means in another sense to discontinue the supply of said agent.

31. Apparatus for controlling a burner to ensure safe operation thereof including means responsive to a predetermined range of resistance values of a path normally including the burner flame, means to ignite the burner if said resistance is higher than the maximum value of said predetermined range of values, said responsive means including means responsive to the resistance of said path and operative thereafter to prevent the operation of said burner if said resistance falls below or rises above said predetermined range of values.

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