

Oct. 1, 1940.

D. B. KIRK

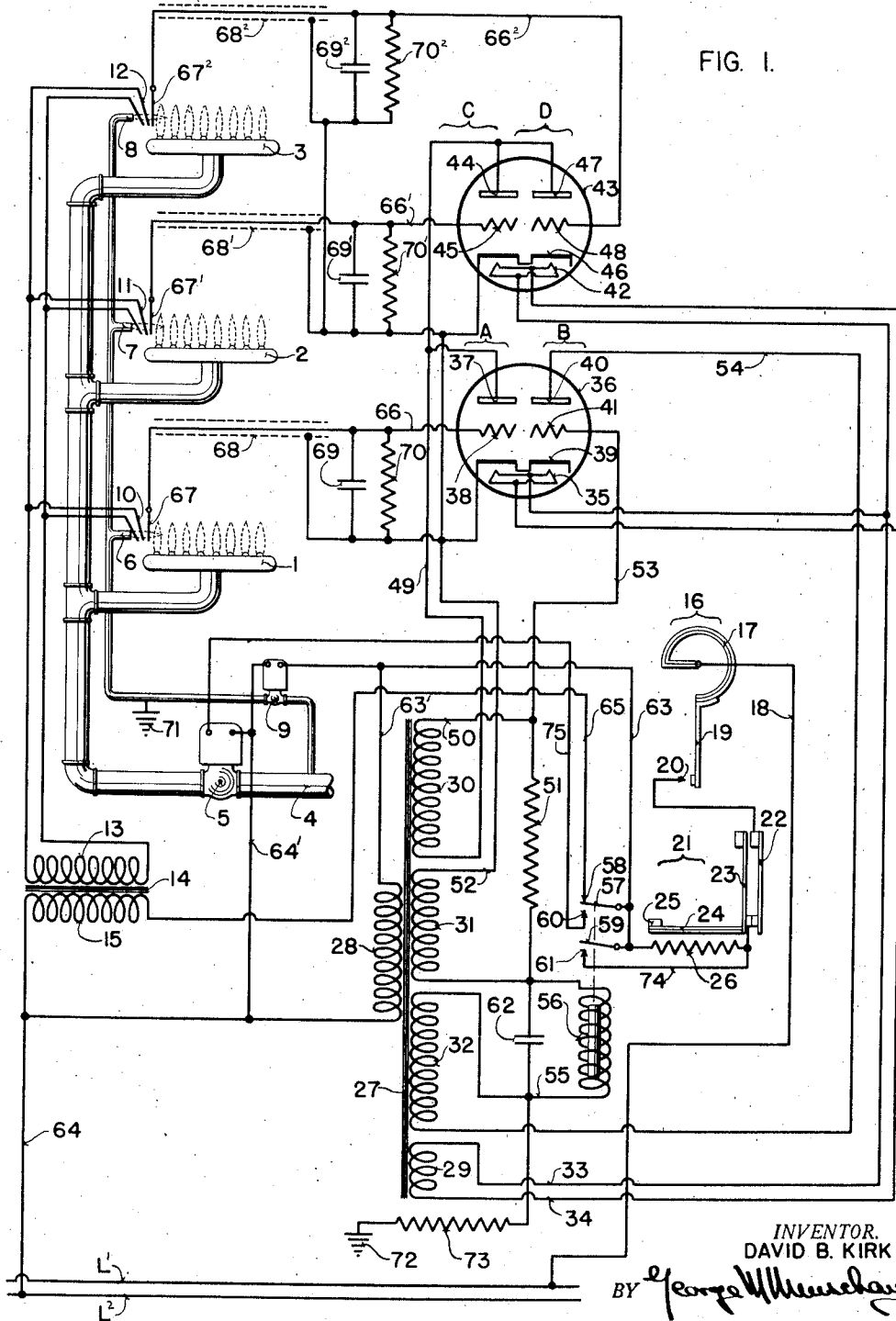
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CONTROL APPARATUS

Filed July 16, 1937

2 Sheets-Sheet 1

FIG. 1.



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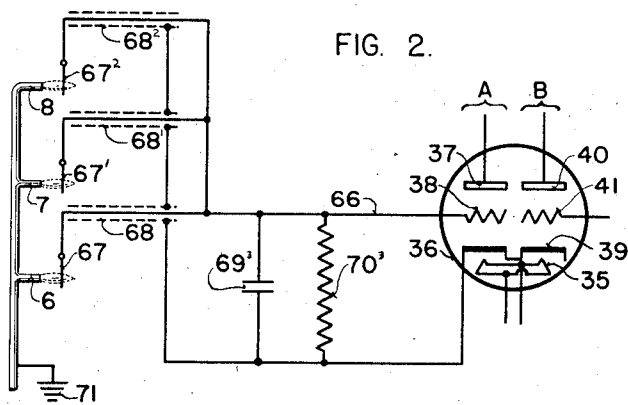
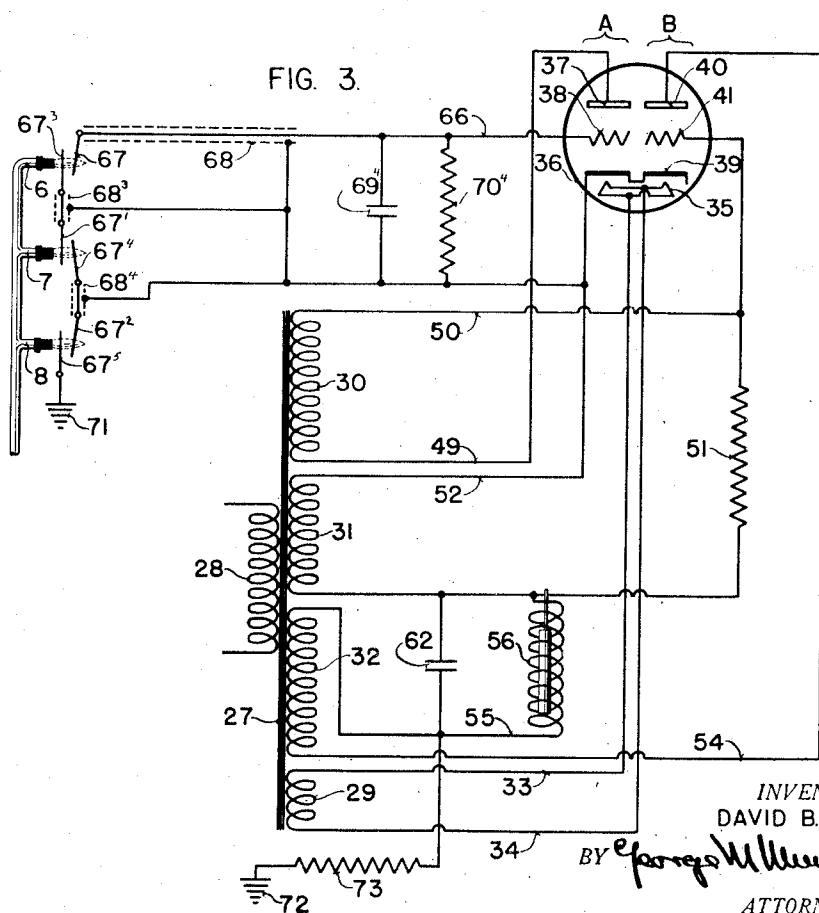
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CONTROL APPARATUS

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2 Sheets-Sheet 2



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2,216,534

CONTROL APPARATUS

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17 Claims. (Cl. 158—28)

The present invention relates to improved control instrumentalities, and more particularly it relates to improved fuel combustion control systems of the type adapted for use with a plurality of fuel fired furnaces in distinguishing between normal and abnormal conditions of combustion in all of the furnaces.

It is a specific object of the invention to provide a 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.

Another object of the invention is to provide an improved fuel combustion control system for a plurality of fuel fired furnaces wherein means are provided for simultaneously distinguishing between actual conditions of combustion and simulated conditions of combustion in all of the furnaces.

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.

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 valve for controlling a 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 supply and ignition from being turned on when such abnormal conditions exist.

Since an abnormal condition of this character simulating combustion may arise after the system is already in operation, it is desirable to provide means for distinguishing between such abnormal conditions and natural 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 flame, 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 control system in which a plurality of burners operate together, as for example for heating in unison and supplied with a common fuel line, it will be apparent that it is relatively important that an abnormal or dangerous condition of any of the burners be guarded against. In such a system, failure of any one of the burners to ignite or accidental extinguishing of the flame after it has ignited 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 plurality of furnaces; and

Figs. 2 and 3 each illustrate a modification of a portion of the arrangement of Fig. 1.

In Fig. 1 of the drawings a plurality of gas burners 1, 2, and 3, are shown as supplied with gas through a conduit 4 and the flow of gas to the burners is controlled by an electrically operated or other suitable valve 5. A respective pilot burner 6, 7, and 8 is provided at each of the burners 1, 2, and 3 and the flow of gas to all of the pilot burners is controlled by an electrically operated or other suitable valve 9. Means are provided for igniting the fuel at each of the pilot burners including pairs of electrodes 10, 11, and 12 which are connected in parallel to the terminals of a secondary winding 13 of an ignition transformer 14 having a primary winding 15 which is adapted to be energized from the alternating current supply conductors L¹ and L².

The fuel valve operating circuit of my control system is controlled by means of a thermostat 16 which may be located in a room or space to be heated. The thermostat 16 may be of any

suitable construction and includes a bimetallic element 17 connected by means of a conductor 18 to the supply line L¹ and a contact blade 19 which is adapted to engage a stationary contact 20.

The contact 20 is connected to the supply line L² through a safety thermal switch 21 and associated apparatus to be controlled which will be described later.

The thermal safety switch 21 is preferably of the form disclosed in the Patent 1,958,081 issued to F. S. Dennison, May 8, 1934, and as shown more or less diagrammatically in the drawings, this switch comprises a stationary arm 22 and a movable arm 23 biased for movement away from arm 22 but normally held in engagement with the latter by means of a bimetallic element 24. Element 24 is rigidly secured at one end to a block 25 and is arranged to be heated by a coil 26, when the latter is energized, through a circuit which will later be described. Upon energization of coil 26 for a predetermined period of time, element 24 will be warped sufficiently in the clockwise direction to permit arm 23 acting under spring or other bias to separate from switch arm 22 thereby interrupting the circuit including thermostat 10. The switch 21 will remain locked in this position until manually returned to its normal closed position.

Energizing current is supplied to the control system from a transformer 27 which is a combination step-up and step-down transformer and comprises a line voltage primary winding 28, a low voltage secondary winding 29, and high voltage secondary windings 30, 31, and 32. The low voltage secondary winding 29 is connected by conductors 33 and 34 to the heater filaments 35 and 42 of a pair of electronic valves 36 and 43, which as shown are of a twin amplifier type and combine two triodes in each bulb. Valve 36 includes an anode 37, a control grid 38, and a cathode 39 as one triode and an anode 40, a control grid 41 and the cathode 39 as the second triode. Similarly, the valve 43 includes an anode 44, a control grid 45, a cathode 46 as one triode, and an anode 47, a control grid 48 and the cathode 46 as the second triode. For convenience in describing the circuit operation the triodes including the anodes 37, 40, 44, and 47 will be referred to hereinafter as the triodes A, B, C, and D, respectively.

As illustrated, the anodes 37, 44, and 47 are connected together and are connected by a conductor 49 to one end of the transformer secondary winding 30. The other end of winding 30 is connected by a conductor 50, in which a resistor 51 is inserted, to one end of the transformer secondary winding 31, and the other end of this winding is connected to the cathodes 39 and 46 of valves 36 and 43 by a conductor 52. It is noted the transformer secondary windings 30 and 31 are so connected that the voltages induced across their terminals by the primary winding 28 assist each other, being additive, and together supply anode voltage to the triodes A, C, and D.

The control grid 41 of the triode B is connected by a conductor 53 to the conductor 50 and the anode 40 is connected by a conductor 54 to one end of the transformer secondary winding 32. The other end of winding 32 is connected by a conductor 55, in which a relay winding 56 is inserted, to one end of the transformer secondary winding 31 and the other end of winding 31 is connected by conductor 52 to the cathode 39. Thus, one end of the resistor 51 is connected

through the transformer secondary winding 31 to the cathode 39, and the other end of the resistor 51 is connected to the control grid 41. The anode currents conducted by the triodes A, C, and D pass through the resistor 51 and in the proper direction to impress a potential on the control grid 41 which is negative with respect to the potential of cathode 39 so that when the triodes referred to are conductive, the triode E will be rendered non-conductive. To this end the voltages produced across the terminals of the transformer secondary windings 30 and 31 are so related to the resistance of resistor 51 and the conductive resistance of the triodes A, C and D that the ratio of V^{30}/V^{31} is greater than the ratio of R_{ACD}/R^{51} where V^{30} and V^{31} are the voltages of windings 30 and 31, respectively, R_{ACD} is the combined anode to cathode resistance of the triodes A, C and D when the latter are conductive, and R^{51} is the resistance of resistor 51.

The relay winding 56 is operatively associated with a pair of switch blades 57 and 58, and when the triode B is non-conductive, the relay winding 56 will be de-energized and the switch blades 57 and 58 will be in the positions shown. The switch blades 57 and 58 are biased by spring means or by any other means in an upward direction and in this position the switch blade 57 is in engagement with a contact 59. When the relay winding 56 is energized the switch blades are pulled down against the action of their opposing spring biases into engagement with contacts 60 and 61, respectively. As will be apparent the output current of triode B will be pulsating, and for the purpose of smoothing out the pulsating current flows through the relay winding 56 and thereby preventing chattering of the contacts 57 and 59, a condenser 62 of suitable value may desirably be connected across the terminals of the winding 56.

When the temperature of the room or space to be controlled falls below the value it is desired to maintain, the thermostat 16 operates to move the switch blade 19 into engagement with the contact 20 to close an energizing circuit to the transformer primary winding 28, the ignition transformer 14, and the operating means for the pilot valve 9. The energizing circuit to the transformer primary winding 28 may be traced from the alternating current supply line L¹, conductor 18, bimetallic element 17, switch blade 19, contact 20, blades 22 and 23 of the thermal safety switch 21, the heating coil 26, conductors 63 and 63' to one end of the transformer primary winding 28, through winding 28, and a conductor 64 to the alternating current supply conductor L². The energizing circuit for the ignition transformer 14 may be traced from the supply line L¹, conductor 18, bimetallic element 17, switch blade 19, contact 20, switch blades 22 and 23 of the thermal safety switch 21, heater winding 26, switch blade 57, contact 58, conductor 65 to one end of the ignition transformer primary winding 15, through winding 15, and conductor 64 to the alternating current supply conductor L². The energizing circuit for the pilot valve operating means may be traced from the supply line L¹, conductor 18, bimetallic element 17, switch blade 19, contact 20, switch blades 22 and 23 of the thermal safety switch 21, heating coil 26, conductor 63, the pilot valve operating means, and conductors 64', and 64, to the supply conductor L². Fuel will then be supplied to the various pilot burners and simultaneously an igniting spark will appear across the electrodes 10, 11, and 12

to ignite the fuel at each of the respective pilot burners.

As was previously pointed out the energization of relay winding 56 is adapted to be controlled by the triode B and this triode in turn is adapted to be controlled by the flow of current through the triodes A, C, and D and as will become apparent the flow of anode current through each of the last mentioned triodes is adapted to be controlled by an individual circuit of which a respective pilot flame is a component part. The control grid 38 of triode A is connected by a conductor 66 to an electrode 67 which is insulated from the burner and extends into the pilot flame. The conductor 66 is preferably encased in a shield 68 of any suitable type and the shield is connected to the cathode 39. The conductor 66 is also connected to the cathode 39 through a parallel circuit including a condenser 69, and a resistor 70. By way of illustration, the condenser 69 may have a value of .002 microfarad and the resistor 70 may have a value of 25 megohms. Similarly, the control grid 45 is connected by a conductor 66' to an electrode 67' which is insulated from the burner and extends into the burner flame. The conductor 66', as shown, is encased in a shield 68' and the shield is connected to the cathode 46. A condenser 69' and a resistor 70' which may have identical values as the condenser 69 and resistor 70 are connected in parallel relation between the conductor 66' and the cathode 46. The control grid 48 is also connected by a conductor 66² to an electrode 67² which extends into the pilot flame and is insulated from burner. The conductor 66² is encased in a shield 68² which is connected to the cathode 46 and a condenser 69² and a resistor 70² are connected in parallel relation between the control grid 48 and the cathode 46. The condenser 69² and resistor 70² may be identical in value with the condenser 69 and resistor 70.

When the system is de-energized the various switch blades are in the positions shown and the control grids 38, 45, and 48 are at substantially the same potential as the cathodes 39 and 46, which, as noted are connected together. The triodes A, C, and D will then be conductive and pulsating current will flow through the resistor 51 producing a pulsating potential drop thereacross. Since the positive end of resistor 51 is connected through the transformer secondary winding 31 to the cathodes 39 and 46 and the negative end of the resistor 51 is connected by conductor 53 to the control grid 41, a negative potential will be applied to the control grid 41 when the triodes A, C, and D are conductive whereby the triode B will be rendered non-conductive, resulting in de-energization of the relay winding 56. The phase relation of the winding 32 is such that the alternating voltage maintained on the anode 40 will be in phase with the alternating voltages maintained on anodes 37, 44, and 47.

As soon as a flame appears at each of the pilot burners, individual circuits are established through the respective flames which operate to bias the control grids 38, 45, and 48 negatively and thereby to render the triodes A, C, and D less conductive. When a flame appears at the pilot burner 6, for example, a circuit is established from the control electrode 38 to the conductor 66, electrode 67, the flame resistance, the pilot burner 6, to ground 71, to ground 72, resistor 73, relay winding 56, and the transformer secondary wind-

ing 31 to the cathode 39 whereby a negative charge will be stored on the condenser 69 during the half cycle when the anode 37 is negative and the control grid 38 will be rendered negative. During the succeeding half cycle, the transformer secondary winding 31 will tend to charge the condenser 69 positively, but, due to the flow of grid current, and the high resistance of the flame, the control grid 38 will not be permitted to swing very far positive, if at all, and as a result the negative charge remaining on the condenser 69 from the preceding half cycle will be greater than the positive charge being impressed thereon so that the control grid 38 will remain somewhat negative. Thus, as long as there is a flame at the pilot burner 6 the control grid 38 will be negative with respect to the cathode 39 and as a result the triode A will be rendered less conductive. Similarly, when a flame appears at the pilot burners 7 and 8 the control grids 45 and 48 will be biased negatively and the triodes C and D will be rendered less conductive.

When the triodes A, C, and D are thus rendered less conductive the pulsating potential drop across the resistor 51 will be reduced whereby the potential on the control grid 41 will become less negative. The flow of anode current through the triode B will thus be increased resulting in energization of the relay winding 56 and actuation of the switch blades 57 and 59 into engagement with the contacts 60 and 61, respectively. It is noted that the flow of anode current through the relay winding 56 produces a potential drop across the winding which is in the proper direction to bias the control grids 38, 45, and 48 negatively and thereby causes a further reduction in the anode current conducted by the valves A, C, and D. The resulting decrease in current through the resistor 51 operates to reduce the bias on the control grid 41 whereby the triode B is rendered more conductive and the potential drop across relay winding 56 is increased. A further decrease in current conducted by the triodes A, C, and D results and this action continues until a condition of equilibrium is reached.

Movement of the arm 57 out of engagement with the contact 58 causes the previously traced circuit through the primary of the ignition transformer to be interrupted so that the ignition means is de-energized. At the same time movement of the arm 57 into engagement with the contact 60 establishes an energizing circuit to the main valve actuating means 5 which may be traced from the alternating current supply conductor L¹, conductor 18, bimetallic element 17, switch blade 19, contact 20, switch blades 22 and 23 of the thermal safety switch, conductor 74, contact 61, switch blade 59, switch blade 57, contact 60, conductor 75, the valve actuating means 5, and conductors 64' and 64 to the supply conductor L². The main fuel valve 5 is then opened and fuel is admitted to the burners 1, 2 and 3, which is subsequently ignited by the individual pilot flames.

It should be noted the energization of the relay 56 with the resultant movement of arm 59 into engagement with contact 61 establishes an energizing circuit from the thermostat to the transformer primary winding 28, the pilot valve 9 and the main valve 5 which does not include the heater resistance 26 of the thermal safety switch but shunts that resistance. Short circuiting of the resistance 26 in this manner operates to render the thermal safety switch 21 inoperative and

the system will then remain in operation as long as normal combustion conditions exist and the thermostat 16 is in closed position.

If, for any reason, any one of the pilot burners should not become lighted, the potential of the control grid controlled by the respective burner flame will not be rendered negative with respect to its corresponding cathode to thereby make the average potential of those grids more positive than they were with normal flame resistance from the electrode 67 to ground and as a result the pulsating potential drop across the resistor 51 will not be sufficiently reduced. The control grid 41 will thus be maintained negative with respect to the cathode 39 and as a result the relay winding 56 will remain de-energized and the shunt circuit around the heater winding 26 will not be established. After a predetermined period of time, this will cause the bimetallic element 24 to be heated sufficiently to result in separation of switch arms 22 and 23. The separation of the switch arms 22 and 23 opens the circuit to the transformer primary winding 28 and de-energizes the entire system. As was previously noted, the switch arms 22 and 23 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.

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 any one of the electrodes 67, 67' or 67² and its respective burner after the system is already in operation, the potential on the respective control grid 38, 45, or 48 will be increased sufficiently in the positive direction to render the corresponding triode conductive to the necessary extent to produce a potential drop across the resistor 51 sufficient to render the triode B non-conductive. The relay 56 will then be de-energized and the thermal safety switch 24 will subsequently operate to de-energize the system.

It is noted that should any of the control grids 38, 45, or 48 be connected directly to ground, the grids so connected to ground will be swung negative and positive in synchronism with the induced voltage across the transformer primary winding 28 and accordingly will render the triode individual thereto more conductive whereby an increased potential drop will be produced across the resistor 51. When the resistance from the flame electrode 67 to ground, for example, is lower than that of a normal flame, the negative charge, accumulated on the condenser 69 during the half cycle when the anode 67 is positive, will leak off at a faster rate through that low resistance than it would through a normal flame resistance, and accordingly the average potential of the control grid will be more positive than it is when the resistance of the path from the flame electrode to ground is that of a normal flame. This increased potential drop across resistor 51 will operate to render the triode B non-conductive resulting in de-energization of the relay winding 56 and consequently in de-energization of the entire system. As illustrated resistor 73 is provided to limit the flow of grid current through the triodes A, C, or D to thereby prevent damage to these triodes in the event any of the control grids is connected directly to ground.

In Fig. 2 I have illustrated, more or less dia-

grammatically, a modification of the arrangement disclosed in Fig. 1 in which the triodes C and D have been omitted. In this modification, as illustrated, the ends of conductors 66, 66' and 66² remote from their respective flame electrodes have been connected together and the shields 68, 68¹ and 68² have also been connected together. The conductor 66 is connected to the control grid 38 of triode A, and the shields are connected to the cathode 39. A condenser 69³ and resistor 70³ of suitable value are connected in parallel relation between the control grid 38 and cathode 39.

Thus, when all of the flames are extinguished the control grid 38 will be at substantially the same potential as the cathode 39 whereby the triode A will conduct sufficient anode current to render the triode B non-conductive and the relay 56 will be de-energized. When a flame appears at each of the pilot burners, however, a circuit path will be closed from the bottom end of the transformer secondary winding 31 through the resistor 73 and the respective pilot flames to the control grid 38, and it is noted that the effect of the appearance of each pilot flame is to increase by a proportionate amount the negative bias applied to the control grid 38. For example, when only one flame is present a negative charge of a magnitude determined by the flame resistance will be stored on the condenser 69³, and when a second flame appears the negative charge will be increased proportionately. It will be readily apparent that condenser 69³ and resistor 70³ may be so proportioned with respect to the other circuit constants that the flow of anode current conducted by triode A will not be reduced sufficiently to cause the triode B to become conductive until all of the pilot flames have been ignited. Thus, failure of any of the pilot flames to ignite will operate to prevent the main fuel supply valve from being opened and subsequently to de-energize the system. Similarly, should any of the pilot flames become extinguished while the system is in operation, the triode A will be rendered sufficiently conductive to render the triode B non-conductive or at least sufficiently less conductive to cause de-energization of the relay 56 and thereby closure of the main fuel supply valve. The establishment of an abnormally low resistance path between any one of the flame electrodes and ground will also operate to de-energize the system.

In Fig. 3 I have illustrated, more or less diagrammatically, a further modification of a portion of the Fig. 1 arrangement in which the triodes C and D have been omitted and all of the pilot flames and flame electrodes have been connected in series relation. With this modification it will become apparent that failure of any one of the pilot flames to appear will operate to maintain the main fuel supply valve closed and similarly extinguishment of any of the pilot flames will operate to close the main fuel supply valve.

Specifically the conductor 66 is connected to the flame electrode 67 and circuit connections are provided including flame electrodes 67³, 67', 67⁴, 67² and 67⁵ whereby when the pilot burners 6, 7, and 8 have been ignited a circuit path will be closed between the flame electrode 67 and ground 74. With this modification the tips of pilot burners 6, 7 and 8 are of electrical insulating material or are electrically insulated from the pilot burners supply pipe and as illustrated the flame elec-

trode 67³ is inserted in the path of the flame of burner 6 near the flame electrode 67 and the electrode 67³ is connected to the flame electrode 67¹ which is inserted in the path of the flame of burner 7. The flame electrode 67⁴ is positioned adjacent the electrode 67¹ in the path of the flame of burner 7 and is connected to the flame electrode 67² which is inserted in the path of the flame of burner 8. The flame electrode 67⁵ is connected to ground as indicated at 71 so that when a flame is present at each of the pilot burners 6, 7, and 8 a circuit path will have been established between the control grid 38 and ground 71. As illustrated the conductors connecting the flame electrodes 67³ and 67¹, and 67⁴ and 67² are preferably run in shielded cables 68³ and 68⁴, respectively, which may be connected to the cathode 39 of valve 36, and a condenser 69⁴ and a resistor 70⁴ are connected between the control grid 38 and the cathode 39.

Thus, when a flame is present at all of the pilot burners a circuit path including all of the pilot flames in series will be established between control grid 38 and ground whereby the triode A will be rendered non-conductive, resulting in energization of the relay 56 and consequently in opening of the main fuel supply valve. If any of the pilot burners should fail to ignite, however, the circuit path referred to will not be closed so that the triode A will be conductive and the triode B will be non-conductive. The relay 56 will then be de-energized and as soon as the thermal safety switch 21 (not shown in this arrangement) heats up sufficiently the entire system will be de-energized.

Similarly, if any of the pilot burner flames should be extinguished while the system is in operation, the circuit path including the burner flames will be opened and the triode A will be rendered conductive whereby the system will subsequently be de-energized. Similarly, if a condition simulating combustion, such for example, as a low resistance path between any one of the flame electrodes and ground by reason of carbonization or direct connection therebetween, should be established after the system is in operation, the potential of control grid 38 will be increased sufficiently in the positive direction to render the triode A conductive and thereby to subsequently cause de-energization of the system.

While in accordance with the provisions of the statutes, I have illustrated and described the best form 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 certain features of my invention may sometimes 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. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a single electrode associated with each of said flames and adapted to be connected to ground thereby, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said valve to control said

second mentioned means, and means responsive to low, intermediate, and high electrical resistance values in the electrode to ground connections to continuously control said valve in said one sense responsively to said intermediate value and in said other sense responsively to said low and high values.

2. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a single electrode associated with each of said flames and adapted to be connected to ground thereby, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said valve to control said second mentioned means, and electrical circuit means including electronic valve means responsive to low, intermediate, and high electrical resistance values in the electrode to ground connections to continuously control said first mentioned valve in said one sense responsively to said intermediate value and in said other sense responsively to said low and high values.

3. A control system comprising, a plurality of isolated burners at each of which a flame is normally burning, a single electrode associated with each of said flames, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an electrical energizing supply source, a plurality of conductive paths energized from said source and each normally including one of said electrodes and one of said flames, an electronic valve having an input circuit and an output circuit, means controlled by the output circuit of said valve for controlling said second mentioned means, and means jointly responsive to all of said conductive paths and electrically connected to the input circuit of said valve to continuously control said valve in said other sense on the establishment of an abnormal condition of said conductive paths.

4. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a single electrode associated with each of said flames, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an electrical energizing supply source, a plurality of conductive paths energized from said source and each normally including one of said electrodes and one of said flames, an electronic valve having an input circuit and an output circuit, means including the output circuit of said valve to control said second mentioned means, and a single electronic valve connected to the input circuit of said first mentioned electronic valve and responsive to low, intermediate and high electrical resistance values in all of said conductive paths to continuously control said first mentioned valve in said one sense responsively to said intermediate value and in said other sense responsively to said low and high values.

5. In a fuel burner system, a plurality of isolated burners having a flame normally burning at each of said burners, burner fuel control

means, a single electrode associated with each of said burners and separated therefrom by a gap adapted to be bridged by the individual burner flames, electronic valve means having an input circuit and an output circuit, means to continuously control the input circuit of said electronic valve means including an electronic valve individual to each of said electrodes and controlled in accordance with the resistance of the gap between the electrode and burner associated therewith, and electrical circuit means including the output circuit of said electronic valve means to control said burner fuel control means.

6. In a fuel burner system, a plurality of isolated burners having a flame normally burning at each of said burners, burner fuel control means, a single electrode associated with each of said burners and separated therefrom by a gap adapted to be bridged by the individual burner flames, electronic valve means having an input circuit and an output circuit, means to continuously control the input circuit of said electronic valve means including an electronic valve individual to each of said electrodes and responsive to low, intermediate, and high resistance values of the gap between the electrode and burner associated therewith, and electrical circuit means including the output circuit of said electronic valve means to control said burner fuel control means to maintain said flames responsively to said intermediate value and to discontinue or prevent the existence of said flames responsively to said low and high resistance values.

7. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a single electrode associated with each of said burners and separated therefrom by a gap adapted to be bridged by the individual burner flames, burner fuel control means to control the supply of fuel to said burners, a device jointly responsive to the ohmic resistance values of the gap between each of said electrodes and its associated burner, an electrical energizing supply source, and continuously effective means energized by said source and under control of said device to control said burner fuel control means in a safe sense upon direct connection of any of said electrodes to its associated burner.

8. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a single electrode associated with each of said flames and adapted to be connected to ground thereby, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said valve to control said second mentioned means, and electrical circuit means including a device jointly responsive to low, intermediate, and high electrical resistance values in the electrode to ground connections to continuously control said valve in said one sense responsively to said intermediate value and in said other sense responsively to said low and high values.

9. A combustion safeguard control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a single electrode associated with each of said flames and adapted to be connected to ground

thereby, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an electronic valve common to all of said electrodes to continuously control said second mentioned means and adapted to be controlled in said one sense in response to intermediate resistance values in the electrode to ground connections and to be controlled in said other sense in response to low and high resistance values in the electrode to ground connections.

10. In a fuel burner system, a plurality of isolated burners having a flame normally burning at each of said burners, burner fuel control means, a single electrode associated with each of said flames and adapted to be connected to ground thereby, an electronic valve having an electrode common to all of said flame electrodes, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said second mentioned electronic valve adapted to cause said burner fuel control means to assume a fuel feeding position to maintain said flames when each of the electrode to ground connections includes the resistance of a respective burner flame, and continuously effective electrical circuit means including said first mentioned valve adapted to render the first mentioned circuit means ineffective in response to two widely separated resistance values in the electrode to ground connections.

11. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a pair of electrodes associated with each of said flames, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an energizing supply source, a conductive path energized by said source and normally including said flames connected in series relation, means continuously responsive to the resistance of said conductive path, and means under control of said responsive means adapted to control said second mentioned means in said one sense when said conductive path includes said flames and to control said second mentioned means in said other sense upon the establishment of a low resistance shunt connection about any of said flames.

12. A control system comprising, a plurality of isolated burners having a flame normally burning at each of said burners, a pair of electrodes associated with each of said flames, means for controlling the condition of combustion of said flames in one sense to maintain said flames and in another sense to discontinue said flames if burning or to prevent their existence if not burning, an energizing supply source, a conductive path energized by said source and normally including said flames connected in series relation, an electronic valve having an input circuit and an output circuit, said input circuit being continuously controlled by said conductive path, and electronic means under control of the output circuit of said electronic valve adapted to control said second mentioned means in said one sense when said conductive path includes said flames and to control said second mentioned means in said other sense upon the establishment of a low resistance shunt about one of said flames.

13. In a control system, a plurality of burner means, a plurality of resistances each of which is

modified by a respective one of said burner means, each of said resistances normally varying over a predetermined intermediate range of values and abnormally adapted to assume two widely displaced high and low values, means for effecting a control operation in one sense to maintain said resistances within said intermediate range of values and for effecting a control operation in another sense upon the occurrence of said resistances assuming one of said widely displaced values, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said electronic valve to control said first mentioned means, and means responsive to said resistances to continuously control the input circuit of said valve in said one sense when the values of said resistances are within said intermediate range of values and in said other sense when the values of said resistances are either one of said widely displaced values.

14. In a control system, a plurality of 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 effecting a control operation 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, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said electronic valve adapted to control said first mentioned means, and means responsive to said conditions to continuously control the input circuit of said valve in said one sense when the values of said conditions are within said intermediate range of values and in said other sense when the values of said conditions are one or the other of said widely displaced values.

15. In a control system, a plurality of 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 effecting a control operation in one sense to maintain said conditions within said predetermined range of val-

ues and in another sense upon the occurrence of said condition assuming one of said widely displaced values, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said electronic valve to control said first mentioned means, and electronic valve means responsive to said conditions to continuously control the input circuit of said valve in said one sense when the values of said conditions are within said intermediate range of values and in said other sense when the values of said conditions are one or the other said widely displaced values.

16. In a control system, a plurality of 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, an electronic valve having an input circuit and an output circuit, electrical circuit means including the output circuit of said electronic valve to control said second mentioned means, and a single electronic valve common to and responsive to said conditions to continuously control the input circuit of said valve in said one sense when the value of said conditions is within said intermediate range of values and in said other sense when the value of said conditions are one or the other of said widely displaced values.

17. In a fuel burner system, a plurality of main burners, a pilot burner associated with each of said main burners, a flame normally burning at each of said pilot burners, fuel control means for said main and pilot burners, a single electrode associated with each of said pilot burners and separated therefrom by a gap adapted to be bridged by the individual pilot burner flames, an electronic valve having an input circuit and an output circuit, means to control the input circuit of said electronic valve in accordance with the resistance of each of the gaps between the electrodes and associated pilot burners, and electrical circuit means included in the output circuit of said electronic valve to control said burner fuel control means.

DAVID B. KIRK.

CERTIFICATE OF CORRECTION.

Patent No. 2,216,534.

October 1, 1940.

DAVID B. KIRK.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, lines 8 to 11 inclusive, strike out the words "to thereby make the average potential of those grids more positive than they were with normal flame resistance from the electrode 67 to ground-- and insert the same after "winding 31" in line 51; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 24th day of December, A. D. 1940.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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