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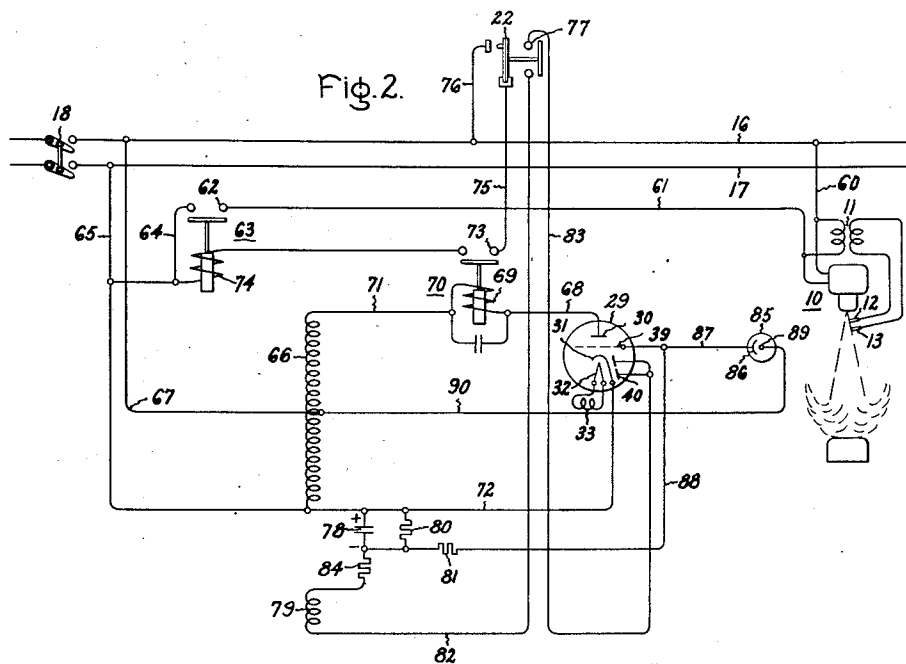
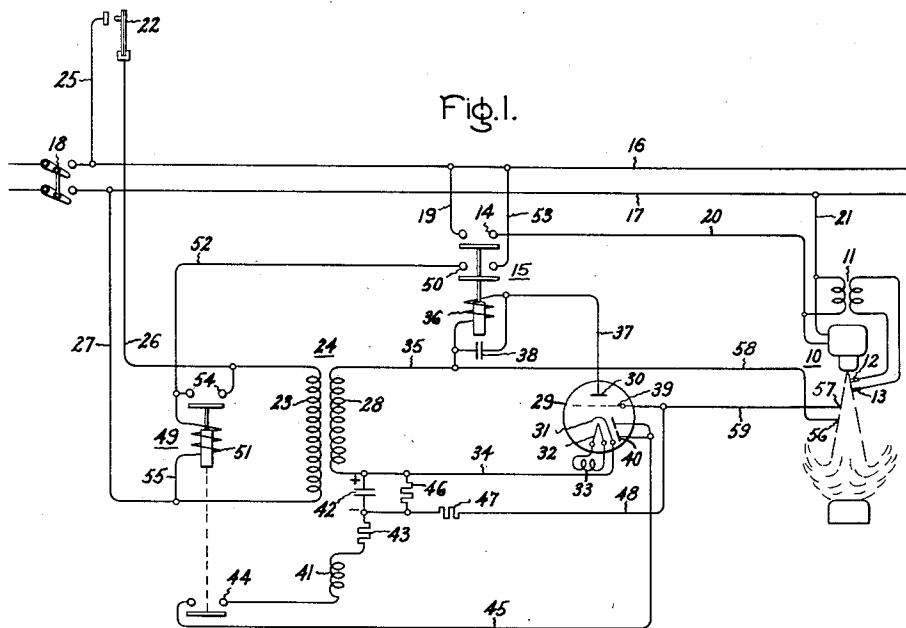
E. D. SCHNEIDER

2,299,501

CONTROL SYSTEM

Filed March 1, 1941

3 Sheets-Sheet 1



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Oct. 20, 1942.

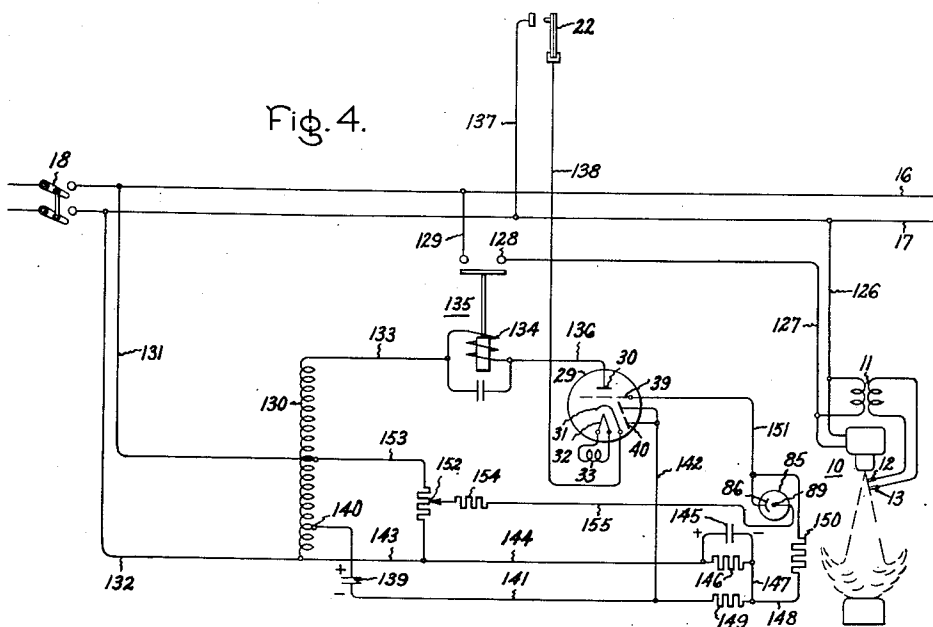
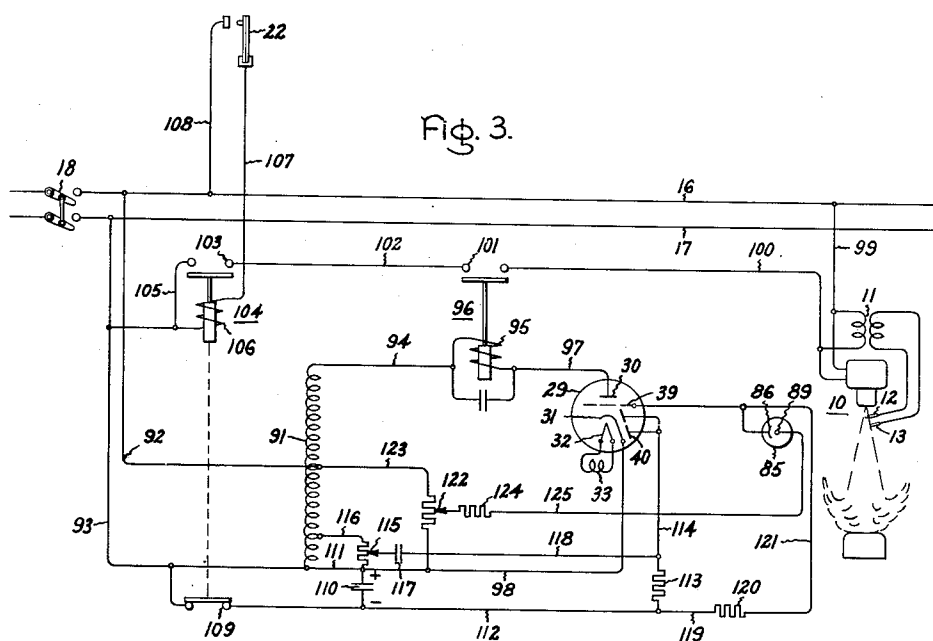
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2,299,501

CONTROL SYSTEM

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3 Sheets-Sheet 2



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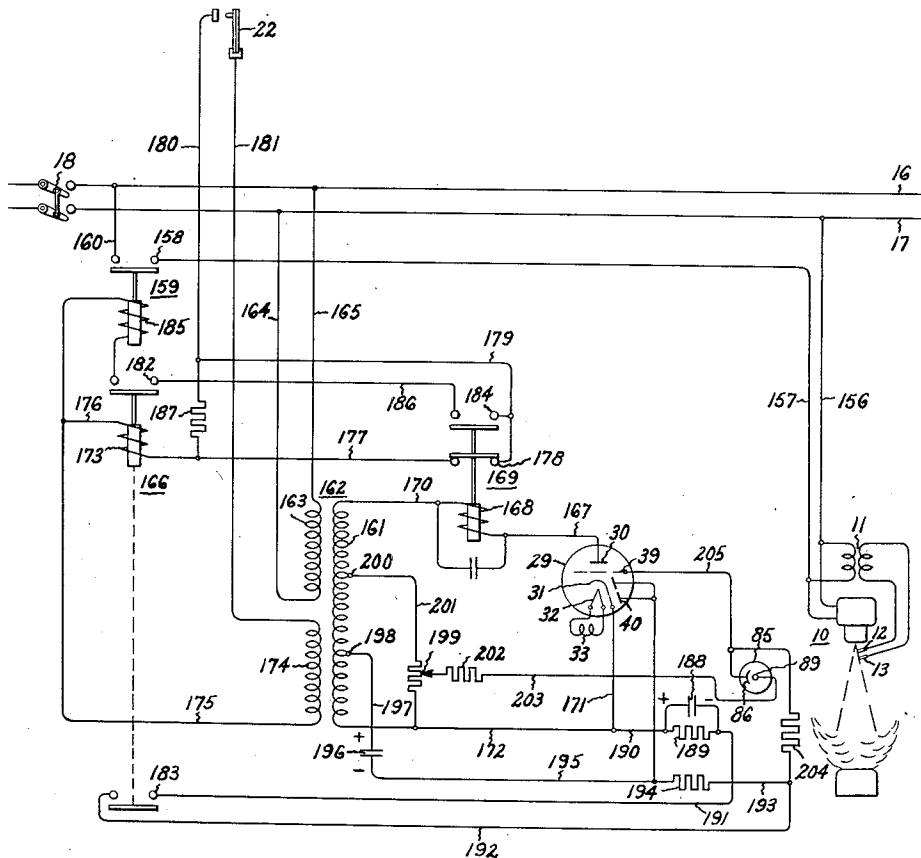
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3 Sheets-Sheet 3

Fig. 5.



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UNITED STATES PATENT OFFICE

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CONTROL SYSTEM

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Application March 1, 1941, Serial No. 381,286

21 Claims. (Cl. 158—28)

My invention relates to control systems, and although not limited thereto, it has application to electric control systems for furnaces.

Furnaces which burn a fluid fuel, such as oil or gas, usually employ an electric control system which includes a thermostat in the space to be heated so that when there is a call for heat a fuel pump motor and electric ignition arrangement are energized so that the fuel may be pumped to the furnace burner and ignited. If the fuel fails to ignite within a predetermined interval of time after the fuel pump has been operated, or should the flame during the operation of the furnace for any reason become extinguished, it is desirable that the burner of the furnace be shut down independently of the thermostat so as to prevent a quantity of unburned fuel from being pumped into the furnace. Heretofore, flame detector control arrangements have been provided with a heat responsive device within the furnace which device after a predetermined time delay provided by some mechanical timing arrangement, will turn off the burner if the device does not become heated by the flame. Also, a flame control arrangement employing the rectifier characteristics of the flame have been employed, as described in Patent 2,112,736—Cockrell, which is assigned to the same assignee as this present invention, and in order to obtain a suitable time delay in which the fuel is given time to ignite, a mechanical timing arrangement has been employed, as described in Patent 2,136,256—Sweet, which is assigned to the same assignee as this present invention.

Furthermore, the general idea of providing a combined time delay and flame detecting furnace control system by the employment of an electric discharge device is disclosed in the Crago Patent 2,243,071, granted May 27, 1941, and which is assigned to the same assignee as this present invention. Since such a combined time delay and flame detecting furnace control system must provide for automatic response of the electric discharge device at any time to the establishment and disestablishment of a main control condition, i. e., normal room temperature, and also provide for automatic response of the electric discharge device at any time to the establishment and disestablishment of a second normal control condition, i. e., proper ignition of the fuel in the furnace, while concurrently employing the electric discharge device for automatically limiting the interval of time permitted for operation of the fuel supply device in re-

sponse to the first control condition without successful establishment of the second control condition, some difficulties in obtaining the desired time delay control may be encountered. The control of the time delay action of the electric discharge device is complicated by the fact that the initiation of operation of the fuel supply device may occur at any time under automatic control and may follow certain extraneous and uncontrollable conditions, such for example as accidental failure of the electric power supply for the electric discharge device, accidental failure of combustion in the furnace after its initial successful establishment or extraneous changes in the main control condition such as might develop on opening doors or windows of the enclosure being heated, or even raising or lowering the desired room temperature to be held by manual adjustment of the calibrating mechanism of the room thermostat.

Further timing control complications are encountered where the termination of the time delay action of the electric discharge device is effected by the detection of the establishment of the second condition in response to variation of an electrical characteristic of the ignited fuel, such for example, as the rectifier characteristic of the flame. Such rectifier characteristic of the flame may be initially somewhat unstable, and where the time delay action of the electric discharge device is made dependent upon a rectifier characteristic thereof, which may at times become relatively feeble and unstable, the time delay control difficulties are multiplied, particularly where both the rectifier characteristic of the flame and the rectifier characteristic of the electric discharge device operate reversely upon the control electrode of the electric discharge device.

Since the time delay control of the electric discharge device is quite critical for safe operation of the automatic furnace control system under all of the varied normal and abnormal control conditions just noted, improvements in the reliability and consistency of the electric discharge time delay control are desirable.

It is, therefore, an object of my invention to provide a control system for an electrically operated device with an improved electric discharge timing control arrangement for providing a predetermined time between the initiation of operation of the electrically operated device and a time in which the electrically operated device will be shut down if it has not at that time at-

tained a predetermined normal condition of operation.

Another object of my invention is to provide an improved electric discharge timing control system for allowing a furnace a predetermined time in which to attain a normal operating condition, and if such condition is not attained within that predetermined time, the furnace will be deenergized, independently of the thermostat in the space to be heated.

A further object of my invention is to provide an improved electric-discharge timing control arrangement for a domestic furnace employing a fluid fuel, which is simple in construction, and reliable in operation.

Further objects and advantages of my invention will become apparent from the following description referring to the accompanying drawings, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In the drawings, Fig. 1 illustrates diagrammatically a furnace control system which is provided with an embodiment of my invention; and Figs. 2, 3, 4 and 5 illustrate modifications of the control arrangement illustrated in Fig. 1.

In the illustrated embodiments of my invention, I have provided a control system for deenergizing a burner of a furnace if a normal flame condition does not obtain within a predetermined time after the burner has been energized. This time delay is provided through a control circuit including an electric discharge device, which, upon a call for heat by a thermostat within the room to be heated, energizes the burner and ignition equipment for the furnace through suitable relay means after a predetermined normal current is flowing in the anode-cathode circuit. Upon actuation of the burner a suitable circuit is rendered operative so that a unidirectional biasing voltage is built up at a control electrode of the tube at a predetermined rate, so that when the control electrode becomes sufficiently negative with respect to the cathode, the plate current will have attained a sufficient minimum value so that the burner mechanism will be shut down if a normal flame condition does not obtain within that time. In order to obtain the proper unidirectional grid bias in a suitable time, I may employ any one of several circuits which will be described in detail as the description proceeds.

Referring more particularly to Fig. 1 of the drawings, I have illustrated a control system for a domestic furnace which burns a fluid fuel, such as oil, the combustibles being provided at the furnace through a burner arrangement indicated generally by the numeral 10. This burner arrangement is of the conventional type and includes an electric motor for operating a compressor and pump and an ignition transformer 11 which is connected to energize electrodes 12 and 13, the latter being placed adjacent the nozzle of the burner arrangement in order to ignite the mixture of fuel and air as it passes therethrough. Instead of a burner arrangement for a domestic furnace, any other suitable electrically operated device, in which a time delay is desired between the time the operation of the device is initiated until it is desirable to deenergize the device if a predetermined normal condition of operation thereof has not been attained, may be controlled with my electric control system. The energization of the burner mo-

tor and ignition transformer is accomplished through the closing of contacts 14 on a relay indicated generally by the numeral 15 so that the burner and ignition transformer may be connected across suitable lines 16 and 17, which may be connected to a suitable source through a line switch 18. Thus, when the relay 15 is energized the burner circuit may be traced from the line 16, through a conductor 19, contacts 14, a conductor 20, the burner mechanism 10 with its motor and transformer 11, and a conductor 21 back to the line 17. A heat responsive device or thermostat 22 is provided in the space to be heated for initiating operation of my control circuit when heat is desired. Any other suitable condition responsive device may be employed for controlling a suitable electrically operated device 10. A primary winding 23 of a suitable transformer 24 is adapted to be connected across lines 16 and 17 through conductors 25, 26, and 27 when the thermostat 22 is actuated. The transformer 24 is provided with a secondary winding 28 for energizing a suitable electric discharge device 29. This electric discharge device includes the usual anode 30 and cathode 31, and an arrangement for suitably heating the cathode is provided through the heater 32 which is connected across a secondary winding 33 of the transformer 24. The cathode 31 is connected to one side of the secondary winding 28 through the conductor 34 and the other side of the secondary winding 28 is connected to the anode of the discharge device through a conductor 35, operating coil 36 of the relay 15, and a conductor 37. Thus, it will be seen that when a predetermined normal current is flowing between the anode and cathode, which is sufficient to pick up the relay 15, the contacts 14 will be closed in order to start the burner motor of the furnace and energize its ignition transformer 11. Since the electric discharge device is a half-wave unidirectional rectifier, a suitable capacitor 38 may be connected in shunt with the operating coil 36 in order that it will not vibrate. In order to be able to control the discharge device a control member, such as a control electrode 39 is provided. A rectifying plate 40 is also provided which is suitably connected to a control electrode biasing circuit so that when the burner 10 is energized suitable unidirectional biasing voltage will be produced on the control electrode 39 at a predetermined rate, and when the electrode 39 has been made sufficiently negative with respect to the cathode 31 the anode-cathode current will have decreased to a predetermined value so that the relay 15 will drop out and deenergize the burner mechanism 10. The control electrode biasing circuit includes a secondary winding 41 of the transformer 24 and a suitable electric storage device, such as a capacitor 42. One side of the capacitor 42 is connected to the secondary winding 28 and to the cathode 31 through the conductor 34, and the other side of the capacitor 42 is connected to one end of the winding 41 through a resistor 43, the other end of the winding 41 being connected to the rectifying plate 40 through contacts 44 and a conductor 45. A resistor 46 is connected in shunt with the capacitor 42 and the terminal of the capacitor, which, as it will be seen becomes negative when it is charged, is connected to the control electrode 39 through a resistor 47 and a conductor 48. Thus the control electrode biasing circuit is in effect separate from the capacitor charging circuit. This prevents the alternating current

voltage produced in the winding 41 from being impressed upon the control electrode 39. Consequently, the control electrode is subject only to the unidirectional biasing voltage produced by charging of the capacitor 42. The contacts 44 for closing the capacitor charging circuit are controlled by a relay 49 which is in turn energized through contacts 50 which close when the relay 15 picks up. Thus, an operating coil 51 of the relay 49 is connected to the line 17 through the conductor 27 and is connected to the other line 16 through a conductor 52, contacts 50, and a conductor 53. Contacts 54 may be provided on the relay 49 so as to provide a holding circuit for the relay 49 even though the relay 15 drops out. The contacts 54 are connected to the line 16 through the conductor 26 and the thermostat 22 and the conductor 25, and the contacts are connected to the line 17 through coil 51 and conductors 55 and 27.

The operation of the control system as illustrated in Fig. 1 will now be described. When the thermostat 22 calls for heat it closes its contacts and energizes the transformer 24 so that a voltage is applied across the anode and cathode. Also, the secondary winding 33 is energized so that the cathode is heated up and the plate current increases. When a predetermined current is flowing between the anode and cathode, sufficient to pick up the relay 15, this relay will be energized and at that moment the burner arrangement 10 is energized so that the motor can pump the fuel and air out the nozzle and the ignition can be provided. At the same time the contacts 50 provide a circuit for picking up the relay 49 which in turn may provide a holding circuit for itself, and at the same time picks up the contacts 44, so as to close the capacitor charging circuit which provides the negative bias for the control electrode 39. Thus, a predetermined time is given the furnace to obtain its predetermined normal condition of operation, that is, a normal flame condition, which time is measured from the time relays 15 and 49 close until electrode 39 becomes sufficiently negative so as to decrease the anode current a predetermined or sufficient amount so that the relay 15 will drop out. In order to provide the desired negative bias the voltage across the winding 41 produces a flow of current in the biasing circuit which is rectified by the rectifying plate 40 and cathode 31, and the capacitor 42 is charged with the polarity indicated, and at a rate depending upon the constants of the circuit, such as the voltages across the transformer windings, the value of the capacitor 42 and of the resistors 46 and 47. Since the anode current will increase to a sufficient amount to cause the relay 15 to be energized before the control electrode charging circuit is even closed, the cathode-anode circuit may reach its normal operation before the control electrode 39 obtains a negative bias. However, as the negative bias on the control electrode continues to increase the plate current will thereby begin to decrease and will continue to decrease until a sufficiently low current is obtained so that the relay 15 is allowed to drop out. When this happens the time given for the burner mechanism 10 to reach a predetermined normal state of operation will have ended. The predetermined time delay will, therefore, be determined by the constants of the circuit which charges the capacitor 42 and the characteristics of the relay 15 which determines the minimum current necessary to maintain the relay in its closed position.

If, however, the predetermined normal condition of operation of the electrically operated device, or in other words the proper flame, has obtained before the relay 15 drops out, I have provided an arrangement responsive to the attainment of this condition for overcoming the negative bias in order that the electric discharge device 29 may remain conductive so that the relay 15 may remain picked up. I have, therefore, employed a flame detector according to that described in the above mentioned Patent 2,112,736, to Cockrell, which includes electrodes 56 and 57 which are placed in the path of the normal flame. The electrode 56 is connected to the transformer secondary winding 28 through a conductor 58 and the conductor 35, and other electrode 57 is connected to the control electrode 39 through conductors 59 and 48. Any other suitable type of flame detector may be employed, such as a photoelectric device, or a heat responsive device, which operates upon the application of heat when the flame is established and which may be operatively so connected to the control electrode 39 so as to allow its negative charge to leak off. Since, as the above-mentioned Cockrell patent indicates the current flows better in a direction opposite to the flame propagation, so it will be seen that the negative bias on the control electrode 39 will be removed through a circuit which includes one side of the secondary winding 28, the conductors 35 and 58, electrodes 56 and 57, conductors 59 and 48, resistor 47, capacitor 42 and conductor 34 back to the other side of the winding 28. The capacitor 42 will be discharged at a rate and to a value depending upon several factors, such as the values of the capacitor 42, resistors 46 and 47, and the value of the voltage appearing across the secondary winding 28. If resistance 47 is relatively small, the plate current will increase slowly when the flame is established as the control electrode is in effect connected directly to the capacitor 42 and due to the high impedance of the conduction to the flame the capacitor 42 cannot be discharged quickly. The capacitor 42 under these conditions will probably be completely discharged or possibly charged in the reverse polarity due to the rectifying characteristics of the flame. The plate current hence cannot follow the fluctuations of the flame and in case of flame failure there would be a time delay before the relay 15 would drop out. If, however, resistance 47 is made a large value the control electrode is instantly made more positive when the flame is established and the plate current jumps to its full value. Hence, the capacitor 42 is discharged to a certain extent. The relative values of the circuit constants, therefore, can be adjusted so that in case of flame failure the relay 15 will drop out instantaneously or after a predetermined time delay.

In Figs. 2 to 5, inclusive, other suitable arrangements are disclosed for providing the time delay by the charging of a capacitor which provides the negative bias on the control electrode 39. In these figures the main lines, the thermostat, the oil burner arrangement, and the electric discharge device will be given the same numerals as they had in Fig. 1, while in view of the differences in the remainder of the circuits the other parts will be given new numerals. Therefore, in Fig. 2 the oil burner 10 is adapted to be connected across the lines 16 and 17 through conductors 60, 61, contacts 62 of a relay 63, and conductors 64, 65. The anode 30 and the cathode 31 are permanently energized from the lines 16 and 17

through an auto transformer 66, which is connected across the lines 16 and 17 through the conductors 65 and 67. Thus, the anode is connected to one side of the transformer winding 66 through a conductor 68, the operating coil 69 of the relay 70, and a conductor 71, while the other end of the transformer winding 66 is connected to the cathode by a conductor 72. Contacts 73 of the relay 70 are connected through an operating coil 74 of the relay 63 and conductors 64 and 65 to one side of a suitable source or the line 17, while the other side of the contacts 73 are connected to the other side of the source, or the line 16 through a conductor 75, thermostat 22 and a conductor 76. The cathode of the discharge device 29 is kept continually heated through the winding 33 of the transformer and so a predetermined normal current flows in the plate circuit in order to keep the relay 70 permanently picked up. When the thermostat 22, therefore, calls for heat it will close its contacts and complete the circuit through the contacts 73 and the operating coil 74 of the relay 63 so as to pick up the relay 63 in order that its contacts 62 will complete the circuit of the burner operating arrangement 10 so that it may be energized. At the same time the thermostat 22 closes in order to energize the burner 10 through the relays 70 and 63, contacts 77 which are operatively connected to the thermostat in any suitable manner, such as being on the thermostat and which are also closed in order to complete a control electrode biasing circuit. The biasing circuit as in Fig. 1, includes a suitable capacitor 78, a source of potential in the form of a winding 79 of the transformer, resistor 80 connected in shunt with the capacitor 78 and resistor 81 which connects the negatively charged side of the capacitor to the control electrode 39. Thus, when the thermostat 22 calls for heat a circuit will be completed which includes the source 79, conductor 82, contacts 77, conductor 83, rectifying plate 40, cathode 31, conductor 72, capacitor 78 and a resistor 84 back to the other side of the winding 79. The capacitor 78 will, therefore, be charged as indicated and a negative bias will be built up at a predetermined rate on the control electrode 39. When the control electrode has been biased sufficiently negative so as to reduce the anode current to a sufficient amount that the relay 70 will drop out, and the relay 63 will also drop out and the burner mechanism will be deenergized. A suitable arrangement, however, is provided for overcoming the bias on the control electrode 39, if the flame should obtain a predetermined normal condition of operation before the relay 70 drops out.

In order that the grid bias may be overcome if the flame obtains its normal condition within the desired predetermined time a photoelectric tube 85 is provided with its cathode 86 in line with the flame so that the light thereof may shine on the cathode and make it conductive. Any suitable type of flame detection may be employed. The cathode is, therefore, connected to the control grid through a conductor 87 which is in turn connected to the negative side of the capacitor 78 through a conductor 88 and the resistor 81. An anode 89 of the photoelectric tube 85 is connected to the transformer 66 at any suitable point, such as its mid-point through a conductor 90. Thus, if the flame is ignited, the photoelectric tube may be made conductive and current will flow from the mid-point of the winding 66 through the conductor 90, the photoelec-

tric tube, conductors 87 and 88, the capacitor 79 and back to the winding 66. Thus, the charge on the capacitor will be reversed so that the negative bias on the control electrode 39 will be overcome.

I have also illustrated in Fig. 3 a control system in which the current flowing between the anode and cathode of the discharge device 29 is normally maintained at a predetermined value, since the anode and cathode may be permanently connected to the lines 16 and 17 through a winding 91 of an autotransformer, or any other suitable arrangement. The autotransformer 91 is connected solidly to the lines 16 and 17 through the conductors 92 and 93 and one end of the winding 91 is connected to the anode 30 through conductor 94, operating coil 95 of a relay 96 and a conductor 97. The cathode 31 is connected to the other end of the winding 91 through the conductor 98. Thus, the relay 96 is normally picked up and the circuit for energizing the burner mechanism 10 includes conductors 99 and 100, contacts 101 of the relay 96, conductor 102, normally open contacts 103 of the relay 104, and conductors 105 and 93. Therefore, when the thermostat 22 closes its contacts upon a call for heat, relay operating coil 106 is connected across the lines 16 and 17 through the conductors 93 and 105, a conductor 107, thermostat 22 and a conductor 108. The burner mechanism 10 is, therefore, connected across the lines 16 and 17 and its operation is, therefore, initiated. At the same time normally closed contacts 109 of the relay 104 will be opened, thus rendering effective the circuit which produces the biasing voltage on the electrode 39. The circuit for obtaining this bias includes a capacitor 110 which is connected to one side of the winding 91 through a conductor 111 and which is also connected to the rectifying plate 40 of the discharge device 29 through a conductor 112, resistor 113, and conductor 114. The grid biasing circuit is completed through the cathode, the conductor 98 back to the other side of the capacitor 110. The voltage necessary to charge the capacitor 110 is provided by the potentiometer arrangement 115 which includes a resistor having one side connected to a tap on the winding 91 through the conductor 116, and the other side of the resistor being connected to an end of the winding 91 through the conductor 111. A movable tap is provided and this is connected to the rectifying plate through a capacitor 117, conductor 118, and conductor 114. Thus, the capacitor 110 is charged with the polarity as indicated, and the negative charge is transferred to the control electrode 39 through the conductor 112, a conductor 119, a resistor 120, and a conductor 121. If the flame ignites before the plate current has reduced sufficiently for the relay 96 to drop out the photoelectric device 81 will be made conductive. Any other suitable flame condition responsive device may, of course, be employed. The voltage necessary to overcome the grid biasing effect is provided through a potentiometer 122 which is connected to a suitable point, such as the midpoint of the winding 91 through a conductor 123. A movable electrode thereof is connected through a resistor 124 and a conductor 125 to the anode 89 of the photoelectric device 85. Thus, the current may flow from the anode to the cathode 86 of the photoelectric device and through the conductor 121, resistor 120, conductor 119, conductor 112, capacitor 110, conductor 98 back to the potentiometer 122, so that the charge

on the capacitor will be reversed and the grid bias removed.

In Fig. 4, I have illustrated a circuit in which the cathode of the electric discharge device 29 is kept in a constantly heated condition but the voltage is not impressed across the anode and cathode until the room thermostat closes. Also, in this illustrated arrangement of my invention only one relay is provided which when energized connects the burner mechanism 10 across the lines 16 and 17 through conductors 126, 127, contacts 128 and conductor 129. An autotransformer winding 130 is constantly energized from the lines 16 and 17 through the conductors 131 and 132. One side of the winding 130 is connected to the anode of the electric discharge device through a conductor 133, operating coil 134 of a relay 135 and conductor 136, while the other end of the winding 130 is connected to the cathode through the conductor 132, line 17, a conductor 137, thermostat 22, and a conductor 138. Since the winding 33 which is connected to the heating arrangement for the cathode is permanently energized the cathode will be kept in a heated condition so that when the thermostat 19 is closed, current will quickly attain its predetermined normal condition so that the relay 135 will pick up in order to energize the burner mechanism 10. Closing of the thermostat 22 will also close a circuit for producing the biasing voltage on the control electrode 39. This circuit includes a capacitor 139 which is connected at one side to a tap 140 of the winding 130. The circuit may be traced from the other side of the capacitor 139 through conductors 141 and 142, rectifying plate 40 and cathode 31 of the electric discharge device, conductor 138, thermostat 22, conductor 137, line 17, conductor 132, tap 140 to the condenser 139. The conductor 132 is also connected through conductors 143 and 144 to a capacitor 145 which is shunted by a resistor 146. This parallel circuit is in turn connected to the negative side of the condenser 139 through conductors 147 and 148, a resistor 149, and conductor 141. When the thermostat 22 closes, capacitor 139 is immediately charged and the capacitor 145 is charged as indicated at a predetermined rate in order to produce the negative bias on the control electrode 39. The negative terminal of the capacitor 145 is connected to the control electrode through the conductors 147 and 148, a resistor 150 and a conductor 151. If, however, the flame is ignited before a sufficient charge is obtained on the electrode in order to stop the tube from firing, the photoelectric cell 85 will be made conducting. Here again, any other suitable flame responsive device may be employed. A suitable voltage is provided through a potentiometer arrangement 152 which has one side connected to a suitable point, such as the midpoint of the winding 130, through a conductor 153, and a movable element which is connected through a resistor 154 and a conductor 155 to the anode of the photoelectric cell 81. The potentiometer is also connected to the positively charged side of the capacitor 145 through the conductor 144. Thus, if the flame is established the current may flow through the potentiometer, the resistor 154, conductor 155, photoelectric cell 81, conductor 151, resistor 150, the parallel circuit including the capacitor 145, and resistor 146, the conductor 144 back to the potentiometer 152 in order to discharge the capacitor 145, so as to remove the grid bias. The resistor 146 is put in parallel with the capacitor 145, since the thermostat is in the

cathode circuit and when it is open the capacitor may discharge through this parallel circuit. When the thermostat closes, the capacitor 139 is charged immediately through the tube and this voltage is supplied through the resistor 149 to the capacitor 145, so that it may be seen that the value of the resistor 149 determines the charging rate and, therefore, the time delay of the circuit.

I have illustrated in Fig. 5 another arrangement for obtaining the time delay with a suitable flame detector, such as a photoelectric tube, and the circuit is so connected that the photoelectric cell may be checked after each cycle of operation in order to insure that it is in satisfactory condition. The control electrode of the electric discharge device is connected to a negative potential whenever the thermostat is opened, and if the photoelectric tube is intact the grid will be biased negatively so as to cause the relay which is operated by the plate circuit to drop out. Then with another relay which can only be operated if the former is closed, I am able to prevent operation of the circuits if the photoelectric tube is defective. This provides an additional arrangement for making my control circuit fail-proof. It is also apparent that in all the modifications shown if the electric discharge device fails the burner may not be energized. Thus, the burner will operate only when it is under proper control.

The burner means 10, as in the other figures, is adapted to be connected across the lines 16 and 17 through conductors 156 and 157, normally open contacts 158 of the relay 159 and conductor 160. A sufficient voltage may be permanently impressed across the anode and cathode of the electric discharge device 29 through a transformer secondary 161 of a transformer 162 since its primary winding 163 is permanently connected across the lines 16 and 17 through conductors 164 and 165. As will be described in more detail, however, as the description proceeds, the tube will be rendered non-conductive since the grid is maintained sufficiently negative to prevent the tube from firing when a relay 166 is deenergized.

The anode 30 of the electric discharge device 29 is connected to one side of the transformer winding 161 through a conductor 167, operating coil 168 of a relay 169 and conductor 170, while the cathode 31 is connected to the other side of the winding 161 through conductors 171 and 172. An operating winding 173 of the relay 166 is connected to a secondary winding 174 of the transformer 162. This circuit may be traced from one side of the winding through conductors 175, 176, operating winding 173, conductor 177, the normally closed contacts 178 of the relay 169, conductors 179 and 180, thermostat 22 back to the other side of the winding 174 through a conductor 181. When the thermostat 22 calls for heat and closes its contacts, the relay 166 will be picked up through the circuit which has just been traced. This will close contacts 182 and 183 of the relay 166. As will be described below, this removes the negative bias on the control electrode 39, due to its being connected to the cathode, and allows a predetermined normal current to flow through the anode and cathode circuit in order to energize the relay 169. When the relay 169 picks up it closes its contacts 184 and since contacts 182 of the relay 166 have been closed, the relay 159 will be energized through a circuit which includes the conductor 175, operating coil 185 of the relay 159, contacts 182 of the relay 166, conductor 186 to the con-

tacts 184, conductor 179, conductor 180, thermostat 22 back to the other side of the transformer secondary 174 through the conductor 181. Also, when the relay 169 picks up it opens its contacts 178. However, relay 166 is prevented from dropping out as its coil remains energized through a circuit which includes conductor 175, operating coil 173 of relay 166, a resistor 187, conductor 180, thermostat 22, and back to the other side of transformer secondary 174 through the conductor 181. The energization of the relay 159 will cause the burner mechanism to be energized. Furthermore, the closing of the contacts 183 of the relay 166 will cause the control electrode biasing circuit to be energized so that a negative bias may be provided at a predetermined rate on the control electrode 39. The grid bias is provided by charging a capacitor 188 which is shunted with a resistor 189 for the same reason that the capacitor in Fig. 4 was shunted by a resistor. One side of this parallel resistor-capacitor combination is connected to one side of the transformer secondary 161 through conductors 190 and 172, and the other side of this parallel circuit is connected through a conductor 191 to the contacts 183 of the relay 166. The circuit may then be traced through conductors 192 and 193, resistor 194, conductor 195, capacitor 196, a conductor 197 back to a tap 198 on the secondary winding 161. The circuit for passing current through the photoelectric tube 85 when it becomes energized includes a potentiometer 199 which is connected to any suitable tap 200 of the winding 162 through a conductor 201, a resistor 202, a conductor 203, photoelectric cell 85, a resistor 204, conductor 192, contacts 183, conductor 191, capacitor 188, conductor 172, back to the potentiometer 199.

When the thermostat 22 in Fig. 5 closes, the relay 166 will be energized which in turn closes the contacts 183 so that the negative bias, which is present when the relay 166 is dropped out, is removed from the control electrode 39 through a conductor 205, resistor 204, conductor 192, contacts 183, conductor 191, capacitor 188 whose voltage at this instant is zero, and then to cathode 31 through the conductor 171, thus allowing the relay 169 to pick up. This in turn provides a circuit for energizing the relay 159 in order to energize the burner mechanism. At the same time due to the closing of the contacts 183, a circuit will be established for providing the voltage bias to be produced on the control electrode 39 at a predetermined rate. This circuit for providing the grid bias may be traced first through the tap 198, capacitor 196, conductor 195, through the rectifying plate 40 and cathode 31 of the electric discharge device 29 back to the tap 198 through the conductors 171 and 172 and a portion of the winding 161. This immediately provides a flow of current from capacitor 196, tap 198, a portion of the secondary winding 161, conductors 172 and 190, the capacitor and resistor combination 188 and 189, conductor 191, contacts 183, conductors 192 and 193, resistor 194, conductor 195 back to the capacitor 196. The capacitor 188 will be charged as indicated and it will be seen that the negative side of the capacitor will be connected to the control electrode 39 through the conductor 191, contacts 183, conductor 192, the resistor 204, and a conductor 205. If the flame is not established before a sufficient bias is provided on the control electrode 39 the anode current will become sufficiently

small so that the relay 169 will drop out and the relay 159 will also drop out and cause the burner mechanism 10 to be deenergized. However, if the flame has reached its predetermined condition the photoelectric cell will become conductive and the voltage impressed across the potentiometer 199 will cause a current to flow through the resistor 202, conductor 203 to the photoelectric cell anode and cathode, conductor 205, resistor 204, conductor 192, contacts 183, conductor 191, through the capacitor 188 in a direction opposite to which it has been charged, back to the potentiometer 199 through the conductors 190 and 172. This will reverse the charge on the capacitor and remove or overcome the grid bias. The burner mechanism may, therefore, run until the call for heat in the room to be heated has been satisfied and the thermostat 22 moves its contacts to an open position.

When the thermostat opens its contacts the relay 166 will be deenergized so that its contacts 183 will be open circuited and the tube to be made non-conducting so that the relay 169 will also drop out. The tube is made non-conductive, since when the contacts 183 open, the control electrode 39 will be connected through the conductor 205, resistor 204, conductor 193, resistor 194, conductor 195, to the negative side of the capacitor 196. Since the capacitor 196 is kept constantly charged through the circuit which includes the rectifying plate and cathode, the grid will be maintained negatively during the time when the contacts 183 are open so as to prevent firing of the tube during that time. As has already been mentioned, this circuit also allows the flame responsive device to be checked, since when the flame goes out, if the photoelectric tube continues to pass current it is defective, and the negative charge on the grid will be overcome through the circuit which has already been described. This will allow the electric discharge device to continue to pass a sufficient current to keep the relay 169 energized and since the other two relays have already been dropped out due to the opening of the thermostat 22, it will be impossible to energize these relays again so long as the relay 169 is picked up, so that if the thermostat were again to call for heat the burner mechanism would not be energized. This is because of the resistor 187, which is of suitable magnitude, has been shunted across the contacts 178. The resistance of the resistor 187 is, therefore, so set that current flowing through it is limited to such a value below that required to energize the relay 166. Therefore, the circuit to energize the relay 166 must include the contacts 178 of relay 169. However, after relay 166 has been energized a sufficient current will pass through the resistor 187 to hold the relay 166 in closed position. Therefore, if the relay 166 has dropped out and the relay 169 is still picked up the contacts 178 will be open and the current passing through the circuit including the resistor 187 and the coil 173 is not sufficient to pick up the relay 166. Thus, closing of the thermostat 22 will not cause the burner mechanism to be energized under these conditions. If, however, the photoelectric cell is working properly, when the thermostat 22 is open, current will not pass through the cell so as to overcome the grid bias and the tube will cease firing and the relay 169 will drop out, thus providing a circuit through contacts 178 so that relay 166 may be energized whenever the thermostat 22 again calls for heat. It will also be apparent that any other suitable condition respon-

sive device may be employed instead of the potentiometer and the operation of it may also be tested to see that it is operating satisfactorily as is described above.

In view of the foregoing it will be seen that I have provided improved circuits for turning off an electrical device within a predetermined time after its actuation has been initiated provided that a predetermined normal condition of operation has not obtained within this time. As an example of an application to which my improved control system finds an efficient use, I have described it in its application to a control circuit for an oil burner. However, it is to be understood that my control system may be employed with any electric device whose operation it is desired to be stopped provided a normal operation is not obtained within a predetermined time. It is also to be noted that although my improved control circuit in the illustrated embodiments has been described in connection with a continuous ignition system for an oil burner circuit, it is to be understood that my improved system may be equally well employed to an ignition circuit of the intermittent type. I should also like it to be understood that any other suitable rectifying arrangement other than the rectifier plate and cathode in the electric discharge tube may be employed for rectifying the current which charges the capacitor, the negative terminal of which is connected to the control electrode. Thus, a separate rectifying tube may be employed in series with an alternating source of supply or a direct current source of supply could be employed to charge the capacitor.

Modifications of the particular arrangements which I have disclosed embodying my invention will occur to those skilled in the art, so that I do not desire my invention to be limited to the particular arrangements set forth and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

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

1. A control system for an electrically operated device including an electric discharge device having an anode, a cathode and a control electrode, a condition responsive device, means including said condition responsive device and said electric discharge device for initiating operation of said electrically operated device, means for producing a unidirectional biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, means for preventing actuation of said control electrode potential changing means until operation of said electrically operated device is initiated, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

2. A control system for an electrically operated condition changing device including an electric discharge device having an anode a cathode and a control member, a condition responsive device, means including said condition responsive device and said electric discharge device for initiating operation of said condition changing

device, a biasing circuit including a capacitor interconnected between said cathode and said control electrode for producing a change in an electrical condition on said control member, an independent circuit starting means for charging said capacitor at a predetermined rate so that after a predetermined time delay a lowering of the current flowing through said discharge device to a predetermined value will cause said condition changing device to be deenergized, means for closing said charging circuit when operation of said condition changing device is initiated, and means responsive to a predetermined normal condition of operation of said condition changing device and connected with said biasing circuit for overcoming said change in an electrical condition on said control member so that said condition changing device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

3. A control system for a furnace having electric means for supplying combustibles and ignition thereto including an electric discharge device having an anode a cathode and a control electrode, a thermostat, means including said thermostat and said electric discharge device for initiating operation of said electric means, a biasing circuit including a capacitor for producing a biasing voltage on said control electrode, a charging circuit including means for charging said capacitor at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, means for initiating actuation of said capacitor charging means when operation of said electric means is initiated, and means responsive to a proper flame condition in said furnace and connected with said biasing circuit for overcoming said biasing voltage so that said electric means will remain energized when said proper flame condition obtains before the expiration of said predetermined time delay.

4. A control system for an electrically operated device including a source of potential, an electric discharge device having an anode a cathode and a control electrode, a condition responsive device, means including said condition responsive device and said electric discharge device for initiating operation of said electrically operated device, an electrical energy storage device, means for operatively connecting said energy storage device to said source so as to charge said energy storage device at a predetermined rate, said operatively connecting means for actuating said connecting means when said electrically operated device is initiated, separate means for connecting the negatively charged side of said energy storage device to supply a unidirectional biasing voltage to said control electrode so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

5. A control system for an electrically operated device including a source of alternating

potential, an electric discharge device having an anode and a cathode, a condition responsive device, means including said condition responsive device and said electric discharge device for initiating operation of said electrically operated device, a control electrode and a rectifying plate within said electric discharge device, a biasing circuit including a capacitor interconnected between said cathode and said control electrode, a separate charging circuit including said rectifying plate and said cathode for charging said capacitor to produce a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said electric discharge device to a predetermined value will cause said electrically operated device to be deenergized, means for closing said charging circuit when the operation of said electrically operated device is initiated, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

6. A control system for an electrically operated device including an electric discharge device having a control member, a biasing capacitor for said control member, rectifier means for charging said capacitor, switch means including a main switch and an auxiliary switch, means including said main switch means and said discharge device for initiating operation of said electrically operated device upon a predetermined current flowing through said discharge device, means including said auxiliary switch for interconnecting said rectifying means and said capacitor to produce a biasing voltage on said control member at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, operation of said biasing voltage means being initiated when the operation of said electrically operated device is initiated, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

7. A control system for a furnace having electric means for supplying combustibles and ignition thereto including an electric discharge device having a control member, a biasing capacitor for said member, means for charging said capacitor, a thermostat within a space to be heated by said furnace, means including said thermostat and said discharge device for initiating operation of said electric means upon a predetermined current flowing through said discharge device, means responsive to said predetermined current flow through said discharge device for interconnecting said rectifying means with said condenser to produce a biasing voltage on said control member at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electric means to be deenergized, and means responsive to a proper flame in said furnace for overcoming said biasing voltage so that said electric means will remain

energized when said proper flame obtains before the expiration of said predetermined time delay.

8. A control system for a furnace having electric means for supplying combustibles and ignition thereto including an electric discharge device having an anode a cathode a control electrode and a separate rectifying plate, a temperature responsive device, means including said temperature responsive device and said discharge device for initiating operation of said electric means upon a predetermined current flowing between said anode and cathode, a source of alternating potential, a biasing circuit including an energy storage device connected between said cathode and said control electrode, a charging circuit including said source energy storage means cathode and rectifying plate for charging said energy storage device to produce a unidirectional biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay the current flowing between said anode and cathode will have been reduced to a predetermined value so that said electric means will be deenergized, means responsive to said predetermined current for rendering operative said charging circuit when operation of said electric means is initiated, and means responsive to a proper flame in said furnace for overcoming said biasing voltage so that said electric means will remain energized when said proper flame obtains before the expiration of said predetermined time delay.

9. A control system for an electrically operated device including a source of alternating potential, an electric discharge device having an anode a cathode and a control electrode, means normally energized from said source for maintaining said cathode in a constantly heated condition, means including a condition responsive device adapted to call for operation of said electrically operated device for connecting said anode and cathode across said source of potential, means responsive to a predetermined flow of current through said discharge device for initiating operation of said electrically operated device, means rendered effective upon connection of said cathode to said source for producing a unidirectional biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of the current flowing through said discharge device to a predetermined value will cause said electrically and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

10. A control system for an electrically operated condition changing device including a source of alternating potential, an electric discharge device having an anode a cathode and a control member, means normally energized from said source for maintaining said cathode in a constantly heated condition, means including a thermal responsive device adapted to call for operation of said condition changing device for connecting said anode and cathode across said source of potential, means responsive to a predetermined flow of current through said discharge device for initiating operation of said condition changing device, means including said current responsive means for producing a unidirectional change in an electrical condition on said control member at a predetermined rate so that after a predeter-

mined time delay a lowering of the current flowing through said discharge device to a predetermined value will cause said condition changing device to be deenergized, and means responsive to a predetermined normal condition of operation of said condition changing device for overcoming said change in said electrical condition of said control member so that said condition changing device will remain energized when said predetermined normal condition of operation appears before the expiration of said predetermined time delay.

11. A control system for an electrically operated device including a source of alternating potential, an electric discharge device having an anode a cathode and a control electrode, means including a condition responsive device adapted to call for operation of said electrically operated device for connecting said anode and cathode across said source of potential, means including a relay for connecting said electrically operated device across said source, an operating coil for said relay, means for connecting said coil in series with said anode and cathode so that said relay will be energized when the current flowing through said electric discharge device is a predetermined value, means under the control of said relay for producing a unidirectional biasing voltage on said control electrode at a predetermined rate so that a lowering of the current flowing through said discharge device to a predetermined value will allow said relay to drop out and deenergize said electrically operated device, means responsive to energization of said relay for energizing said biasing voltage means, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

12. A control system for a furnace having electric means for supplying combustibles and ignition thereto including, a source of alternating potential, an electric discharge device having an anode a cathode and a control electrode, means including a thermostat within the space to be heated by the furnace for connecting said anode and cathode across said source of potential, means responsive to a predetermined current flowing between said anode and cathode for initiating operation of said electric means, a rectifying plate within said discharge device, an energy storage device, a transformer adapted to be energized from said source, a circuit closed under the control of said current responsive means and including said transformer energy storage device cathode and rectifying plate for producing a unidirectional biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of the current flowing between said anode and cathode will cause said electric means to be deenergized, and means responsive to a proper flame condition in said furnace for overcoming said biasing voltage so that said electric means will remain energized if said proper flame obtains before the expiration of said predetermined time delay.

13. A control system for an electrically operated device including an electric discharge device having an anode a cathode and a control electrode, means for maintaining said cathode in a constantly heated condition, means for constantly impressing a voltage across said anode and cath-

ode, means including a condition responsive device for controlling said electric discharge device to effect current flow therethrough, a relay responsive to the current flow through said discharge device for initiating operation of said electrically operated device, means controlled by said condition responsive device for producing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

14. A control system for a furnace having electric means for supplying combustibles and ignition thereto including an electric discharge device having an anode a cathode and a control electrode, means for maintaining said cathode in a constantly heated condition, means for constantly impressing a voltage across said anode and cathode to effect current flow therebetween, means including a thermostat and a relay responsive to said current flow through said electric discharge device for initiating operation of said electric means, means including a second relay under the joint control of said thermostat and said first relay for producing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, means responsive to a proper flame condition in said furnace for overcoming said biasing voltage so that said electric means will remain energized when said proper flame condition obtains before the expiration of said predetermined time delay.

15. A control system for an electrically operated device including a source of alternating potential, an electric discharge device having an anode a cathode and a control electrode, means including a transformer for maintaining said cathode in a constantly heated condition and for connecting said source across said anode and cathode so as to produce a predetermined current therebetween, a relay having an operating coil in said anode circuit and having contacts in a circuit including said electrically operated device and said source, means including a condition responsive device and a second relay under the joint control of said first relay and said condition responsive device and a third relay under the joint control of said first and second relays for completing said electrically operated device circuit, means under the control of said second relay for producing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing between said anode and cathode to a predetermined value will cause said electrically operated device to be deenergized, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

16. A control system for a furnace having electric means for supplying combustibles and ignition thereto including an electric discharge device having an anode a cathode a control electrode and a rectifying plate, a relay having an operating coil in series with said anode and contacts in a circuit including said electric means, means for permanently connecting said source across said anode and cathode producing a predetermined normal current therebetween, means including a thermostat within a space to be heated for completing the circuit including said relay contacts and electric means when said thermostat calls for heat, an energy storage device, a circuit including said energy storage device, cathode, and rectifying plate for producing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay the current flowing between said cathode and anode will have been reduced a sufficient amount so that said relay will be deenergized and said electric means turned off, means including switch means responsive to movement of said thermostat to said heat calling for position for connecting said biasing circuit to said source, and means responsive to a proper flame condition in said furnace for overcoming said biasing voltage so that said electric means will remain energized when said flame obtains before the expiration of said predetermined time delay.

17. A control system for a furnace having electric means for supplying combustibles and ignition thereto including an electric discharge device having an anode a cathode a control electrode and a rectifying plate, a relay having an operating coil in series with said anode and contacts in a circuit including said electric means, means including a transformer for permanently connecting said source across said anode and cathode so as to produce a predetermined normal current therebetween, means including a thermostat within a space to be heated for completing said circuit including said relay contacts and said electric means when said thermostat calls for heat, a potentiometer connected across a portion of said transformer, a capacitor, a circuit including said potentiometer, capacitor, rectifying plate and cathode for providing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay the current flowing between said anode and cathode will have been reduced a sufficient amount so that said relay will be deenergized and said electric means turned off, normally closed contacts for short circuiting said capacitor, means for opening said contacts for initiating the biasing of said control electrode when said thermostat calls for heat, and means responsive to a proper flame condition in said furnace for overcoming said biasing voltage so that said electric means will remain energized when said proper flame condition obtains before the expiration of said predetermined time delay.

18. A control system for a furnace having electric means for supplying combustibles and ignition thereto including a source of potential, an electric discharge device having an anode a cathode and a control electrode, a relay having an operating coil in series with said anode and contacts adapted to close when said relay is energized, means including a transformer for connecting said source across said anode and cathode so as to produce a predetermined current therebetween, a thermostat within the space to be heated, a second relay having an operating

coil in series with said thermostat and contacts adapted to close when said second relay is energized in series with said contacts of said first mentioned relay, means including said contacts of said first and second mentioned relays for connecting said electric means across said source when the thermostat calls for heat, means for connecting said control electrode to a source of negative potential when said second mentioned relay is deenergized, and contacts on said first mentioned relay adapted to be closed when said first mentioned relay is deenergized in series with said operating coil of said second mentioned relay and said thermostat so that said first mentioned relay must move to its deenergized position before said second mentioned relay can be energized when said thermostat moves to its circuit closing position upon a call for heat.

19. A control system for a furnace having electric means for supplying combustibles and ignition thereto including a source of potential, an electric discharge device having an anode a cathode and a control electrode, a relay having an operating coil in series with said anode and contacts adapted to close when said relay is energized, means including a transformer for connecting said source across said anode and cathode so as to produce a predetermined current therebetween, a thermostat within the space to be heated, a second relay having an operating coil in series with said thermostat and having contacts adapted to close when said second relay is energized in series with said contacts of said first mentioned relay, means including said contacts of said first and second mentioned relays for connecting said electric means across said source when the thermostat calls for heat, means for producing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device to a predetermined value will cause said electrically operated device to be deenergized, means responsive to a predetermined normal condition for operation of said electrically operated device for overcoming said biasing means so that said electrically operated device will remain energized when said predetermined normal condition of operation obtains before the expiration of said predetermined time delay, and contacts on said first mentioned relay adapted to be closed when said first mentioned relay is deenergized in series with said operating coil of said second mentioned relay and said thermostat so that said first mentioned relay must move to its deenergized position before said second mentioned relay can be energized when said thermostat moves to its circuit closing position upon a call for heat.

20. A control system for a furnace having electric means for supplying combustibles and ignition thereto including a source of potential, an electric discharge device having an anode a cathode and a control electrode, a relay having an operating coil in series with said anode and contacts and adapted to close when said relay is energized, means including a transformer for connecting said source across said anode and cathode so as to produce a predetermined current therebetween, a thermostat within the space to be heated, a second relay having an operating coil in series with said thermostat and contacts adapted to close when said second relay is energized in series with said contacts of said first mentioned relay, means including said contacts of said first and second mentioned relays for con-

necting said electric means across said source when said thermostat calls for heat, a capacitor, a circuit connected to said transformer and including said capacitor for producing a biasing voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said discharge device will cause said first and second mentioned relay to drop out and said electric means to be deenergized, switch means operable to a closed position in response to movement of said second relay to a closed position for completing said control electrode biasing circuit, contacts on said first mentioned relay in series with said operating coil of said second mentioned relay so that said second mentioned relay cannot be energized unless said first mentioned relay is deenergized, and means responsive to a proper flame condition in said furnace for overcoming said biasing voltage so that said electric means will remain energized if said flame obtains before the expiration of said predetermined time delay, and means to connect said control electrode with said cathode so that said discharge device will be rendered non-conductive when said thermostat moves to open circuit position unless said flame responsive means overcomes the biasing voltage on said control electrode.

21. A control system for an electrically operated device including a source of alternating potential, an electric discharge device having an anode and a cathode, means normally energized from said source for maintaining said cathode in

a constantly heated condition, means for constantly connecting said source across said anode and cathode to effect current flow therebetween, a relay responsive to said current flow, a condition responsive device, a second relay having an energizing circuit under the joint control of said condition responsive device and said first relay and having a holding circuit under the control of said condition responsive device, a third relay under the joint control of said first and second relays for initiating operation of said electrically operated device, a control electrode and rectifying plate within said electric discharge device, a biasing circuit including a capacitor interconnected between said control electrode and said cathode, a charging circuit under the control of said second relay and including said rectifying plate and said cathode for charging said capacitor to produce a unidirectional voltage on said control electrode at a predetermined rate so that after a predetermined time delay a lowering of current flowing through said electric discharge device to a predetermined value will cause said electrically operated device to be deenergized, and means responsive to a predetermined normal condition of operation of said electrically operated device for overcoming said biasing voltage so that said electrically operated device will remain energized if said predetermined normal condition of operation obtains before the expiration of said predetermined time delay.

ELBERT D. SCHNEIDER.

CERTIFICATE OF CORRECTION.

Patent No. 2,299,501.

October 20, 1942.

ELBERT D. SCHNEIDER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 8, second column, line 51, claim 9, after "electrically" insert "--operated device to be deenergized,--"; page 9, second column, line 39, claim 14, before "means" insert "--and--"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of December, A. D. 1942.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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