Nov. 8, 1938. A. L. SWEET 2,136,256

FURNACE CONTROL SYSTEM

Filed Dec. 18, 1935 2 Sheets-Sheet 1

Fig. 1.

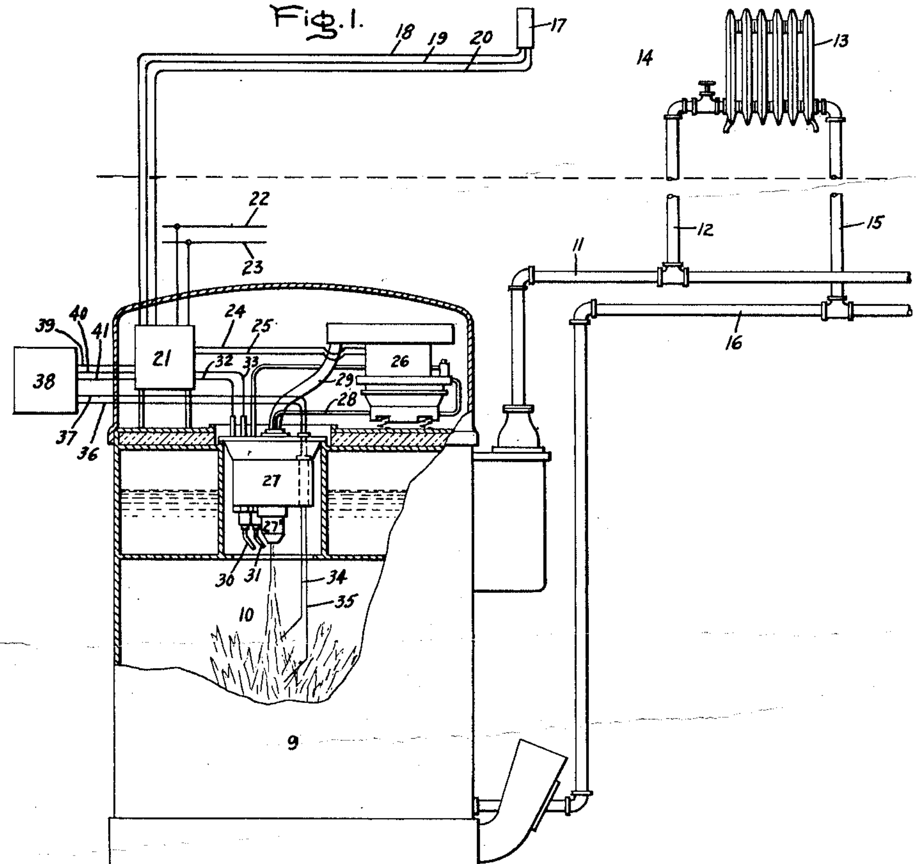
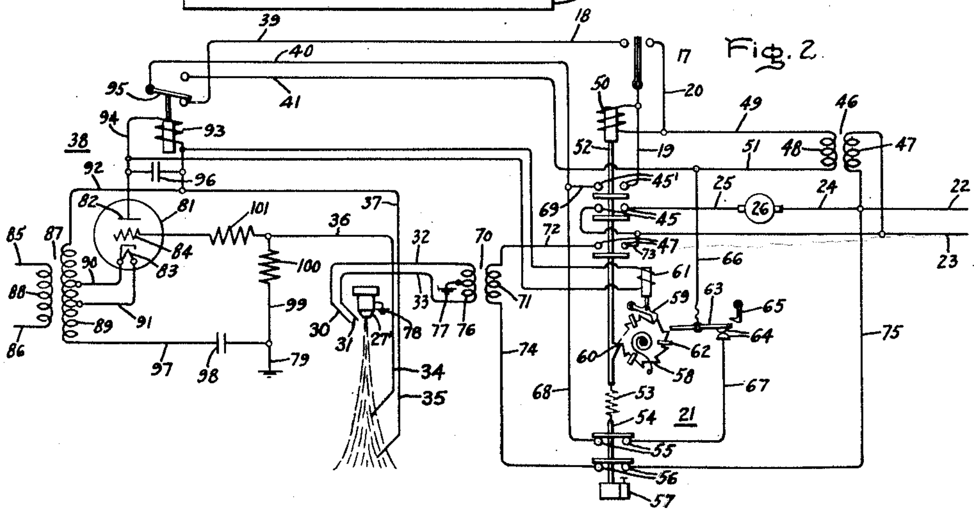


Fig. 2.



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FURNACE CONTROL SYSTEM

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Fig. 3.

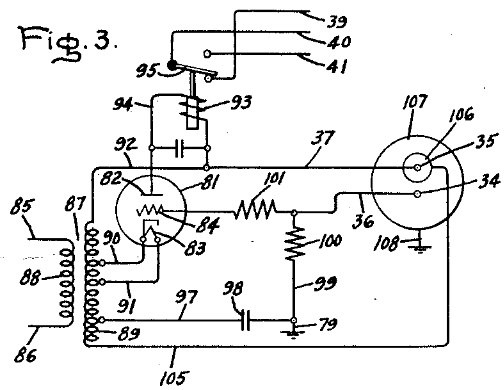


Fig. 6.

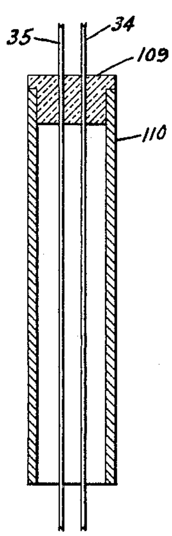


Fig. 4.

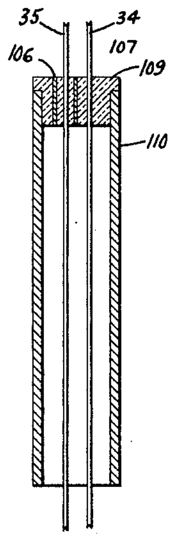
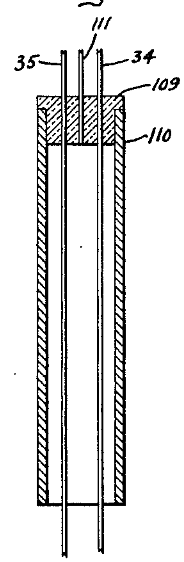


Fig. 5.



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UNITED STATES PATENT OFFICE

2,136,256

FURNACE CONTROL SYSTEM

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Application December 18, 1935, Serial No. 55,132

14 Claims. (Cl. 158—28)

My invention relates to control systems and particularly to furnace control systems having electric ignition.

In a contemporaneously filed application of W. D. Cockrell, Serial No. 55,133, filed December 18, 1935, assigned to the assignee of the present application, there is disclosed a flame detector of the type utilizing an electric discharge device and in which use is made of the fact that a flame possesses a certain rectifying property, that is, the flame is a better conductor of electricity in one direction than in the other. The above mentioned application also relates to a simplified method of applying a negative bias upon the control electrode or grid in the absence of flame and a positive bias when the flame is present in order to render the electric discharge device conductive in response to the presence of flame. The flame detector itself consists of a multi-element electric discharge device having its elements in conductive relation with the flame through a pair of flame electrodes. Since the fuel supply is grounded in practically all installations the cathode flame electrode may be eliminated by simply connecting the cathode to ground. This latter construction is shown as a modification in the application.

The flame detector disclosed in the said application performed satisfactorily in the detection of flames produced by any well known types of fuel ignited by a pilot flame or by some other means such, for instance, as a match. However, when the device was installed in an oil burner using electric spark ignition of the type in which the ignition transformer secondary has its midpoint grounded, and the use of which is desirable because of the elimination of radio interference, the device did not operate satisfactorily. At certain times the flame detector would respond substantially immediately to the presence of flame and at other times there would be a relatively long delay before the electric discharge device would respond. An investigation showed that there was apparently an excess of positive ions introduced in the flame in proximity to the spark electrodes when ignition first was established and that these positive ions tended to charge the anode flame electrode positively and the grid negatively for a relatively brief period which, however, was of sufficient duration to cause unsatisfactory operation of the flame detector due to the delay before the electric discharge device became conductive. Just what phenomenon causes the excess of positive ions is not known to me at the present time but it may be that they result from the spark itself which, upon the break down of the electrostatic field, is known to produce ion pairs from which the negative ions most readily depart due to the potentials set up by the ignition transformer leaving an excess of positive ions, and probably also from the fact that the oil particles which are projected from the nozzle carry and produce electric charges. The condition just described I found to be a more or less transitory condition as the flame responsive device in each case always responded, but only after an unpredictable time delay.

To obviate this difficulty and provide a flame detector adapted to be used in control of furnaces utilizing the desired type of ignition, as well as other types, I propose to place an additional flame electrode electrically connected to the control electrode and positioned in the path of the flame intermediate the nozzle or point where the fuel is projected into the furnace and the anode flame electrode. This additional flame electrode would thus be intermediate the anode flame electrode and the ignition electrodes, as the latter are usually positioned near the nozzle and in proximity to the fuel stream. Or, looking at the arrangement of flame electrodes in another manner, the additional flame electrode and anode flame electrode are spaced from the nozzle at increasing distances in the direction of flame propagation. By direction of flame propagation I mean the general direction in which the flame and hot gases of the flame move. Generally, this is in a direction outwardly from the nozzle or source of supply of fuel. When this was done the flame responsive device became very efficient in its operation and responded practically immediately to the presence of flame. It appears that the positive ions present in the flame are prevented from traveling in the direction of the electrode connected to the anode and are collected upon this flame electrode, which might be termed a shield electrode, connected to the control electrode of the electric discharge device and thus the control electrode is rendered positive much more rapidly than would otherwise be the case. Not only are the positive ions removed from the path of the negative ions moving in the direction of the anode flame electrode but they are also collected on the flame electrode connected to the control electrode to provide an additional source of positive bias for the latter. Thus, it is an object of my invention to provide a simple, highly efficient, and immediately responsive means for detecting the presence of flame in the combustion chamber of a fuel burner.

Another object of my invention is to provide a fuel burner control system including a single electric discharge device for exerting control over certain phases of operation of the system.

Another object of my invention is to provide an improved control system for fuel burners employing an electric spark ignition system and particularly a spark ignition system of the type employing a transformer secondary winding having its midpoint grounded.

Still another object of my invention is to provide a simple means for checking electrical leakage across the electrodes of the flame responsive means to render the system unresponsive in case the leakage is such that unsafe conditions would result.

My invention will be better understood from the following description when considered in connection with the accompanying drawing and its scope will be pointed out in the appended claims. In the accompanying drawings:

Fig. 1 illustrates a view partially in elevation and partially in section of a heating system and furnace, with a partial representation of the control.

Fig. 2 illustrates a control circuit embodying my invention.

Fig. 3 illustrates a modification of my invention showing the means for checking electrical leakage.

Fig. 4 is a cross-sectional view of the flame electrode assembly shown schematically in Fig. 3.

Fig. 5 is a cross-sectional view of a modified form of the flame electrode assembly illustrated in Fig. 4; and

Fig. 6 is a cross-sectional view of the flame electrode assembly schematically shown in Figs. 1 and 2.

Referring to Fig. 1, reference numeral 9 illustrates a furnace of any conventional type having a combustion chamber 10 and from which a heating medium, such as steam, is led through conduits 11 and 12 to a heat exchange device, which may be a radiator 13, located in a zone 14 which is to be heated. In the closed heating system I have chosen to illustrate in my preferred embodiment, the condensate from the radiator 13 is led back to the furnace through return conduits 15 and 16. The temperature within the zone 14 which may be a room, a group of rooms, a building, a group of buildings or the like is kept within predetermined limits by a thermal responsive means such as a bimetallic thermostat 17. The thermostat may be of any conventional type, for instance, of the type in which "start" and "stop" contacts are engaged by the thermal responsive member and from which electrical connections 18, 19 and 20 lead to a control 21. The control 21 may be of the type disclosed in the copending application of John Eaton, Serial No. 11,100, filed March 14, 1935, and assigned to the assignee of the present application. Sufficient control will be hereafter described to completely describe my invention and its operation.

The control is supplied with energy from any suitable source of alternating current 22 and 23. Electrical connections 24 and 25 connected to main control 21 are provided to supply energy to an electrical motor 26 provided for the purpose of supplying fuel and air to the burner head 27 from which the nozzle 27' projects the atomized fuel into the combustion chamber 10. The fuel is led to the burner head through conduit 28 and air is supplied thereto through conduit 29. In the preferred embodiment herein illustrated the fuel may be oil, but my invention may be practiced with different types of fuel that may be projected into the combustion chamber of a furnace. Positioned on the burner head adjacent the atomizing nozzle 27' are ignition electrodes 30 and 31 which are connected to the secondary of a suitable ignition transformer forming part of the main control equipment 21 by means of electrical connections 32 and 33. Also supported by the burner head are flame electrodes 34 and 35 connected by means of electrical connections 36 and 37 to a flame responsive control device 38 in which is incorporated my improved flame detector, and which I shall describe in detail later. Electrical connections 39, 40 and 41 interconnect controls 21 and 38.

From the figure it will be noted that the flame electrodes are so positioned that flame electrode 34 is positioned intermediate flame electrode 35, the nozzle 27'; and ignition electrodes 30 and 31. Inasmuch as the flame is directed downwardly from a nozzle 27' the flame electrode 35 is at a greater distance therefrom in the direction of flame propagation than flame electrode 34.

The control apparatus will now be described with more particularity in connection with Fig. 2 of the drawings. Similar parts in Figs. 1 and 2 have been given like reference numerals. The room thermostat is shown at 17 and from it lead electrical connections 18, 19 and 20. A suitable source of alternating current electricity is illustrated at 22, 23. The main control is illustrated at 21, the flame responsive device at 38, and from an inspection of the latter it will be noted that electrical connections 36 and 37 lead to flame electrodes 34 and 35, respectively, and that electrical connections 39 and 40 and 41 also lead therefrom. It may be further noted that electrical connections 39 and 18 unite to interconnect one of the contacts associated with room thermostat with one of the contacts associated with the flame detector.

The burner motor 26 is energized from the source 22, 23 through electrical connections 24 and 25. The motor is energized when normally open contacts 45 are closed to connect electrical connection 25 with supply line 23. The control for the system is energized through a suitable transformer 46 having a primary winding 47 connected directly to the source of supply of electrical energy and a secondary winding 48, one side of which is connected by means of an electrical connection 49 to the main operating solenoid 50, and the other side of which is connected to electrical connection 41 by means of connection 51. Associated with the main solenoid 50 is an extended armature member 52 provided with a plurality of bridging members adapted to close the normally open contacts 45, 45' and 47. It will be evident from an inspection of the figure that the aforesaid contacts will be closed simultaneously upon the energization of the solenoid 50. Attached to the armature member 52 by means of a spring connection 53 is an extended member 54 adapted to open contacts 55 and 56 after a time delay determined by the adjustment of a device such as a dash pot 57.

In order to prevent continued intermittent energization of the solenoid 50 in response to certain conditions, to be described more fully later, I have provided means for deenergizing the control after a predetermined number of operations if combustion does not occur and for resetting the same if combustion occurs. This means consists of a spring biased ratchet wheel 58 restrained from movement in one direction by a pawl 59. The ratchet wheel is moved each time the main operating relay is energized by means of a notch 60 on the armature 52 of the relay. If proper combustion occurs within a desired number of starting operations the pawl 59 is moved upwardly by a solenoid 61 connected in parallel with a relay 93 of the flame responsive device and the ratchet returns to its initial position. If combustion does not occur continued reciprocation of armature 52 rotates ratchet 58 until a projection 62 carried thereby moves a contact carrying arm 63 to open a pair of normally closed contacts 64. A latch member 65 is provided to maintain these contacts open until manually reset. The normally closed contacts 64 are provided in a holding circuit for the solenoid 50 leading from line 51 through line 66, contacts 64, line 67, contacts 55, line 68, line 69, contacts 45' and line 19 to the solenoid 50 and from thence through line 49 to the transformer. It may be noted that lines 68 and 69 are interconnected with line 40 leading to the flame responsive device.

In order to obtain proper ignition I have provided an ignition transformer 70 having a primary 71 connected to one side of the source of current 23 through electrical connection 72, contacts 47 and connection 73. The other side of the primary is connected to the source of the supply 22 through electrical connections 74, normally closed contacts 56 and electrical connection 75. It is obvious that the ignition transformer will be energized upon the energization of solenoid 50 through the closing of contacts 47 and will be opened after a predetermined period of time by the opening of contacts 56. The ignition transformer is provided with a secondary winding 76, the midpoint of which is grounded at 77 in order to eliminate, as far as possible, radio interference. Electrical connections 32 and 33 lead from secondary winding of the ignition transformer to ignition electrodes 30 and 31 positioned adjacent nozzle 27'. The latter is grounded as at 78 in order to establish a conductive path through ground from the nozzle to the ground connection 79 of the flame responsive device.

The flame responsive device that I propose to use is of the type disclosed in the copending application of W. D. Cockrell mentioned above comprising an electric discharge device 81 which is rendered conductive in response to the presence of flame. The discharge device is provided with an anode 82, a cathode 83 and a control electrode or grid 84. The device is supplied with proper voltage from any suitable source of alternating current electricity 85 and 86, which may be connected to supply lines 22, 23 by means of a transformer 87 having a primary winding 88 and a secondary winding 89. The cathode is heated through a circuit composed of electrical connections 90 and 91 leading to the taps on the secondary winding. The anode is connected to the secondary winding through electrical connection 92, a relay 93, and an electrical connection 94 in such manner that when the discharge device is rendered conductive, the relay is energized and actuates its associated armature member and a movable contact carrying control member 95 from its lower position, where the control member is in contact with electrical connection 39, to its second and upper position where it is in contact with connection 41. It may be noted at this point that the resetting solenoid 61, referred to previously, being connected in parallel to the relay 93 will be energized simultaneously with the latter. In this embodiment of my invention the position in which the movable contact member 95 is shown constitutes the start position of the flame detector and the upper position constitutes the run position, as will be brought out more fully when the description of the operation as a whole is given. In order to avoid as far as possible the effect of current pulsations in the relay 93 I have connected a condenser 96 across it to smooth out these pulsations which result from the fact that the discharge device conducts current only every other half cycle.

The discharge device is maintained in a non-conducting condition during the absence of flame by the application of a negative bias on the grid through electrical connections 97, condenser 98, electrical connection 99, and resistances 100 and 101, the latter being in the grid circuit. Condenser 98 serves also to control the length of time required to render the tube non-conducting upon the cessation of combustion, this time being dependent on the time required for the condenser to discharge. The condenser thus serves to make the flame responsive device responsive only to flame variations of a predetermined character in a manner well known to those skilled in the art. The flame electrodes 34 and 35 are connected to the electric discharge device by means of electrical connections 36 and 37 which lead to a point between resistances 100 and 101 and to the anode side of the transformer winding, respectively.

The operation of the control system will now be described. Assuming that the furnace has ceased operation and that the temperature within zone 14 has decreased to a value where heat is required therein, then the thermal responsive element of room thermostat 17 will move over to its left or start position wherein the thermostatic element engages electrical connection 18. At the same time, due to the fact that no flame is present, the electric discharge device 81 will be non-conductive because of the negative bias on the control electrode, and relay 93 and solenoid 61 will therefore be deenergized. Thus, the movable control member 95 associated with the relay will be in its lower or start position, as indicated in Fig. 2. An energizing circuit for the main operating solenoid 50 is then closed and it is as follows: from the secondary winding 48 of the control transformer 46 through electrical connection 49, solenoid 50, thermal responsive element of thermostat 17 in its start position, electrical connection 18—39, movable control member 95 in its start position, electrical connections 40 and 68, normally closed contacts 55, electrical connection 67, normally closed contacts 63, and electrical connections 66 and 51 to the other side of the secondary winding 48. Energization of the solenoid 50 results in the upward movement of its associated contact actuating armature 52 and a consequent closing of normally open contacts 45, 45' and 47. The closure of contacts 45 results in the energization of the burner motor 26 which supplies fuel and air to the burner chamber through conduits 28 and 29 respectively. Simultaneously with the energization of the burner motor the ignition transformer 70 is energized through a circuit which is as follows: source 23, electrical connection 73, contacts 47, electrical connection 72, primary winding 71 of the transformer, electrical connection 74, normally closed contacts 56, and electrical connection 75 which leads to the other side 22 of the source of power. In order that the motor and ignition transformer will remain energized while the flame responsive device and its associated movable contact member 95 is actuated from its lower to upper position in response to initiation of combustion a holding circuit is established around the solenoid 50 by means of electrical connection 19, contacts 45' and electrical connection 69. It will be noted from the figure that the establishment of this holding circuit cuts out the room thermostat 17 and the flame responsive device.

In my control system, as in most control systems, fuel is supplied to the burner during the starting period by the motor for a predetermined length of time. If the fuel is ignited properly during the starting period a further holding circuit including the run contacts of the flame responsive device for the solenoid 50 is established. However, if the flame is not produced within the allotted time the burner is deenergized by the opening of normally closed contacts 55 arranged in the holding circuit previously described for the relay 50. In order to simplify the description of the operation I shall assume that proper ignition results prior to the time that contacts 55 controlling the holding circuit are opened. Then, in response to the presence of flame, the relay 93 is energized, as will be described more in detail later, and actuates movable control member 95 to its upper position wherein electrical lines 40 and 41 are connected. The solenoid 50 thereupon is energized through a second holding circuit which is as follows: electrical connections 19, contacts 45', electrical connections 69 and 40, movable control member 95 and electrical connection 41. It will be seen that the result is that the solenoid 50 is connected directly across the secondary winding 48 of the control transformer 46 through electrical connections 49 and 51. Simultaneously with the energization of relay 93 the resetting solenoid 61, connected in parallel thereto, will be energized. Pawl 59 is consequently moved upward and ratchet 58 will be returned to its initial position.

Upon the lapse of the allotted time the first holding circuit is broken by the movement of contacts 55 to their open position but the solenoid 50 will remain energized as described above. Simultaneously with the breaking of the aforesaid holding circuit the ignition transformer is deenergized through the opening of contacts 56. The ignition transformer, however, may be energized continuously if desired by removing contacts 56 and connecting the primary directly to the source of supply. The continued energization of relay 50 maintains the burner motor 26 energized and a combustible mixture will be supplied to the burner until such a time as the room thermostat 17 reaches its right or stop position at which time a short circuit is placed across the relay winding 50 by means of the thermal responsive element of the room thermostat 17 and electrical connection 20. Upon the deenergization of the solenoid winding 50 all the parts return to the position shown in Fig. 2 and the burner motor 26 is deenergized until such a time as the room thermostat again calls for heat.

The operation of my flame responsive device and the manner in which it actuates the movable contact member 95 from its lower to upper position will now be described in greater detail. As brought out above, the control electrode 84 is normally negatively biased so that the discharge device 81 is non-conductive. Upon the appearance of a flame a conductive path from the anode to the control electrode through the flame is formed as follows: from electrical connection 37 to the flame electrode 35, through the flame to electrode 34 and thence through electrical connection 36, and resistor 101 to the grid or control electrode 84. The anode flame electrode is also in conductive relation with the cathode through the flame, the ground connection 78 of the nozzle 27' and the ground connection 79 of the cathode-grid circuit. It is obvious to those skilled in the art that the discharge device is conductive only during the half cycle when the anode is positive and when the control electrode is sufficiently positive with respect to the cathode. During the half cycle that the anode is positive the flame electrode 35 will have imposed on it the same potential as the anode, and flame electrode 34, due to the conductivity of the flame, will have imposed on it a positive potential determined by the circuit characteristics. This potential is imposed upon the control electrode rendering it more positive with respect to the cathode and the discharge device will become conductive. As has been brought out previously there is present upon initiation of combustion a transient condition in the furnace chamber during which an excess of positive ions is present. These ions are collected on the flame electrode 34 and they aid in the application of a positive bias on the grid and their collection in this manner also aids in the conduction of current from the anode flame electrode 35 to the cathode flame electrode 34.

The exact explanation of the presence of the positive ions is not known to me at present but, as stated previously, they apparently result for the most part from the use of a particular type of ignition. The effect of the rapidly projected fuel particles may also have some bearing on the creation of these ions as my experience has shown that the flame velocity has a bearing on the flame current intensity. After a brief time interval the transient condition subsides and for all practical purposes the flame electrode 34 could then be removed from the circuit, i. e., it does not greatly affect the operation of the system thereafter.

It will be evident to those skilled in the art that my invention provides a flame responsive device that is rapid in operation and certain in its operation. Sensitivity is increased, as is the sensitivity of the flame detector described in the aforementioned application of W. D. Cockrell, by utilizing the property of flames to conduct current better in one direction than in the other. The conduction, as previously mentioned, is better in a direction opposite to flame propagation and the current passes through the flame in this direction in the system described. Furthermore, the addition of the flame electrode 34, which acts as a shield, gives far greater certainty of operation.

To render the electric device unresponsive to minor fluctuations and allow it to become deenergized only after a time delay I provide the condenser 98 in the grid-cathode circuit. This condenser is charged so that its ground side is negative when no flame is present. However, upon the appearance of a flame a positive charge is placed on that side of the condenser, the value of the charge depending upon circuit characteristics. It will be seen that upon fluctuations in the flame and resulting changes in the potential upon the grid flame electrode 34 the condenser will tend to discharge through a path consisting of electrical connections 99, resistors 100 and 101, the control electrode 84, and across therefrom to the cathode 83, through the transformer secondary 89 and electrical connection 97 back to the condenser. The length of time necessary to discharge the condenser is fixed by resistors 100 and 101, as well as by the size of the capacitor itself and the resistance of the discharge device, and consequently the tube will not become non-conducting upon the disappearance of flame until the lapse of a certain length of time.

The operation of the system when flame does not appear within the predetermined time will now be described. In this event the movable contact member 95 will not close a circuit between connections 40 and 41 within the specified time and consequently the main holding circuit described above will not be energized. However, the initial holding circuit which was also described above will be closed through contacts 45′ but this holding circuit will be opened by the opening of contacts 55 after a predetermined time interval, as determined by the time delay device 57. Consequently upon the opening of the holding circuit solenoid 50 will be deenergized and the armature member 52 associated therewith will move downwardly to open its various contacts. Inasmuch as no heat would be supplied to the zone 14 during this starting period, the room thermostat 17 will remain in its start position in which the thermal responsive element is in contact with connection 18. If no flame appeared in the furnace the movable contact member 95 will remain in the position illustrated and the circuit conditions are such that the relay 50 will be energized to actuate its armature member 52 upwardly to again close its associated contacts as described above. Each time that the solenoid is energized armature member 52 is moved upwardly and its associated notch 60 actuates ratchet 58 a single step in a clockwise direction. After a predetermined number of actuations, three for example, the normally closed contacts 64 are opened by movement of member 63 by projection 62 on the ratchet wheel. The contacts remain open until the latch member 65 and pawl 59 are released manually. Upon the release of the latch and pawl the system will again recycle the predetermined number of times if combustion does not take place.

In the event of the existence of abnormal conditions as, for instance, the existence of leakage paths on the surface or through the support for the electrodes either across the flame electrodes 34 and 35 or from the flame electrodes to ground, the flame electrode 34 would be in conductive relation with flame electrode 35 and thus a potential would be imposed upon the grid just as though flames were present. While the possibility of such conditions existing is rather remote, the effect of their existence may be avoided by the addition of a source of electricity between the two flame electrodes of such polarity that each time the anode is positive a negative potential would be imposed upon the control electrode. In this manner the tube would be rendered nonconductive during the half cycle that it would be conductive under normal conditions. Such an arrangement is disclosed in Fig. 3 wherein I have shown a circuit similar in all respects to that shown in Fig. 2 with the exception that I have added the additional source of potential between the flame electrodes 34 and 35. This source of potential is obtained from an extension of the secondary winding 89 of the transformer 87 and extends through electrical connection 105 to a cylindrical conducting portion 106 placed between the flame electrodes 34 and 35. The cylindrical conducting portion 106 and the flame electrodes are maintained in proper spaced apart relationship by a supporting member 107 comprised of insulating material 109 as will be described later in connection with Fig. 4. An outer metallic portion of the electrode holding member 107 is grounded as at 108. The operation of this system is the same as that of Fig. 2 whenever normal conditions exist, that is, the discharge device 81 is rendered conductive during the alternate half cycles that the anode is at a positive potential and the grid 84 has imposed upon it a potential rendering it positive with respect to the cathode. Under normal conditions there is no leakage from the cylindrical conducting member 106 to the grid flame electrode 34 and the fact that a negative potential is imposed on the member will not swing the grid negative in the absence of such leakage. However, upon the occurrence of leakage paths between the electrodes or therefrom to ground on the surface of or through the supporting member, which are usually of high resistance, it will be seen that each time the anode becomes positive, and at which time the electric discharge device would be normally rendered conductive, a negative potential from the opposite side of the transformer is applied to the control electrode, thus preventing the electric discharge device from becoming conductive.

In case a leakage path does exist between electrodes 34 and 35 on the surface of or through the insulating support 109 then, if the electrical connection 105 and the cylindrical conducting portion 106 surrounding flame electrode 35 were omitted, the electric discharge device 81 would be rendered conductive each time that the anode became positive irrespective of the presence of flame. With a suitable negative potential imposed upon the conducting member each time that the anode becomes positive, then the potential of the grid with respect to the cathode is determined by the magnitudes of the anode potential, the negative potential and the resistance of the leakage paths from the anode and conducting member to the cathode. With a suitable negative potential, then when the resistance of the leakage paths reaches a predetermined value, the grid becomes more negative with respect to the cathode and finally the discharge device will become non-conductive. It may be noted that if the leakage paths are not on the surface of or through the insulating material, as would be the case if the flame electrodes would be brought into physical contact at their outer extremities, then there will be no leakage from the conducting member and the electric discharge device will become conducting. However, the possibility of the flame electrodes coming into physical contact is very slight when properly designed.

In case both flame electrodes become grounded through leakages paths on the surface of or through the insulation it is likely that there will be formed at the same time a leakage path directly across the electrodes. If the electrodes become grounded through separate leakage paths there results a leakage path across the electrodes through ground and the operation will be as described above. In case electrode 35 alone becomes grounded through the above described leakage paths, then the conducting member 106 will likewise become grounded because it surrounds the electrode and any ground leakage path will necessarily extend through it. The anode potential and the negative potential are both imposed upon the grid through the leakage path to ground and through conductor 99 and resistors 100 and 101 to the grid. If the leakage path to ground becomes of sufficiently low resistance the negative potential is sufficient to overcome the positive potential imposed on the grid and maintain it sufficiently negative with respect to the grid to prevent the discharge device from becoming conductive.

When the above described leakage paths are present and the room thermostat calls for heat the control will function in the previously described manner to initiate starting of combustion. As soon as flame appeared there would be formed a conductive path from the anode flame electrode 35 to the grid through the flame to grid flame electrode 34 and ground, but with a suitable negative potential imposed upon the conducting member 106, as described above, the discharge device cannot be made conductive The flame detector switch 95 will remain, therefore, in its start position. After three such starting cycles the switch 64 will be opened and held open by latch 65, thereby preventing further starting until the leakage paths are removed.

The construction of the flame electrode assembly forming part of the system shown in Fig. 3 is disclosed in Fig. 4 and it consists of the flame electrodes 34 and 35 which are embedded in an insulating material 109. The cylindrical conducting member 106 is shown as completely surrounding a portion of flame electrode 35 and embedded in the insulating material and held by the latter in spaced relationship to the flame electrodes. A portion of each flame electrode is surrounded by a metallic conducting member 110, the latter also forming a support for the insulating material 109. Under normal conditions, when no leakage paths are present, a conductive path exists between the flame electrodes only when the flame is present. Upon the occurrence of leakage paths across the flame electrodes or from the latter to ground the control will be prevented from responding as described in connection with Fig. 3.

A modification of the flame electrode assembly is disclosed in Fig. 5. In this case I have disclosed practically the same construction as shown in Fig. 4 with the exception that I have replaced the cylindrical conducting member 106 by a simple conducting member 111. It will be obvious to those skilled in the art that upon the occurrence of leakage paths across the flame electrodes or from the latter to ground the operation will be the same as described in connection with Figs. 3 and 4.

In Fig. 6 I have disclosed a flame electrode assembly of the type utilized in connection with the systems shown in Figs. 1 and 2. It consists merely of the flame electrodes 34 and 35 embedded in an insulating material 109 positioned at the top of and within a cylindrical metallic member 110, as described in connection with Figs. 4 and 5.

Various modifications may be made in the device and system embodying my invention without departing from the spirit and scope thereof and I desire therefore that only such limitations shall be imposed therein such as are imposed by the prior art or set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. In combination, a furnace having a combustion chamber, means including a nozzle for supplying a combustible mixture to said chamber and propagating the same in a predetermined direction therein, means including a transformer of the type having the midpoint of its secondary grounded and ignition electrodes positioned in proximity to said nozzle for igniting said combustible mixture, and means for controlling said supply means in response to flame conditions, said means including an electric discharge device having an anode, a cathode, and a control electrode, said cathode being in electrical conducting relation with said nozzle, a first electrode positioned in the flame and electrically connected to said anode, and a second electrode positioned in the flame intermediate said nozzle and said first electrode and connected to said control electrode.

2. In combination, a furnace, means for supplying fuel thereto, electrical spark ignition means for igniting said fuel to establish a flame, and means for controlling said fuel supplying means in response to the presence of flame, said means including an electric discharge device having an anode, a cathode, and a control electrode, said cathode being in electrical conducting relation with said fuel supply means, and a first flame electrode positioned in the path of said flame and electrically connected to said anode and a second flame electrode positioned in the path of said flame intermediate said fuel supply means and said first flame electrode and connected to said control electrode.

3. In combination, a furnace having a combustion chamber, means including a nozzle for supplying a combustible mixture to said chamber and propagating the same in a predetermined direction therein, means including the transformer of the type having the midpoint of its secondary grounded and ignition electrodes positioned in proximity to said nozzle for igniting said combustible mixture, and means for controlling said first mentioned means in response to the presence of flame, said means including an electric discharge device having a cathode, an anode, and a control electrode, an electrical connection from said cathode to said nozzle, a flame electrode electrically connected with said anode and positioned in the path of the flame, a second flame electrode electrically connected to said control electrode and positioned in the path of the flame at a position intermediate last named flame electrode and the ignition electrodes and nozzle.

4. In combination, a furnace having a combustion chamber, means for supplying a combustible mixture of air and oil to said combustion chamber and propagating the same in a predetermined direction therein, means including a transformer of the type having the midpoint of its secondary grounded and ignition electrodes positioned in proximity to said mixture for igniting said combustible mixture, and means for controlling said first mentioned means in response to the presence of flame, said means including an electric discharge device having an anode, a control electrode and cathode, the latter being in electrical conducting relation with the combustible mixture, and flame electrodes connected to said con-

trol electrode and anode positioned respectively in the path of the flame at progressive distances from the point at which the combustible mixture enters the combustion chamber.

5. In combination, a furnace having a combustion chamber, electrically operated means for supplying a combustible mixture thereto, means for propagating the combustible mixture and flame in a predetermined direction in said chamber, means for igniting said mixture to establish a flame, an energizing circuit for said mixture supplying and igniting means, and means for controlling the energization of said circuit in response to the presence of a flame within said combustion chamber, said means including an electric discharge device having an anode, a cathode, and a control electrode, said cathode being in electrical conducting relation with said combustible mixture propagating means, and a pair of flame electrodes progressively positioned in the direction of flame propagation in the path of the flame, the first flame electrode being connected to said control electrode and the second flame electrode being connected to said anode.

6. In combination, means for supplying and projecting a combustible mixture of air and oil in a predetermined direction, means for igniting said mixture to establish a flame, and means responsive to the presence of said flame for controlling said first mentioned means, said means including an electric discharge device having an anode, a cathode, and a control electrode, said cathode being in electrical conducting relation with said combustible mixture projecting means, and means including flame electrodes positioned in the flame and connected to the anode and control electrode respectively, the flame electrode connected to the control electrode being positioned between the flame electrode connected to the anode and the point at which the combustible mixture is projected.

7. In combination, a furnace having a combustion chamber, means including a nozzle for supplying a combustible mixture of air and oil to said combustion chamber and propagating the same in a predetermined direction therein, said nozzle being electrically grounded, means including a transformer having the midpoint of its secondary grounded and ignition electrodes positioned in proximity to said nozzle for igniting said combustible mixture, said igniting means and combustible mixture providing a source of positive ions on the initiation of combustion, and means for controlling the first named means in response to the presence of flame, said means including an electric discharge device having a control electrode, means for rendering said device normally non-conductive in the absence of a flame, and means including a flame electrode adapted to collect said positive ions positioned in the path of the flame and electrically connected to the control electrode for substantially immediately rendering said electric discharge device conductive upon the occurrence of flame.

8. In a control system, the combination including a furnace, means for supplying a combustible mixture thereto, means for igniting said mixture to establish a flame, means including a multi-element electric discharge device for controlling said first mentioned means in response to the presence of flame, means including flame electrodes positioned in the path of the flame and electrically connected to the elements of said discharge device establishing a conductive path through the flame for rendering said device conductive, supporting means for said flame electrodes, and means for maintaining said device non-conductive upon the establishment of conductive paths across said flame electrodes on the surface of or through said supporting means.

9. In combination means for supplying and igniting a combustible mixture to establish a flame, an electric discharge device having a cathode, a control electrode and an anode, means including a plurality of flame electrodes positioned in the path of a flame for rendering said device conductive upon the appearance of flame, supporting means for said flame electrodes, and means for preventing the operation of said device upon the occurrence of a leakage path across said flame electrodes on the surface of or through said supporting means.

10. In combination, means for supplying and igniting a combustible mixture to establish a flame, an electric discharge device having a cathode, a control electrode, and an anode, means including a plurality of flame electrodes electrically insulated from each other and ground positioned in the path of a flame and across which the flame establishes a conductive path for rendering said device conductive upon the appearance of the flame, and means for rendering said device non-conductive upon the occurrence of a leakage path on the surface of or through the insulation across said flame electrodes or from said flame electrodes to ground.

11. In a flame detector the combination including a multi-element electric discharge device having a cathode, a control electrode and an anode, means for applying a negative bias upon said control electrodes in the absence of flame, means for applying a positive bias on said control electrode to render said device conductive upon the appearance of said flame, said means including a plurality of flame electrodes electrically insulated from each other and ground having electrical connections to elements of said discharge device and so positioned in the path of the flame that the latter establishes a conductive path across them, and means for preventing said device from becoming conductive upon the occurrence of a leakage path across said flame electrodes on the surface of or through the insulation, said means including means for applying a negative bias on said control electrode during the half cycle the discharge device normally would be operative.

12. In a flame detector, the combination including a multi-element electric discharge device having a cathode, a control electrode and an anode, means for applying a negative bias upon said control electrode in the absence of flame, means for applying a positive bias on said control electrode to render said device conductive upon the appearance of said flame, said means including a plurality of flame electrodes having electrical connections to elements of said discharge device and across which the flame establishes a conductive path, means for supporting said flame electrodes and means including a source of potential intermediate said flame electrodes for rendering said device non-conductive upon the occurrence of leakage to ground on the surface of or through said supporting means from said flame electrodes.

13. In a flame detector the combination including a multi-element electric discharge device having a cathode, a control electrode and an anode, means for applying a negative bias upon said control electrode in the absence of flame, means for applying a positive bias on said con-

trol electrode to render said device conductive upon the appearance of said flame, said means including a plurality of flame electrodes having electrical connections to elements of said discharge device and so positioned in the path of the flame that the latter establishes a conductive path across them, means for supporting said flame electrodes, and means including a source of potential intermediate said flame electrodes for rendering said device non-conductive upon the occurrence of a leakage path on the surface of or through said supporting means across said flame electrodes.

14. In a flame responsive device, the combination including an electric discharge device having an anode, control electrode and cathode, means for maintaining said device non-conductive in the absence of flame, and means for rendering said device conductive in the presence of flame, said means including electrical connections placing said cathode in electrical conducting relation with the flame and connections from the control electrode and anode to selected points in the path of the flame, the anode connection to the flame being at a greater distance in the direction of flame propagation from the cathode connection than the control electrode connection.

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