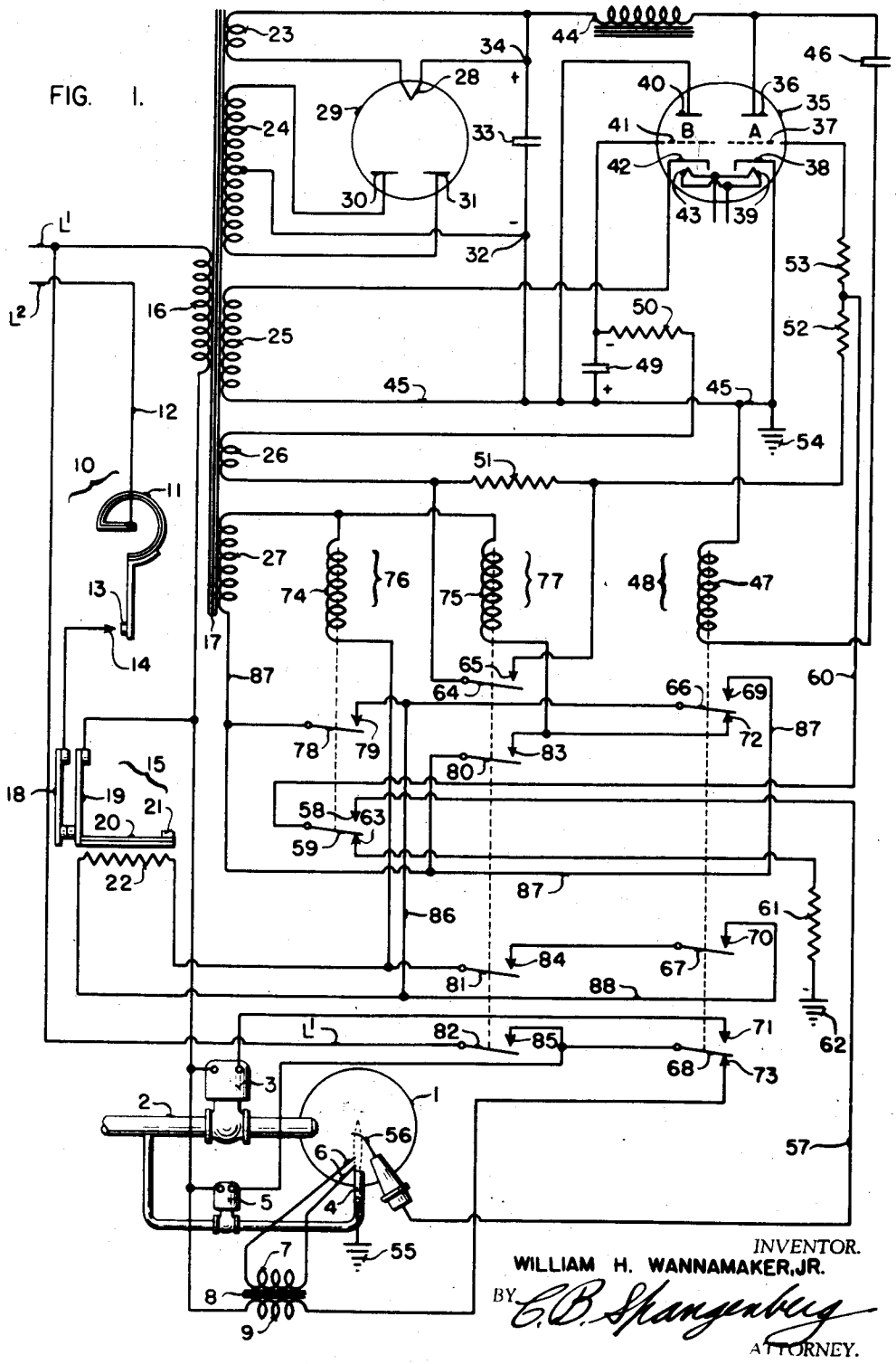
Nov. 18, 1941. W. H. WANNAMAKER, JR 2,263,430

CONTROL APPARATUS

Filed April 12, 1940 2 Sheets-Sheet 1

FIG. 1.



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CONTROL APPARATUS

Filed April 12, 1940 2 Sheets-Sheet 2

FIG. 2.

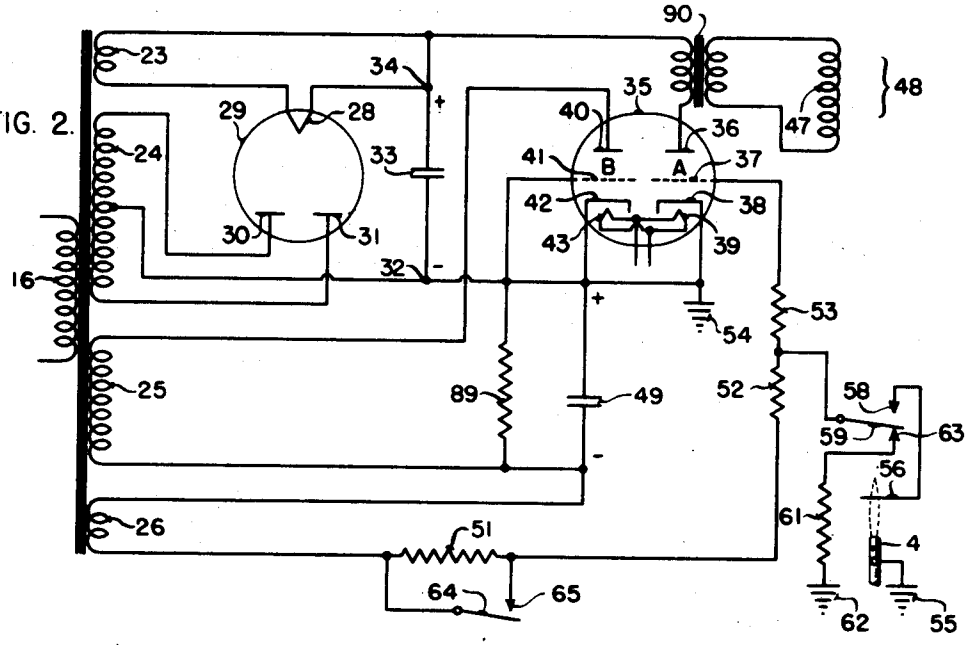
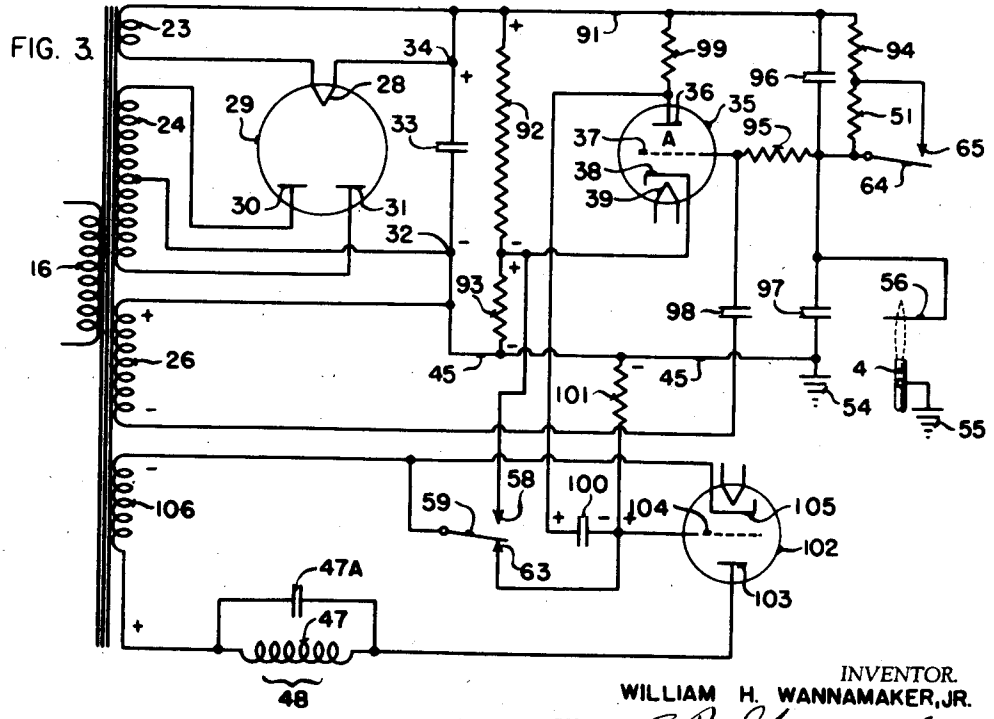


FIG. 3.



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CONTROL APPARATUS

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Application April 12, 1940, Serial No. 329,280

16 Claims. (Cl. 158—28)

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

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

Another object of the invention is to provide an improved safety control system for a fuel burner which operates in accordance with the conductivity of a flame of the burner fuel.

A further object of the invention is to provide a safety control system of the flame conductivity responsive type which utilizes an electric discharge device the conductivity of which is changed substantially immediately in response to the establishment or extinguishment of the flame.

A further object of the invention is to provide a safety control system of the flame responsive type which employs a pair of electrodes, one of which may be the burner itself, in engagement with the flame for measuring the flame conductivity, and wherein means are provided for distinguishing between normal flame conductivities and apparent conductivities of the path between the electrodes that may be set up due to accidental engagement of the electrodes or established by virtue of carbonization thereof.

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.

The various features of novelty which characterize my invention are pointed out with particularity in the claims anexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects attained with its use, 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:

Figure 1 illustrates a safety control system for a fuel burner embodying my invention;

Figure 2 illustrates a modification of the flame-responsive circuit of Figure 1; and

Figure 3 illustrates another modification of the flame-responsive circuit of Figure 1.

In Fig. 1 of the drawings, I have illustrated, more or less diagrammatically a gas burner 1 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^1 and L^2.

The fuel valve operating circuit of my control system is controlled by means of a 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^1 through a thermal switch 15 and winding 16 of a 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 counter-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 comprises the primary winding 16, and secondary windings 23, 24, 25, 26 and 27. The winding 23 supplies current to a cathode 28 of a rectifier tube 29, which may be of any convenient type, such as a tube known commercially as the type 80. The winding 24 supplies current to the anodes 30 and 31 of the valve 29, each anode being connected to an opposite terminal thereof. A center tap of winding 24 is connected to a terminal 32 of a condenser 33. The opposite terminal 34 of condenser 33 is connected to cathode 28. This rectifier circuit is of a well known type, and may be replaced by any other suitable means of rectification. The circuit connections are such that a potential is produced across condenser 33 of the proper polarity to make terminal 34 positive with respect to terminal 32. This potential is used to supply the output circuit of an electric discharge device, which may be one half of a double triode 35. For convenience of description, that half of the double triode 35 will be designated triode A, and the other half triode B. Double triode 35 may be of any suitable type, for example, a commercial type 6Y7 or 6C8.

Triode A comprises an anode 36, a control electrode 37, a cathode 38 and a heater filament 39. Triode B comprises an anode 40, a control electrode 41, a cathod 42, and a heater filament 43. Heater filaments 39 and 43 are shown connected in parallel and may be energized from any suitable source, such for example, as another secondary winding (not shown) of transformer 17. The output circuit of triode A has two branches, one of which may be traced from positive terminal 34 of condenser 33, through a choke coil 44, anode 36, cathode 38, and a conductor 45 to the negative terminal 32 of condenser 33. The other output circuit branch may be traced from anode 36 through a condenser 46, a winding 47 of a relay 48, and conductor 45 to cathode 38.

Relay 48 comprises the winding 47 and switch arms 66, 67 and 68 which cooperate respectively with upper contacts 69, 70 and 71. Switch arms 66 and 68 also cooperate with lower contacts 72 and 73, respectively.

Triode B serves as a rectifier to supply a continuous potential to the input circuit of triode A. The anode circuit of triode B may be traced from anode 40 through conductor 45, and transformer secondary winding 25, to cathode 42. Control electrode 41 which functions in this circuit as a second anode is connected to conductor 45 through a condenser 49. The anode 40 of triode B in this arrangement operates to shield the rectifying section from the triode A. Due to rectification of the alternating current by triode B, a charge is built up on condenser 49 such that the terminal thereof connected to conductor 45 is positive with respect to the terminal connected to the control elecrode 41.

The input circuit of triode A has two branches, one of which may be traced from cathode 38, through conductor 45, condenser 49, a protective resistor 50, transformer secondary winding 26, a resistor 51, a resistor 52 and a protective resistor 53 to the control electrode 37. The second branch of the input circuit of triode A may be traced from cathode 38 through a ground connection 54, another ground connection 55, pilot burner 4, the flame conductance, an electrode 56 positioned in the flame path, a conductor 57, a stationary contact 58, a switch arm 59, a conductor 60, and resistor 53 to the control electrode 37. It is noted that when the burner operation is being initiated, the flame conductance is replaced in this second branch by an artificial flame resistance 61. This branch may then be traced from cathode 38 through ground connection 54, another ground connection 62, resistor 61, and a contact 63, to switch arm 59, and thence along the last described circuit to control electrode 37. After the burner has been placed into operation, resistor 51 is shunted from the first mentioned input circuit of triode A by closure of a switch arm 64 on a stationary contact 65. The function of resistor 51 will be described hereinafter.

It will be noted that the input circuit of triode A contains in its first branch, a source of continuous potential, namely the potential maintained across the condenser 49, and a source of alternating potential which is obtained from the transformer winding 26. The polarity of the potential maintained on condenser 49 is such that the control electrode 37 is biased negatively with respect to cathode 38. The magnitude of the potential on condenser 49 is of such value that when no flame exists between the flame electrode 56 and the pilot burner 4, that potential is effective to bias the control electrode 37 sufficiently negative with respect to the cathode 38 to reduce to substantially zero the flow of current in the output circuit of triode A. It is noted that with a large negative direct current bias effective on the triode A, the alternating potential impressed on the input circuit of triode A by transformer secondary winding 26 is ineffective to vary to any significant extent the current in the output circuit of triode A. This is the case because with a large negative bias on the control electrode 37 the triode A is operating at a point along the grid voltage-plate current characteristic curve at which the slope is substantially zero. Consequently, the application of an alternating potential on the input circuit of triode A by the transformer secondary winding 26 is ineffective to produce more than some slight fluctuation in the flow of current in the output circuit of triode A.

When a flame exists between the flame electrode 56 and the burner 4, a circuit is completed for the flow of current from condenser 49, which may be traced from the positive terminal of said condenser, through conductor 45, ground connections 54 and 55, burner 4, the flame conductance, electrode 56, conductor 57, contact 58, switch arm 59, conductor 60, resistor 52, resistor 51 or the shunt connection including contact 65 and switch arm 64, winding 26, and resistor 50 to the negative terminal of condenser 49. Current flowing in this circuit produces a potential drop across each of resistors 50, 51 (if not shunted out), and 52 which is in opposition to the potential on condenser 49 and which, therefore,

operate to reduce the negative bias on the control electrode 37. This reduction in negative bias on the input circuit of triode A shifts the operating range of the triode A to a point of increased slope along the grid voltage-plate current characteristic curve thereof. At this operating point of the triode A, the alternating potential impressed on the input circuit thereof by the transformer secondary winding 26 is effective to produce an appreciable fluctuation in the flow of current in the output circuit thereof. Because of the filtering action of choke coil 44, substantially all of the fluctuating component of the output current of triode A flows through the condenser 46 and the relay winding 47. This fluctuating component of the output current of triode A is effective when a flame exists between the electrode 56 and the burner 4 to energize the relay winding 47 the amount required to effect movement of its switch arms upward.

If a path more conductive than a flame occurs between the flame electrode 56 and the pilot burner 4, which path may be established as a result of carbonization of the electrode 56 or by accidental engagement of the burner 4 and the electrode 56, the sum of the potential drops across resistors 50, 51 and 52 is increased and accordingly the negative bias on the input circuit of the triode A is further reduced. This reduction in negative bias on the triode A operates to shift the operating point of the triode A further along its grid voltage-plate current characteristic curve. It is noted that such shift of the operating point of the triode A is permitted by the apparatus of my invention without affecting the operation of relay 47 as long as the slope of the grid voltage-plate current characteristic curve remains substantially the same or increases since the shift then only is effective to maintain or increase the energization of relay 47. The grid voltage-plate current characteristic curve of the triode A is so chosen that with a large negative bias on the input circuit thereof the slope of that curve is substantially zero, and with substantially zero bias on the input circuit thereof the slope of that curve is also substantially zero. With an intermediate range of negative bias on the input circuit of the triode A, the slope of said curve is appreciable. Therefore, as the negative bias on the input circuit of triode A is further reduced, a point is reached at which the slope of the grid voltage-plate current characteristic curve begins to decrease, and accordingly the fluctuating component of current in the output circuit of triode A is correspondingly decreased. Further reduction in the negative bias on the input circuit of triode A produces a further reduction in the fluctuating component of the current in the output circuit of triode A. As the fluctuating component of current in the output circuit of triode A is so decreased, a point is reached at which the flow of energizing current to the relay 47 is insufficient to maintain the relay switch arms in their upward position and as a result those switch arms fall under the force of gravity or under the force of spring means, not shown, to their lower positions.

It will be noted, therefore, that the apparatus of my invention is effective to cause energization of the relay winding 47 when a flame is present at the burner 4 and is ineffective to maintain the energization of the relay winding 47 when there is no flame at the burner or when the electrode 56 is connected through a resistance path substantially lower in resistance than that of a flame to the burner 4.

It is noted that when resistor 51 is not shunted out by the switch arm 64 and contact 65, the maximum value of resistance between the flame electrode 56 and burner 4 which will cause the relay winding 47 to actuate its associated switch arms to its upward position is increased. This resistor is inserted in the input circuit of the triode A only during the time of initiation of burner operation, that is at a time when no flame exists at the burner 4, in order that a test may be made for high resistance leakage paths between the electrode 56 and ground. If such high resistance leakage paths exist, the circuit responds in an abnormal manner which is explained in detail hereinafter and effects de-energization of the entire system.

Transformer secondary winding 27 supplies current to windings 74 and 75 of relays 76 and 77, respectively, through circuits to be described hereinafter. Relay 76 comprises the winding 74 and a switch arm 78 which cooperates with an upper contact 79 in addition to the switch arm 59 previously mentioned, which cooperates with upper contact 58 and lower contact 63. Relay 77 comprises winding 75 and switch arms 80, 81 and 82, cooperating with upper contacts 83, 84 and 85, respectively, in addition to switch arm 64 and its associated upper contact 65, previously mentioned.

When the burner is not in operation, all parts of the system are in the positions shown in Fig. 1 of the drawings. 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 switch blade 13 into engagement with contact 14, resulting in closure of an energizing circuit to the transformer primary winding 16 and thereby energization of the transformer secondary windings. As soon as the cathodes of the electric discharge devices become heated, relay winding 47 is energized because resistor 61 is at this time connected in the input circuit of triode A through switch arm 59 and contact 63 which are then in engagement.

Energization of relay 47 causes switch arm 66 to engage contact 69, completing an energizing circuit for winding 74 of relay 76 and heater coil 22 of thermal safety switch 15 which may be traced from the upper terminal of secondary winding 27, as it appears in the drawing, through winding 74, heater coil 22, a conductor 86, switch arm 66, contact 69, and a conductor 87 to the lower terminal of winding 27.

Energization of relay 76 results in the closure of a holding circuit for itself and heater coil 22, and in the removal of resistor 61 from the input circuit of triode A and the insertion of the conductance of the path between electrode 56 and burner therein. The said holding circuit may be traced along the last described circuit to conductor 86, and thence through contact 79, switch arm 78 and conductor 87 to the lower terminal of winding 27.

Connection of the conductance of the flame path in the input circuit at this time normally results in de-energization of relay winding 47 because there is then no flame at burner 4 and consequently no conductive path between electrode 56 and ground. If a leakage conductive path should exist, however, relay winding 47 will be maintained energized, and no further action of the control system will occur until after a predetermined interval, thermal switch 15, act-

ing under the influence of heater coil 22, opens to effect de-energization of the entire system. It is noted that since resistor 51 is connected in the input circuit of triode A during initiation of the system operation the sensitivity of the system to the presence of leakage paths to ground is then greater than normal as previously explained and accordingly, the relay winding 47 will be maintained energized even though the leakage path is of high resistance. By properly proportioning resistor 51, it will be apparent to those skilled in the art that leakage conductances of the order of flame conductance or even lower conductances may maintain relay 47 energized until the thermal safety switch 15 de-energizes the system.

If conditions at the flame electrode 56 are normal, and winding 47 is accordingly de-energized when the flame path is connected in the input circuit of triode A, and an energizing circuit for winding 75 of relay 77 is completed which may be traced from the upper terminal of winding 27 through winding 75, contact 72, switch arm 66, contact 79, switch arm 78, and conductor 87 to the lower terminal of winding 27.

Energization of relay 77 effects the closure of a holding circuit for itself, the shunting of resistor 51, and the energization of the pilot burner fuel supply valve 5 and the ignition transformer primary 9. The holding circuit for relay winding 75 may be traced from the upper terminal of secondary winding 27, through winding 75, contact 83, switch arm 80 and conductor 87 to the lower terminal of secondary winding 27. The shunting of resistor 51 is accomplished by engagement of switch arm 64 with contact 65. The energizing circuit for valve 5 may be traced from line L^1 through switch arm 82, contact 85, valve 5, thermal safety switch 15 and thermostat 10 to line L^2. The energizing circuit for the ignition transformer primary 9 may be traced from line L^1 through switch arm 82, contact 85, switch arm 68, contact 73, primary winding 9, thermal safety switch 15 and thermostat 10 to line L^2.

Simultaneous opening of valve 5 and energization of ignition transformer 8 normally effects the establishment of a flame between electrode 56 and burner 4. If no flame appears, however, the control system continues in the condition described until de-energized by thermal safety switch 15. If a flame appears, however, relay winding 47 is again energized, thereby completing a shunt circuit around heater coil 22 of the thermal safety switch, completing a circuit for energizing the main burner fuel supply valve 3, and opening the circuit to the ignition transformer primary 9, thus placing the burner in full operation. The shunt circuit around heater coil 22 may be traced from the left end terminal thereof through conductor 88, contact 70, switch arm 67, contact 84 and switch arm 81 back to the other terminal. The energizing circuit for valve 3 may be traced from line L^1, through switch arm 82, contact 85, switch arm 68, contact 71, valve 3, thermal safety switch 15 and thermostat 10 to line L^2. The circuit through ignition transformer primary winding 9 is opened by disengagement of switch arm 68 from contact 73.

If, after the burner is in full operation, the flame disappears, or a low resistance path to ground occurs at the flame electrode 56, relay winding 47 is de-energized and effects de-energization of valve 3, and energization of ignition transformer primary 9. If normal flame conditions are not then re-established within a predetermined interval, thermal safety switch 15 operates to de-energize the system.

The system described distinguishes between the presence and absence of flame, responding to such absence by attempting to relight the burner, and if unsuccessful, de-energizes the entire system. The system also de-energizes the entire system when a leakage path to ground exists at the flame electrode, thereby preventing operation of the burner during conditions which might make the control system unresponsive to the absence of a flame.

In Fig. 2 of the drawings I have illustrated, more or less diagrammatically, a modified flame responsive circuit which may be employed in the system of Fig. 1. The differences between this circuit and that of Fig. 1 are only in the circuit of rectifier triode B, and in the method of coupling the output of triode A to the relay winding 47. Parts of the circuit which have equivalents in Fig. 1 are given the same reference numerals in Fig. 2.

The circuit of triode B in the arrangement of Fig. 2 may be traced from the upper terminal of secondary winding 25, through anode 40, cathode 42, condenser 49 and a resistor 89 in parallel to the lower terminal of winding 25. Control electrode 41 is connected to cathode 42.

The output circuit of triode A is coupled to relay winding 47 through a transformer 90 instead of through a condenser 46 as in the Fig. 1 arrangement. The operation of this circuit otherwise is identical to that of the arrangement of Fig. 1.

In Fig. 3 of the drawings I have illustrated still another flame responsive circuit which may be used in the control system of Fig. 1. This modified arrangement differs from that of Fig. 1 in that one rectifier circuit only is used, the input circuit of the triode A is in the form of a bridge, and a stage of amplification is added between the output circuit of triode A and relay winding 47. Also, a different starting connection is provided which avoids the necessity of using the artificial flame resistor 61 of Figs. 1 and 2.

Specifically in this modification, the potential maintained across the terminals of condenser 33 is used to supply both the input circuit and output circuit of triode A, which is shown as a single triode in this modification, rather than as one-half of a double triode. Conductor 45 is connected to negative terminal 32 of condenser 33 and serves as a negative supply line, while a conductor 91, connected to positive terminal 34, serves as a positive supply line.

Direct current bias is supplied to the input circuit of triode A through a bridge circuit whose four branches are comprised of fixed resistors 92, 93 and 94, and the resistance between flame electrode 56 and grounded burner 4. Resistors 92 and 93 are connected in series across the supply lines 91 and 45, and resistor 94 and the flame resistance likewise are connected in series across the lines. Cathode 38 of triode A is connected to the common terminal of resistors 92 and 93, and control electrode 37 is connected to the common terminal of resistor 94 and the flame resistance through a resistor 95. Filtering condensers 96 and 97 are connected across resistor 94 and the flame resistance, respectively.

An alternating potential is supplied to the input circuit of triode A by secondary winding 26, one terminal of which is connected to the cathode 38 through negative line 45, and resistor 93, the other terminal is connected to the control electrode 37 through a condenser 98 of suitable value.

The output circuit of triode A may be traced from positive line 91 through a resistor 99, anode 36, cathode 38, and resistor 93 to negative line 45. The alternating component of the output current is coupled through a condenser 100 and a resistor 101 to the input circuit of an electric discharge device 102, hereinafter referred to as an amplifier. Amplifier 102 comprises an anode 103, a control electrode 104, and a cathode 105. The amplifier input circuit may be traced from cathode 105 through switch arm 59, contact 58, resistor 93, conductor 45, and resistor 101 to control electrode 104. The amplifier output circuit may be traced from one terminal of a transformer secondary winding 106, through a relay winding 47 and a condenser 47A in parallel therewith, anode 103 and cathode 105 to the opposite terminal of secondary winding 106. Condenser 47A is employed in this form to smooth out the flow of pulsating current flows therethrough in order to prevent chattering of the switch contacts associated with winding 47.

The capacitance of condenser 98 is desirably so chosen that the amplitude of the alternating potential impressed between control electrode 37 and cathode 38 is small.

When a flame exists at electrode 56, the bridge circuit referred to hereinbefore is unbalanced so that the direct current bias supplied thereby to the input circuit of triode A causes the latter to operate on a relatively steep portion of its grid voltage-plate current characteristic curve. The fluctuating voltage applied to the input circuit of triode A is then effective to appreciably affect the output current of triode A and consequently the triode A output current has a large fluctuating component. This fluctuating component is coupled through condenser 100 to the input circuit of amplifier 102 and is effective to produce a conductive condition of said amplifier, and thereby energization of relay winding 47. The phase relations of secondary windings 26 and 106 must be, as shown in the drawing, such as to produce a positive bias on the control electrode 104 of amplifier 102 during the half cycles when the anode 103 is positive.

When no flame exists at electrode 56, control electrode 37 is strongly biased positively through resistor 94, and causes triode A to operate on a relatively flat portion of the upper part of its grid voltage-plate current characteristic, so that the fluctuating component of the output of triode A is small, being insufficient to cause response of amplifier 102 and energization of relay winding 47.

When electrode 56 is grounded, control electrode 37 is strongly biased negatively through resistor 93, and causes the triode A to operate on a relatively flat part of the lower portion of its grid voltage-plate current characteristic curve. The fluctuating component of the output current of triode A, if any, under this condition is reduced substantially to zero and the relay winding 47 accordingly is de-energized.

Resistor 51, which in this modification is inserted in series with resistor 94 during initiation of the system operation, functions in the same manner in this circuit as in the Fig. 1 and 2 arrangements. In order to energize relay winding 47 during starting, without regard to flame conditions, control electrode 104 is connected to cathode 105 through engagement of switch arm 59 with contact 63. This causes amplifier 102 to be conductive and energize relay winding 47. During the starting operation, switch arm 59 is moved from contact 63 to contact 58, as in the previous arrangements described, and the Fig. 3 modification then operates as previously explained.

The circuit of Fig. 3 therefore operates similarly to the circuit of Fig. 1, that is, it causes energization of relay winding 47 when a flame is present, and de-energization of the relay winding when a flame is absent, or when electrode 56 becomes grounded.

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 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 flame responsive device, the combination including two spaced electrodes insulated from each other and adapted to be positioned in the path of said flame, an electric discharge device having an anode, a cathode, and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means connected to said circuit and operative in one sense in response to the presense of sustained fluctuations in the current flow through said circuit and operative in another sence in the absence of sustained fluctuations in the curent flow through said circuit, means to apply a negative voltage to the control electrode of said discharge device to render said discharge device substantially nonconductive and thereby to render said first mentioned means ineffective, and means including the impedance of the path between said electrodes to render said last mentioned means ineffective and thereby to render said discharge device conductive and said first mentioned means effective.

2. In a flame responsive device, the combination including a pair of spaced electrodes insulated from each other and the impedance between which is controlled responsively to the presence of flame, said impedance being one value when a flame is present and a higher value in the absence of flame, an electric discharge device having an anode, a cathode, and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of alternating voltage of regular frequency, means to produce fluctuations of regular frequency in the current flow through said circuit including a connection to apply said alternating voltage to the control electrode of said discharge device, means connected to said circuit

and operative in one sense in response to the presence of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained fluctuations in the current flow through said circuit, means to apply a negative voltage to the control electrode of said discharge device to render said discharge device substantially non-conductive and thereby to render said first mentioned means ineffective, and means including the impedance of the path between said electrodes to render said last mentioned means ineffective and thereby to render said discharge device conductive and said first mentioned means effective.

3. In a flame responsive device, the combination including a pair of spaced electrodes insulated from each other and the impedance between which is adapted to be controlled responsively to the presence of flame, said impedance being one value when a flame is present, a higher value in the absence of flame, and a lower value when an abnormal condition of said spaced electrodes exists, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means tending to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means connected to said circuit and operative in one sense in response to the presense of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained fluctuations in the current flow through said circuit, means to apply a negative voltage to the control electrode of said discharge device to render said discharge device substantially non-conductive and thereby to render said first mentioned means ineffective, and means including the impedance of the path between said electrodes to render said second mentioned means ineffective and thereby to render said discharge device conductive and said first mentioned means effective when the impedance between said spaced electrodes is said one value, said last mentioned means being ineffective to render said second mentioned means ineffective when the impedance between said electrodes is said higher or said lower value.

4. In a flame responsive device, the combination including a pair of spaced electrodes insulated from each other and the impedance between which is adapted to be controlled responsively to the presence of flame, said impedance being one value when a flame is present, a higher value in the absence of flame, and a lower value when an abnormal condition of said electrodes exists, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, a control device operative in one sense in response to the presence of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained fluctuations in the current flow through said circuit, means presenting high resistance to the flow of direct current but readily passing fluctuating current to couple said control device to said circuit, means to apply a negative voltage to the control electrode of said discharge device to render said discharge device substantially non-conductive and thereby to render said first mentioned means ineffective, and means including the impedance of the path between said electrodes to render said third mentioned means ineffective and thereby to render said discharge device conductive and said first mentioned means effective when the impedance of the path between said spaced electrodes is said one value, said last mentioned means being ineffective to render said third mentioned means ineffective when the impedance of the path between said spaced electrodes is said higher value or said lower value.

5. In a flame responsive device, the combination including a pair of spaced electrodes insulated from each other and the impedance between which is adapted to be controlled responsively to the presence of flame, said impedance being one value when a flame is present, a higher value in the absence of flame, and a lower value when an abnormal condition exists at said electrodes, an electric discharge device having an anode, a cathode and a control electrode, a source of direct current energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of alternating voltage of regular frequency, means to produce fluctuations of regular frequency in the current flow through said circuit including a connection to apply said alternating voltage to the control electrode of said discharge device, a control device operative in one sense in responsive to the presence of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained fluctuations in the current flow through said circuit, reactive means to couple said control device to said circuit, means to apply a negative direct current voltage to the control electrode of said discharge device to render said discharge device substantially non-conductive and thereby to render said first mentioned means ineffective, and means including the impedance of the path between said electrodes to render said third mentioned means ineffective and thereby to render said discharge device conductive and said first mentioned means effective when the impedance of the path between said electrodes is said one value, said last mentioned means being ineffective to render said third mentioned means ineffective when the impedance of the path between said electrodes is said higher value or said lower value.

6. In an impedance responsive device, the combination including a pair of spaced electrodes insulated from each other and adapted to be connected by said impedance, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means connected to said circuit and operative in one sense in response to the presence of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained

fluctuations in the curent flow through said circuit, means to apply a negative voltage to the control electrode of said discharge device to render said discharge device substantially non-conductive and thereby to render said first mentioned means ineffective, and means to reduce the negative voltage on the control electrode of said discharge device and thereby to render said discharge device conductive and said first mentioned means effective, said last mentioned means including the impedance of the path between said spaced electrodes.

7. In an impedance responsive device, the combination including a pair of spaced electrodes insulated from each other and adapted to be connected by said impedance, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of alternating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said alternating voltage to the control electrode of said discharge device, a control device operative in one sense in response to the presence of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained fluctuations in the current flow through said circuit, reactive means to couple said control device to said circuit, means for applying a negative voltage to the control electrode of said discharge device to render said discharge device substantially non-conductive and thereby to render said first mentioned means ineffective, and means to reduce the negative voltage on said control electrode and thereby to render said discharge device conductive and said first mentioned means effective, said last mentioned means including the impedance of the path between said electrodes.

8. In a flame responsive device, the combination including a pair of spaced electrodes insulated from each other and the impedance between which is adapted to be controlled responsively to the presence of flame, said impedance being one value when a flame is present, a higher value in the absence of flame, and a lower value when an abnormal condition exists at said flame electrodes, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of alternating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said alternating voltage to the control electrode of said discharge device, said last mentioned means being effective only when the potential of said electrode is in a range within a predetermined negative potential and another predetermined potential which is less negative, a control device operative in one sense in response to the presence of sustained fluctuations in the current flow through said circuit and operative in another sense in the absence of sustained fluctuations in the current flow through said circuit, means presenting high resistance to the flow of direct current but readily passing fluctuating current to couple said control device to said circuit, means to apply a voltage to the control electrode of said discharge device to establish on said control electrode said predetermined negative potential, and means including the impedance of the path between said electrodes to reduce the negative voltage on said control electrode in response to the presence of the flame to thereby establish a potential on the control electrode of said discharge device which lies within said range, said last mentioned means being adapted in response to the presence of an impedance lower than that of a flame between said electrodes to establish said predetermined potential which is less negative on the control electrode of said discharge device.

9. The combination of claim 8 wherein said coupling means comprises an electrical reactance.

10. The combination of claim 8 wherein said coupling means comprises a capacitance.

11. The combination of claim 8 wherein said coupling means comprises a transformer.

12. An electric circuit including in combination a control device having an actuated position and an unactuated position, a variable impedance, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means to apply the fluctuations in the current flow through said circuit to said control device, said control device being adapted to operate to its actuated position in response to the presence of sustained fluctuations in the current flow through said circuit and being adapted to operate to its unactuated position in the absence of sustained fluctuations in the current flow through said circuit, means to apply a negative voltage to the control electrode of said discharge device to render the latter substantially non-conductive and thereby to render said first mentioned means ineffective, means controlled by said impedance and adapted when the magnitude of the latter lies within a predetermined range having finite minimum and maximum values to render said third mentioned means ineffective and thereby to actuate said control device to its actuated position.

13. A safety control system including in combination, a burner, means for supplying fuel to said burner, means for igniting said fuel to establish a flame, a device to control said fuel supplying means and having a position in which it causes said fuel supplying means to assume a fuel supplying condition and a position in which it causes said fuel supplying means to assume a condition preventing the supply of fuel, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means to apply the fluctuations of the current flow in said circuit to said control device, said control device being operated to its fuel supplying position in response to the presence of sustained fluctuations in the current flow in said circuit and being operated to its position preventing the supply of fuel in the absence of sustained fluctuations of the current flow in said circuit, means to apply a negative voltage to the control electrode of said

discharge device to render the latter substantially non-conductive and thereby to render said fluctuation producing means ineffective, a flame electrode insulated from said burner and positioned in the path of said flame, and means including the impedance of the path between said flame electrode and said burner to render said negative voltage applying means ineffective and thereby to render said discharge device conductive, to render said fluctuation producing means effective, and to actuate said control device to its first mentioned position, said last mentioned means being ineffective in the absence of flame or in the event of the establishment of a conductive path lower in impedance than that of a flame between said flame electrode and said burner to render said fluctuation producing means effective and thereby causing said control device to assume its second mentioned position.

14. A safety control system including in combination, a burner, means for supplying fuel to said burner, means for igniting said fuel to establish a flame, a device to control said fuel supplying means and having a position in which it causes said fuel supplying means to assume a fuel supplying condition and a position in which it causes said fuel supplying means to assume a condition preventing the supply of fuel, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means to apply the fluctuations of the current flow in said circuit to said control device, said control device being operated to its fuel supplying position in response to the presence of sustained fluctuations in the current flow in said circuit and being operated to its position preventing the supply of fuel in the absence of sustained fluctuations of the current flow in said circuit, means to apply a negative voltage to the control electrode of said discharge device to render the latter substantially non-conductive and thereby to render said fluctuation producing means ineffective, a flame electrode insulated from said burner and positioned in the path of said flame, and means including the impedance of the path between said flame electrode and said burner to render said last mentioned means ineffective and thereby to render said discharge device conductive and said fluctuation producing means effective when the impedance of said path is substantially that of said flame.

15. A safety control system including in combination, a burner, means for supplying fuel to said burner, means for igniting said fuel to establish a flame, a device to control said fuel supplying means having a position in which it causes said fuel supplying means to assume a fuel supplying condition and a position in which it causes said fuel supplying means to assume a condition preventing the supply of fuel, an electric discharge device having an anode, a cathode and a control electrode, a source of direct current energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of alternating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said alternating voltage to the control electrode of said discharge device, reactive means to couple said control device to said circuit, said control device being operated to its fuel supplying position in response to the presence of sustained fluctuations in the current flow in said circuit and being operated to its position preventing the supply of fuel in the absence of sustained fluctuations of the current flow in said circuit, means to apply a negative voltage to the control electrode of said discharge device to render the latter substantially non-conductive and thereby to render said fluctuation producing means ineffective, a flame electrode insulated from said burner and positioned in the path of said flame, and means including the impedance of the path between said flame electrode and said burner to reduce the effect of said negative voltage applying means and thereby to render said discharge device conductive and said fluctuation producing means effective, when the impedance of said path is substantially that of said flame.

16. A safety control system including in combination, a burner, means for supplying fuel to said burner, means for igniting said fuel to establish a flame, a device to control said fuel supplying means and having a position in which it causes said fuel supplying means to assume a fuel supplying condition and a position in which it causes said fuel supplying means to assume a condition preventing the supply of fuel, an electric discharge device having an anode, a cathode and a control electrode, a source of energizing voltage, a circuit including said voltage source and the anode to cathode impedance of said discharge device, a source of fluctuating voltage, means to produce fluctuations in the current flow through said circuit including a connection to apply said fluctuating voltage to the control electrode of said discharge device, means to apply the fluctuations of the current flow in said circuit to said control device, said control device being operated to its fuel supplying position in response to the presence of sustained fluctuations in the current flow in said circuit and being operated to its position preventing the supply of fuel in the absence of sustained fluctuations of the current flow in said circuit, means to apply a negative voltage to the control electrode of said discharge device to render the latter substantially non-conductive and thereby to render said fluctuation producing means ineffective, a flame electrode insulated from said burner and positioned in the path of said flame, the impedance of the path between said flame electrode and said burner being within a range of values when a flame is present, a higher value in the absence of flame and a lower value when an abnormal condition of said flame electrode relative to said burner exists and means including the impedance of the path between said flame electrode and said burner to render said negative voltage applying means ineffective thereby to render said discharge device conductive and said fluctuation producing means effective when the impedance between said flame electrode and said burner is within said range of values, said last mentioned means being ineffective to render said negative voltage applying means ineffective when the impedance between said flame electrode and said burner is said higher or said lower value.

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