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CONTROL SYSTEM

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FIG. 2.

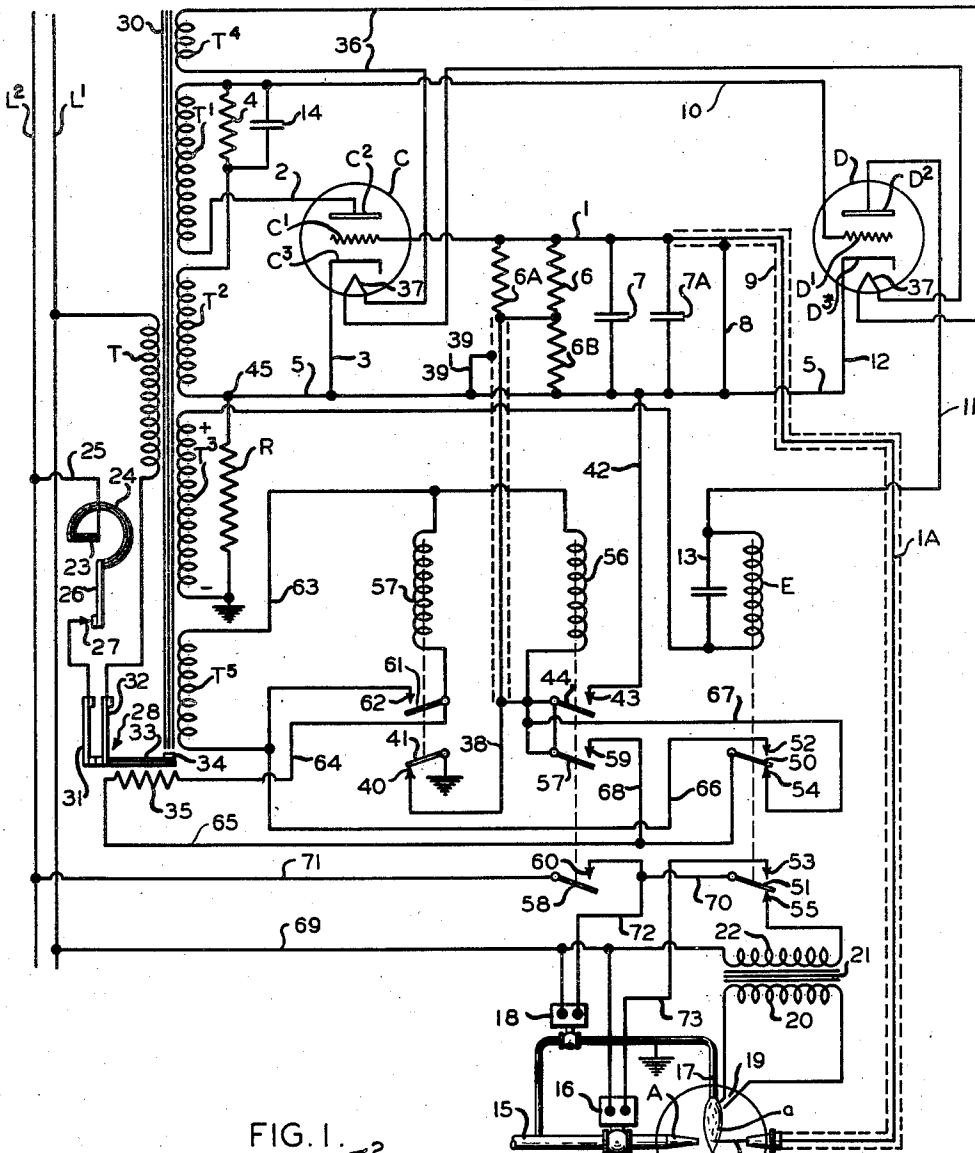
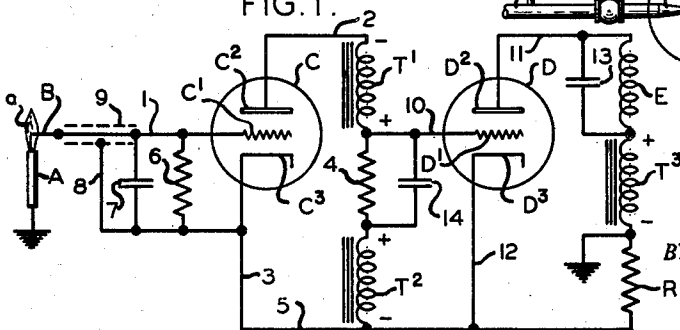


FIG. 1.



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2,402,117

CONTROL SYSTEM

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Application November 21, 1942, Serial No. 466,471

4 Claims. (Cl. 250—27)

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The general object of the present invention is to provide an improved protective apparatus or system adapted for use in effecting the closure of a fuel valve or the actuation of a signal or other suitable corrective element, on and in response to an abnormal variation in the electrical conductivity of a flame such as that due to its extinction.

The operation of ordinary gas burning apparatus, and particularly of industrial gas burners, ovens and furnaces, involves an explosion hazard or risk, of which the chief cause is the accumulation of unburned gas in or about the apparatus as a result of accidental flame extinction or failure of the fuel ignition means. To minimize such explosion risks, regular use is now being made of a protective system disclosed and claimed in the application of Jones, Serial No. 404,523, filed July 29, 1941. Said protective system comprises means for establishing an electric circuit including the flame, and comprises electric discharge means for impressing a pulsating, unidirectional potential on said circuit and for detecting and amplifying such changes in current flow through said circuit as a result of the extinction of the flame and for effecting a corrective valve or signal actuating relay operation.

A specific object of the present invention is to improve the means included in the protective system disclosed in said application, Serial No. 404,523, for impressing a pulsating unidirectional voltage on the flame circuit, and for detecting and amplifying the effect on the flame circuit current of the extinction of the flame. In the system disclosed in said application, the electric energy required for the operation of the protective system is supplied through a transformer from a commercial alternating current supply source, and the means for impressing a pulsating unidirectional current on the flame circuit is an electronic valve rectifier, separate from the detecting and amplifying section of the system.

A protective system embodying the present invention comprises associated detection and amplifying sections each including a separate electronic valve element and avoids need for a separate electronic valve rectifier element by its inclusion of means through which the pulsating current flow in an output circuit of the amplifying section of the system impresses a pulsating unidirectional voltage on the flame circuit.

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 under-

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standing of the invention, however, its advantages, and specific objects attained with its use, reference should be had to the accompanying drawing and descriptive matter in which I have illustrated and described preferred embodiments of the invention.

Of the drawing:

Fig. 1 is a wiring diagram illustrating a simple embodiment of the present invention; and

Fig. 2 is a wiring diagram illustrating a second embodiment of the present invention.

In Fig. 1 I have diagrammatically illustrated an embodiment of the present invention in which an electrode B extends into the flame α from a grounded gas burner A. The electrode B is connected by a conductor 1 to the control electrode C' of an electronic valve C which serves as a detector and which may be a type 27 triode valve. The terminals 2 and 3 of the anode and cathode elements C² and C³, respectively, of the tube C, are connected in the output circuit of the valve C in series with a transformer secondary winding T', a resistance 4, a transformer secondary winding T² and a section of a conductor 5. The input circuit of the valve C includes a resistance 6 connected between the conductor 1 and the cathode terminal 3 and a condenser 7 in parallel with said resistance.

As shown in Fig. 1, the conductor 1 is electrostatically shielded by enclosing it in a metallic sheath 9 which is connected by a conductor 3 to the cathode terminal 3 of valve C. The purpose of the shield 9 is to minimize the tendency of distributed capacitance along the conductor 1 to prevent the detector from being suitably sensitive to variations in flame resistance. As hereinafter pointed out the shield 9 may be dispensed with in some cases.

The output circuit of the detector valve C is connected by a conductor 10 to the control electrode D' of an electronic amplifier valve D, which may be a 45 type triode valve comprising an anode D² and cathode D³. The anode terminal 11 and cathode terminal 12 of the valve D are connected in series with the winding of a relay E, a transformer secondary winding T³, a resistance R and a section of the conductor 5, in the output circuit of the valve D. A condenser 13 is connected in shunt to the relay E winding to prevent chattering of the relay E during the half cycles in which the valve D is non-conductive. The terminal of the resistance R which is connected to one terminal of the transformer winding T³, is also connected to ground. As shown in Fig. 1, a third section of the conductor 5 con-

nects the cathode terminals of the valves C and D. The input circuit of the amplifier tube D includes the transformer winding T², the resistance 4 and a condenser 14 which is connected in shunt to the resistance 4.

The flame circuit of the apparatus shown in Fig. 1 comprises the burner A and its ground connection, the electrode B, the conductor 1, the resistance 6 and condenser 7, the cathode terminal 3, the conductor 5, and the resistance R and its ground connection. The flame α , when in its normal condition, provides a conductive path of current flow between the electrode B and grounded burner A. A pulsating current flow in the output circuit of the valve D will create unidirectional voltage pulsations in the resistance R, which will be impressed on the flame circuit in which the resistance R is also included.

The transformer windings T', T² and T³, which ordinarily are secondary windings of the same transformer as shown in Fig. 2, are arranged to have the polarities indicated in Fig. 1. The windings T' and T² are so proportioned that when the cathode-control electrode potential relation of the valve C is such as to make that valve conductive, the transformer winding T¹ creates a current flow in the output circuit of said valve, although the transformer winding T² opposes and diminishes the magnitude of that current flow. Furthermore, the windings T' and T², the resistance 4, and the condenser 14 are relatively proportioned to maintain the potential of the control electrode D' of the valve D high enough relative to the potential of the cathode D³, to continuously maintain some current flow in the output circuit of the valve D so that the impression of a pulsating unidirectional voltage on the flame circuit by the resistance R will not be interrupted. As will be apparent, however, when the valve C is conductive, the resultant current flow through the resistance 4 will create a potential drop in that resistance and thus reduce the potential of the control electrode D' relative to that of the cathode D³, and thereby effect a reduction in the conductivity of the valve D. That reduction in the conductivity of the valve D is utilized, in accordance with the present invention, to reduce the magnitude of the output current of the valve D sufficiently to interrupt the energization of the relay E winding.

The energization of the relay E winding is thus dependent upon the conductivity of the detector valve C. When the burner A is in operation and maintains the flame α in its normal condition, the pulsating unidirectional voltage impressed on the flame circuit by the amplifier D through the resistance R, maintains a current flow through the flame circuit in the direction toward the burner A from the electrode B. That direction is opposite to the direction of flame propagation and is the direction in which the flame is most conductive. The flame circuit current flow produces a potential across resistor 6 which is stored on the condenser 7 and is of the proper polarity to apply a negative bias potential to the control electrode C' and thereby prevent or minimize the current flow in the output circuit of the detector C. This potential is stored on the condenser 7 during the half cycles when the detector C is non-conductive and will normally be maintained on the condenser 7 during the succeeding half cycle when the anode C² is positive, if the condenser 7 and resistor 6 are properly proportioned. The result is that little

or no current is conducted in the output circuit of detector C during the condition of normal flame.

However, on the accidental formation of a path more conductive than the normal flame between the flame electrode and ground, the charge which is stored on the condenser 7 during the half cycle when the anode C² is negative, will leak off through that conductive path during the same cycle and the initial portion of the succeeding half cycle, and thereby substantially reduce the potential on the condenser 7 during the succeeding half cycle. In consequence, the bias potential applied to the control electrode C' will then be rendered substantially less negative, and as a result, current will then flow in the output circuit of detector C.

On the extinction of the flame α , also, the resultant interruption of the normal current flow in the flame circuit, eliminates the previously maintained negative bias potential of the control electrode C' and thus makes the valve C sufficiently conductive, to reduce the conductivity of the valve D to the extent required to effect the deenergization of the relay winding E without interrupting the impression of a pulsating unidirectional voltage on the flame circuit.

The relay E of Fig. 1 may form the actuating element of a signal calling the attention of an attendant to the extinction of the flame, or it may be employed, as it is employed in Fig. 2, to close a fuel valve (not shown in Fig. 1) in the fuel supply line of the burner A.

As will be readily apparent, instead of enclosing the triode electrodes C', C² and C³ in one envelope and the triode elements D', D² and D³ in a separate envelope, they may all be mounted in a single envelope to form a twin triode tube which may be of the 7N7 type.

While the apparatus shown diagrammatically in Fig. 1 embodies the general principles of the present invention and is operative to produce a suitable corrective action on the extinction of the flame α , the invention may sometimes be advantageously embodied in control systems including additional protective features. In particular, the present invention may well be incorporated, as shown diagrammatically in Fig. 2, in a preferred form of the commercially used system, disclosed and claimed in the above mentioned Jones application, Serial No. 404,523. The apparatus shown in Fig. 2 has safety and operating characteristics and features not possessed by the apparatus shown in Fig. 1, and in particular, is operative to prevent the gas valve from being opened, when as sometimes happens, a current leakage path at the burner is accidentally formed with a resistance to current flow through the flame circuit of the order of the resistance of the normal flame α . By way of illustration and example it is noted that the resistance of most flames is of the order of 50 megohms, and that the system shown in Fig. 2 may well be adapted to make the detector valve C responsive to variations in resistance between the flame electrode B and ground from about 0.13 to 150 megohms.

The apparatus shown in Fig. 2 comprises a burner A, an electrode B, a detector valve C and amplifier valve D, a relay winding E, transformer secondary windings T', T² and T³, a resistance R, and circuit elements 1-14 inclusive, all coacting generally as do the correspondingly

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designated parts of Fig. 1, but in Fig. 2 there are two condensers 7 and 7A connected in parallel between the conductors 1 and 5 and two resistors 6 and 6A connected in parallel with one another and in series with a resistor 6B between the conductors 1 and 5. The use of the parallel condensers 7 and 7A, and the parallel resistors 6 and 6A, rather than a single condenser and resistor is to insure safe operating conditions in the event of failure of one of the condensers or of one of the parallel resistors. The above mentioned parts, common to Figs. 1 and 2, are associated in Fig. 2 with elements not shown in Fig. 1.

In Fig. 2 the gas burner A is supplied with gas from a conduit 15, and the flow of gas to the burner is controlled by an electrically operated or other suitable control valve 16. A pilot burner 17 adjacent the burner A receives gas through an electrically operated or other suitable valve 18. In Fig. 2 means are provided for igniting the pilot flame, said means including a pair of electrodes 19 which are connected to the terminals of the secondary winding 20 of an ignition transformer 21. The latter has a primary winding 22 energized from the alternating current supply lines L' and L².

The fuel valve operating circuit of the protective system shown in Fig. 2, is controlled by means of a thermostat 23 which may be located in a room or space to be heated. The thermostat 23 which may be of any suitable construction, is shown as including a bimetallic element 24 connected by a conductor 25 to the alternating current supply line L², and a contact plate 26. The latter is adapted to move into and out of engagement with a stationary contact 27 which is connected to the alternating current supply line L' through a thermal safety switch 28 and the primary winding T of a transformer 30.

The thermal safety switch 28 is preferably of the form disclosed in the F. S. Denison Patent 1,958,081, granted May 8, 1934. As illustrated more or less diagrammatically in the drawing, the switch 28 comprises a stationary arm 31 and a movable arm 32 which is biased for movement away from the arm 31, but is normally held in engagement with the latter by means of a bimetallic element 33. The bimetallic element 33 is rigidly secured at one end to a stationary block 34 and is arranged to be heated by a coil 35 when the latter is energized through a circuit hereinafter described.

Upon energization of coil 35 for a predetermined period of time, the bimetallic element 33 will be warped sufficiently in the counterclockwise direction to permit the arm 32 acting under spring or other bias force, to separate from the arm 31 to thereby interrupt the circuit including the thermostat 23 and the transformer primary winding T. The thermal safety switch 28 will remain locked in its circuit interrupting position until manually adjusted to its normal closed position.

The transformer 30 which supplies power for the control system shown in Fig. 2 is a combination step-up and step-down transformer and comprises the previously mentioned primary winding T and secondary windings T¹, T² and T³, and low voltage secondary windings T⁴ and T⁵. The low voltage secondary winding T⁴ is connected by conductors 36 to the heater filaments 37 of the electronic valves C and D, respectively, and supplies energizing current thereto. The two filaments 37 are connected in series and the failure of either will render both valves C and D

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inoperative and thus avoid the possibility that the failure of one valve would leave the system unsafely operable. The secondary winding T⁵ supplies energizing current for hereinafter described purposes.

The detector valve C of Fig. 2 is supplied with electrical energy by the transformer secondary winding T¹ through an output circuit which may be traced from the lower terminal of winding T' to anode C², cathode C³, its terminal 3, a portion of a conductor 5, the winding T², and the resistance 4 which connects the upper terminals of the windings T' and T².

The conductivity of the output circuit of the detector tube C of Fig. 2 is controlled by an input circuit comprising three branches, one of which comprises conductors 1 and 1A connecting the controlling electrode C' to the electrode B which projects into the flame paths of the burners A and 17, said burners and their ground connection to negative terminal of resistance R, the latter and cathode terminal 3.

A second branch of the input circuit of the valve C connects the control electrode C' to the negative grounded terminal of the resistor R through a connection which includes the parallel resistors 6 and 6A, a conductor 38, a contact 40 and a switch arm 41, the latter being connected to ground. As shown, the conductor 38 is electrostatically shielded by a surrounding shell of metal 39 connected by a conductor 39' to the conductor 5. Ordinarily, the shield 39 is not essential and is omitted unless the conductor 38 needs to be unusually long. During the normal operation of the system shown in Fig. 2, the switch arm 41 is held out of engagement with the contact 40, but said arm and contact are in engagement at certain times for a purpose described later.

The third branch of the input circuit of the detector C connects the control electrode C' to the cathode C³ of the valve C through the parallel resistors 6 and 6A, the resistor 6B or a low resistance which is normally closed about the resistor 6B, a portion of the conductor 5, and the cathode terminal 3. The low resistance shunt which normally short circuits the resistor 6B, comprises conductors 38 and 42 connected to the upper and lower ends of the resistor 6B, and a contact 43 and a switch arm 44 which in its normal position engages the contact 43 and thereby connects the lower ends of the conductors 38 and 42.

The secondary windings T² and T³ of the transformer 30 are so wound that the amplifier D can be fully conductive only during the half cycles in which the detector C cannot be conductive and vice versa. The phase of the pulsating direct current potential drop produced across resistor R during the half cycles when the detector D is conductive, is such that it will be at a maximum value when the anode C² of detector C is positive. The said pulsating potential drop, or biasing potential is applied to the input circuit of the detector C through the flame, if present, and the polarity thereof is such as to cause a pulsating direct current to flow through the flame in the direction opposite to the direction of flame propagation. This input circuit of detector C may be traced from the positive terminal 45 of resistor R through the conductor 5; resistors 6B, 6 and 6A shunted by the condensers 7 and 7A, the conductor 1, flame electrode B, the flame resistance, burner 17 to ground, and

through ground to the grounded negative terminal of the resistor R.

When a flame is not present at the burners and the switch arm 41 is out of engagement with the contact 40 and no other conductive path exists from the control electrode C' to ground, no bias potential will be applied to said electrode C' and the latter will then be at substantially the same potential as the cathode C³ of the detector valve C, since the control electrode C' and cathode C³ are connected by resistors 6, 6A and 6B. As a result the detector valve C will then be conductive during the periods in which its anode C is positive.

The input and output circuits of the valve D of Fig. 2 are precisely like those shown in Fig. 1. Furthermore, in Fig. 2, as in Fig. 1, when there is no burner flame, and when the flame electrode B is grounded, the current flow in the output circuit of the detector C prevents the valve D from being sufficiently conductive to maintain the energization of the relay E, and when the normal burner flame is maintained, the current flow, if any, in the output circuit of the detector C is insufficient to prevent the tube D from maintaining the energization of said relay. In Fig. 2, as in Fig. 1, also, the maintenance of the burner flame does not reduce the conductivity of the valve D sufficiently to prevent the valve from operating through the resistance R to continuously impress a pulsating unidirectional voltage on the flame circuit.

As illustrated in Fig. 2, the relay E mechanism comprises switch arms 50 and 51 which engage upper or front contacts 52 and 53, respectively, when the relay is energized. When the relay E is deenergized the switch arms 50 and 51 engage lower or back contacts 54 and 55, respectively. The Fig. 2 system includes two other relays, 56 and 57, which are utilized for purposes explained hereinafter. Relay 56 operates the previously mentioned switch 44 and also operates switches 57 and 58. The switches 57 and 58 respectively engage front or upper contacts 59 and 60 when relay 56 is energized. Relay 57 operates the previously mentioned switch 41, and also operates a switch 61. When the relay 57 is energized the switch 61 engages a contact 62 and the switch 41 disengages the contact 40.

In the operation of the apparatus shown in Fig. 2, when the temperature of the space to be heated is higher than the desired value, all parts of the system are in their positions shown in Fig. 2, and the fuel burner is then deenergized. When thereafter, the temperature of said space falls below the value it is desired to maintain, the thermostat 23 operates to move the switch blade 26 into engagement with the contact 27. This results in the energization of the transformer primary winding T and thereby the energization of the transformer secondary windings T⁵—T⁶.

The detector C is not immediately rendered conductive, however, because the switch arm 41 and contact 40 are then in engagement and operate to apply the full negative potential across the resistor R to the control electrode C'. However, the amplifier D becomes conductive and energizes the winding of the relay E as soon as its filament 37 becomes heated. The relay E then moves switch arm 50 into engagement with contact 52 to complete a circuit energizing relay 56 and the heater coil 35. That circuit may be traced from the upper terminal of transformer secondary winding T⁵ through a conductor 63, winding of relay 57, a conductor 64, heater coil

35, a conductor 65, switch arm 50, contact 52, and a conductor 66 back to the lower terminal of winding T⁵.

The energization of relay 57 causes its switch arm 61 to engage the contact 62 and thereby complete a holding circuit for the relay 57. This holding circuit may be traced from the upper terminal of winding T⁵, through conductor 63, winding of relay 57, switch arm 61 and contact 62 to the lower terminal of winding T⁵. Relay 57, when energized, also moves switch arm 41 out of engagement with contact 40 thus opening the circuit previously applying a negative potential bias to the control electrode C³ of detector C, and thereby permits the detector C to become conductive, providing conditions between the flame electrode B and ground are proper.

Before the starting cycle is allowed to proceed further, however, the system effects an automatic check to detect the presence of a leakage resistance path between the electrode B and ground, and prevents initiation of the burner flame in a manner described hereinafter when such a leakage path exists and has a resistance of the order of the normal flame resistance, or slightly higher. This desirable result is obtained by so interlocking the relays E and 57 that the starting cycle cannot proceed unless the relay E is first deenergized and then reenergized.

If the resistance of the leakage path between the flame electrode B and ground is of the order of a normal flame, a charge is stored on the condensers 7 and 7A which maintains the detector C non-conductive and consequently maintains the amplifier D conductive and thus prevents the deenergization of the relay E. The resistor 6B which is connected in series with the parallel resistors 6 and 6A between the control electrode C' and cathode C³ of detector C is provided to accomplish this result. At this point in the system starting cycle the shunt circuit around the resistor 6B is open at the switch arm 44, and the resistor 6B adds to the resistance in shunt with the condensers 7 and 7A, so that a higher average negative potential is maintained on the control electrode C' by the condensers 7 and 7A than would be maintained if the resistance 6B were shunted.

The detector C at this point in the starting cycle of the system is therefore sensitive to a conductive path between the electrode B and ground of resistance greater than that of a normal flame. If such a conductive path exists, the detector C will remain non-conductive and the system will continue in the condition last described, namely, with both relays E and 57 energized. The magnitude of the resistance of such a leakage conductive path from electrode B to ground to which the detector C is sensitive, is determined by the total capacitance of the condensers 7 and 7A and by the effective value of the resistances 6, 6A and 6B.

If no such leakage path between the flame electrode B and ground exists, however, no potential is stored on condensers 7 and 7A following the energization of the relay 57, and, in consequence, the detector C then becomes conductive thereby decreasing the conductivity of the amplifier D sufficiently to deenergize the relay E. On the deenergization of relay E switch arm 50 engages contact 54 and thereby completes an energizing circuit for the relay 56. This energizing circuit may be traced from the upper terminals of transformer secondary winding T⁵ through conductor 63, winding of relay 56, a conductor 67, contact

54, switch arm 50, conductor 65, heater coil 35, conductor 64, switch arm 61, and contact 62 back to the winding T⁵.

Energization of the relay 56 causes it to close a holding circuit for itself, to shunt resistor 6B, and to energize the ignition transformer primary winding 22 and the pilot valve 13. The holding circuit for the relay 56 may be traced from the transformer secondary winding T⁵ through conductor 63, winding of relay 56, switch arm 57, contact 59, a conductor 63, conductor 65, heater coil 35, conductor 64, switch arm 61 and contact 62 back to winding T⁵. The resistor 6B is shunted when the energization of relay 56 moves switch arm 44 into engagement with contact 43 and thereby connects conductors 33 and 42. The energizing circuit for the ignition transformer winding 22 which is closed when relay 56 is energized, may be traced from the alternating current supply line L' through a conductor 69, the primary winding 22, contact 55, switch arm 51, a conductor 70, contact 60, switch arm 53, and a conductor 71 to the alternating current supply line L². The energizing circuit for the pilot fuel valve 13 may be traced from the supply line L' through conductor 69, valve 13, a conductor 72, contact 60, switch arm 53, and conductor 71 to the supply line L².

As a result of the energization of the ignition transformer 21 and the pilot fuel valve 13, a flame should appear at the pilot burner 17. If no flame appears no further action will take place until the system is deenergized by the action of the heater coil 35 of the thermal safety switch 28. If a flame appears, however, detector C will become non-conductive as previously described, and consequently, amplifier D will become conductive and relay E will again be energized. The reenergization of relay E closes a short circuit around the heater coil 35, opens the energizing circuit of the ignition transformer 21 and energizes and opens the main fuel valve 16 and thereby places the burner A in full operation.

The short circuit around the heater coil 35 closed by the reenergization of the relay E, may be traced from the left end of said coil, as seen in Fig. 2, to conductor 65, switch arm 53, contact 52, conductor 66, contact 62, switch arm 61 and conductor 64 to the right end of heater coil 35. The reenergization of relay E opens the energizing circuit of transformer primary winding 22 by moving switch arm 51 out of engagement with contact 55. The energizing circuit for the main fuel valve 16 closed by the reenergization of relay E, may be traced from the supply line L' through conductor 69, fuel valve 16, a conductor 73, contact 53, switch arm 51, conductor 70, contact 60, switch arm 53 and conductor 71 to the supply line L².

After the burner has thus been placed in full operation, the extinction of the flame causes the detector C to become conductive, and the amplifier D to become non-conductive, and deenergizes the relay E and thereby closes the main burner valve 16, reenergizes the ignition transformer 21, and opens the shunt circuit around the heater coil 35 of the thermal safety switch 28. If this results in the reappearance of the pilot flame, the main burner will again go into full operation. If the flame does not reappear within a predetermined time, however, the heating action of the coil 35 will open the safety switch 23 and effect the deenergization of the system including the closure of the pilot valve 13.

From the foregoing, it will be seen that the sys-

tem of Fig. 2 is adapted to distinguish between normal and abnormal flame conditions and operates to deenergize the system if an abnormal condition prevails longer than a predetermined time.

The capacitance of each of the two condensers 7 and 7A may well be one-half the total capacitance desirably included between the conductors 1 and 5, so as to reduce the possibility of unsafe failure of the system. Thus, with the arrangement shown in Fig. 2, when the value of the normal capacitance between conductors 1 and 5 is reduced to one-half by the open circuiting of one of the other of the condensers 7 and 7A the circuit will still fail safe upon flame failure or upon direct connection of the flame electrode with ground. Advantageously, also, the parallel resistors 6 and 6A each have double the resistance which they collectively provide so that they may effectively reduce the risk of unsafe operation of the system if and when one of the resistors is open circuited.

In such systems as are illustrated herein, the range of flame resistance to which the system will properly respond, and the time required for the system response, depend upon the amounts of capacitance and resistance between the flame electrode B and ground. Specifically, in a system of the type and form shown in Fig. 2, the said flame resistance range and time of response depend mainly upon the distributed capacitances of the conductors 1 and 38, upon the capacitance of the condensers 7 and 7A, and upon the effective resistance of the resistors 6 and 6A.

In general, an increase in said distributed capacitance tends to decrease the flame resistance range in which the system is operatively responsive, and should be attended by an increase in the capacitance of condensers 7 and 7A, as the last mentioned increase tends to increase the said range. In general, also, the time required for the detector C to operate in response to a significant change in flame resistance is proportional to the product obtained when the effective resistance of the resistors 6 and 6A, is multiplied by the capacitance of the condensers 7 and 7A.

The principles determining the capacitance of the condensers 7 and 7A and the effective resistance of the resistors 6 and 6A which will give optimum results under particular operating conditions, are set forth in the above mentioned Jones application, Serial No. 404,523, and need not be restated herein. By way of illustration and example, it is noted, however, that with conductors 1 and 38 of an aggregate length of 25 feet and unshielded, the capacitance of the condensers 7 and 7A may well be of the order 0.01 microfarads, and the effective value of the resistances 6 and 6A may well be of the order of 25 megohms, and in such case the time required for the detector C to operate in response to a significant change in flame resistance will be of the order of one second, which will be quite suitable in many cases.

While in accordance with the provisions of the statutes, I have illustrated and described the best forms 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 forms 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. The combination of a load device, of means for controlling said device in accordance with the impedance of a flame, comprising a pair of spaced electrodes insulated from each other and adapted to be connected by the flame, electronic detecting means comprising an input circuit including said flame electrodes and an output circuit, and electronic amplifying means comprising an input circuit connected to said output circuit and comprising an output circuit including said device, said second output circuit including means for impressing a fluctuating substantially unidirectional potential across said electrodes.
2. The combination of a load device, of means for controlling said device in accordance with the impedance of a flame, comprising a pair of spaced electrodes insulated from each other and adapted to be connected by the flame, electronic detecting means comprising an input circuit including said flame electrodes and an output circuit, and electronic amplifying means comprising an input circuit connected to said output circuit and comprising an output circuit including said device and operable to energize and deenergize said device accordingly as the conductivity of the path of current flow between said electrodes has one or the other of two predetermined values, and means actuated by current flow in the last mentioned output circuit for impressing a fluctuating, substantially unidirectional potential across said electrodes when the conductivity of said path has either of said values.
3. The combination of a load device, of means for controlling said device in accordance with the impedance of a flame, comprising a transformer having a plurality of secondary windings, a flame

- circuit including a pair of spaced electrodes insulated from each other and adapted to be connected by the flame, electronic detecting means comprising an input circuit including said flame electrodes and an output circuit including one of said secondary windings, a resistance included in said output circuit, electronic amplifying means comprising an input circuit connected to said output circuit and including said secondary winding and resistance and comprising an output circuit including said device and a second one of said secondary windings and including means for impressing a fluctuating, substantially unidirectional potential on said flame circuit.
4. The combination of a load device, of means for controlling said device in accordance with the impedance of a flame, comprising a pair of spaced electrodes insulated from each other and adapted to be connected by the flame, electronic detecting means comprising an input circuit including said flame electrodes and an output circuit, a source of alternating voltage included in said output circuit and operable to create a current flow therein under certain input circuit conditions, a resistance and a second source of alternating voltage also included in said output circuit, the last mentioned voltage being opposite in direction to, and smaller in magnitude than the first mentioned voltage, electronic amplifying means comprising an input circuit on which the resultant of the first mentioned voltage and the potential drop in said resistance is impressed and comprising an output circuit including said device, and means actuated by current flow in the last mentioned output circuit for impressing a fluctuating, substantially unidirectional potential across said electrodes.

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