Jan. 23, 1951 M. A. SCHULTZ ET AL 2,539,208

FLAME CONTROL DEVICE

Filed April 1, 1948

Fig. 1.

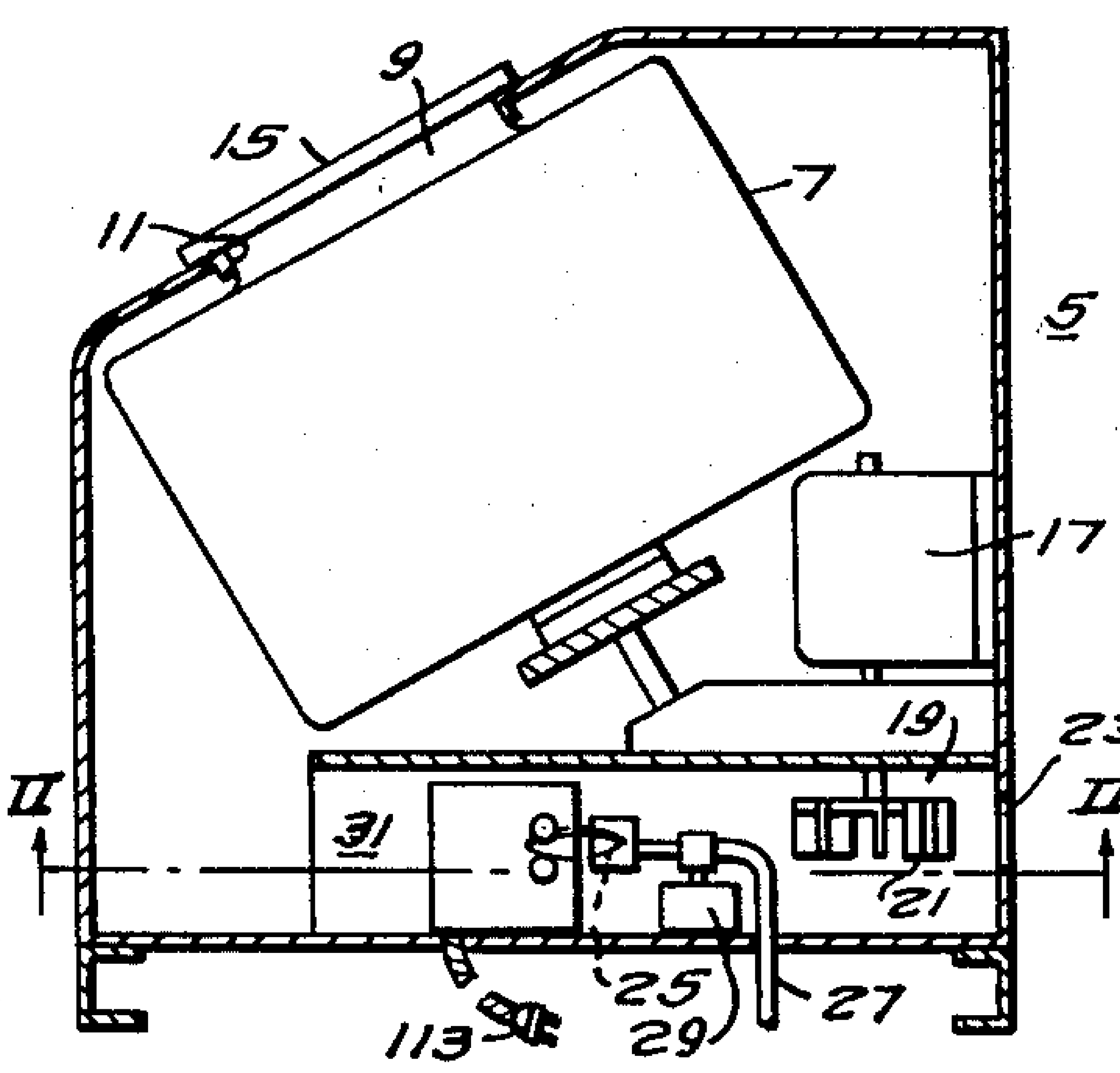


Fig. 4.

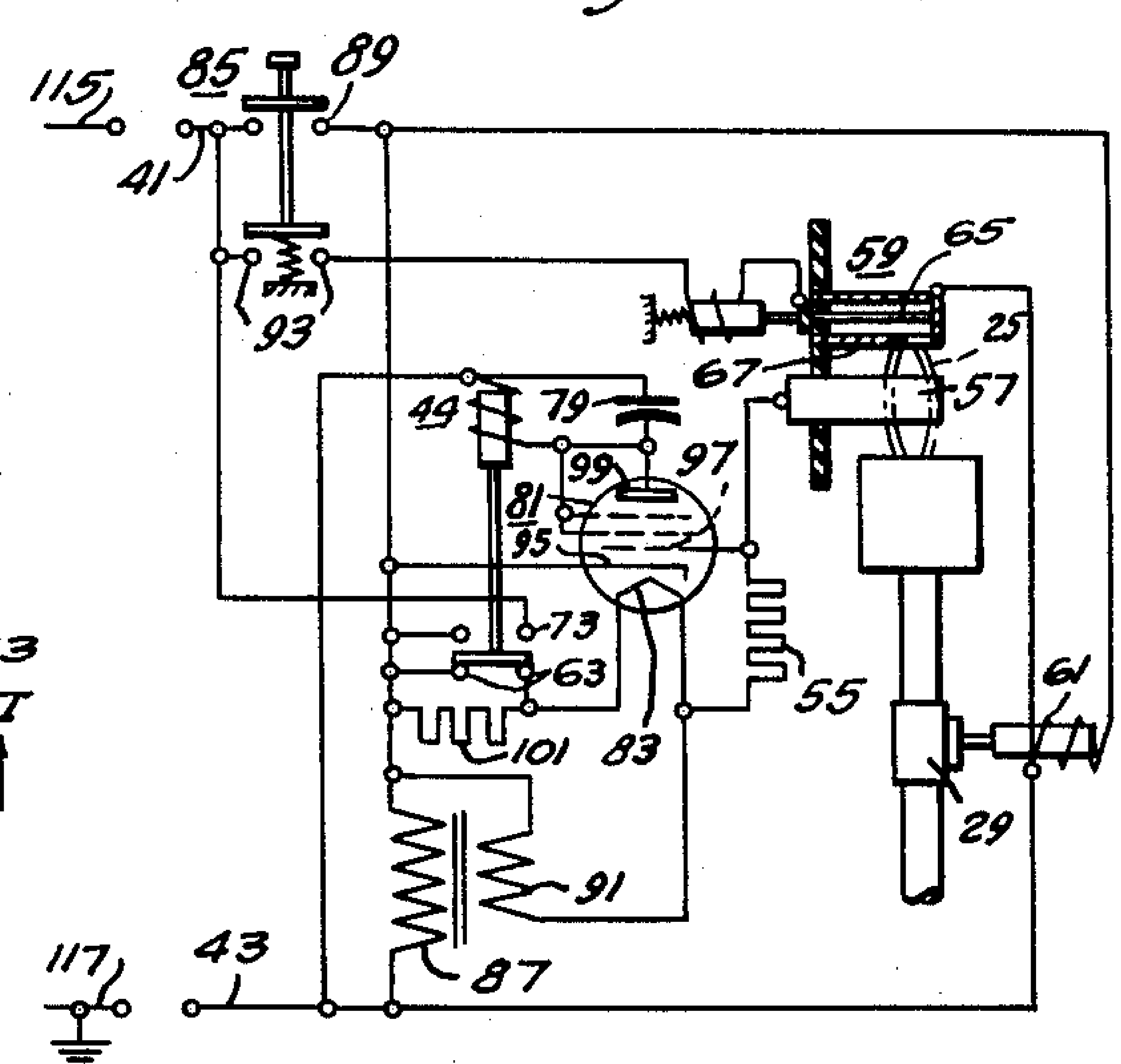


Fig. 2.

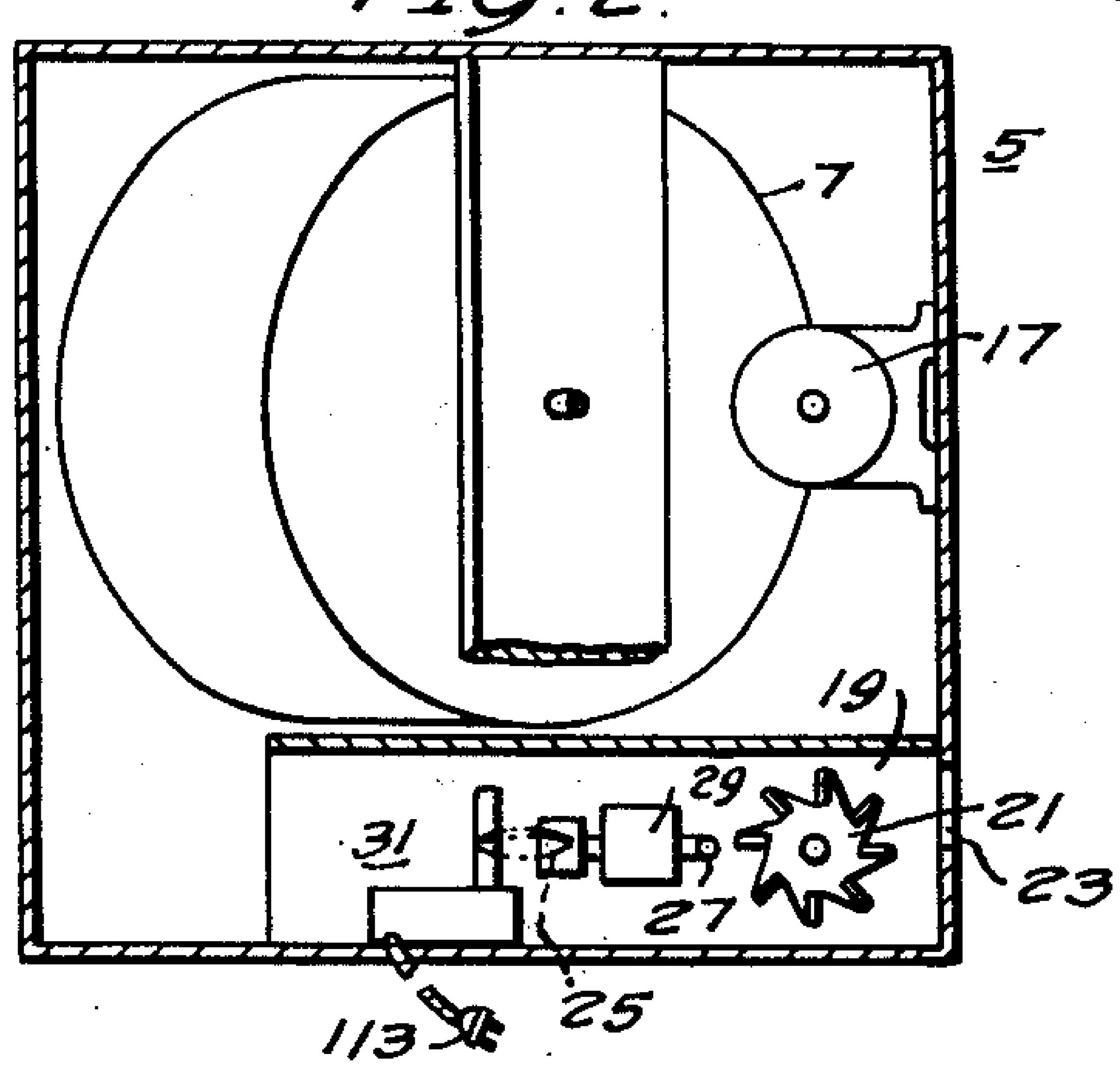


Fig. 5.

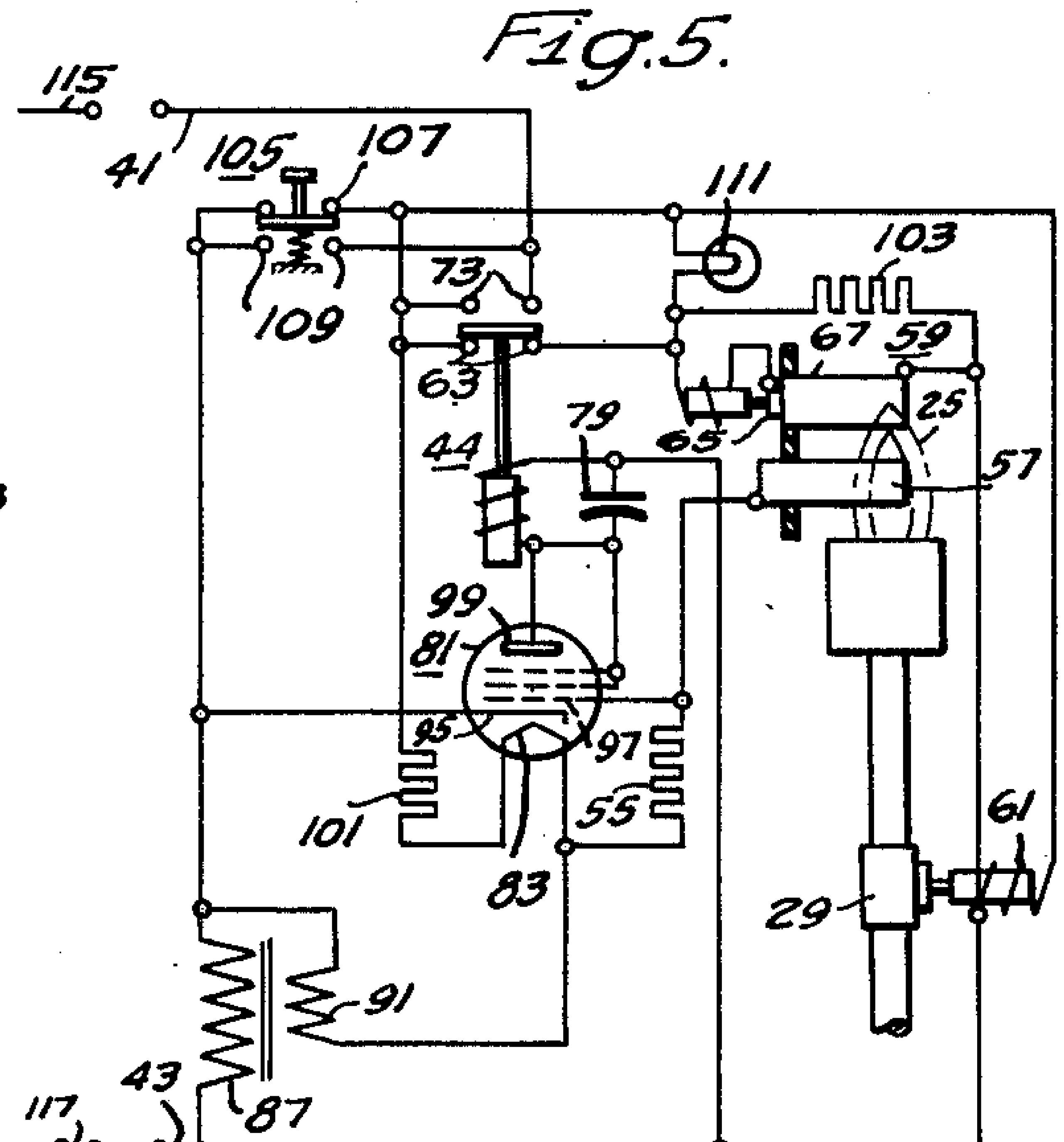
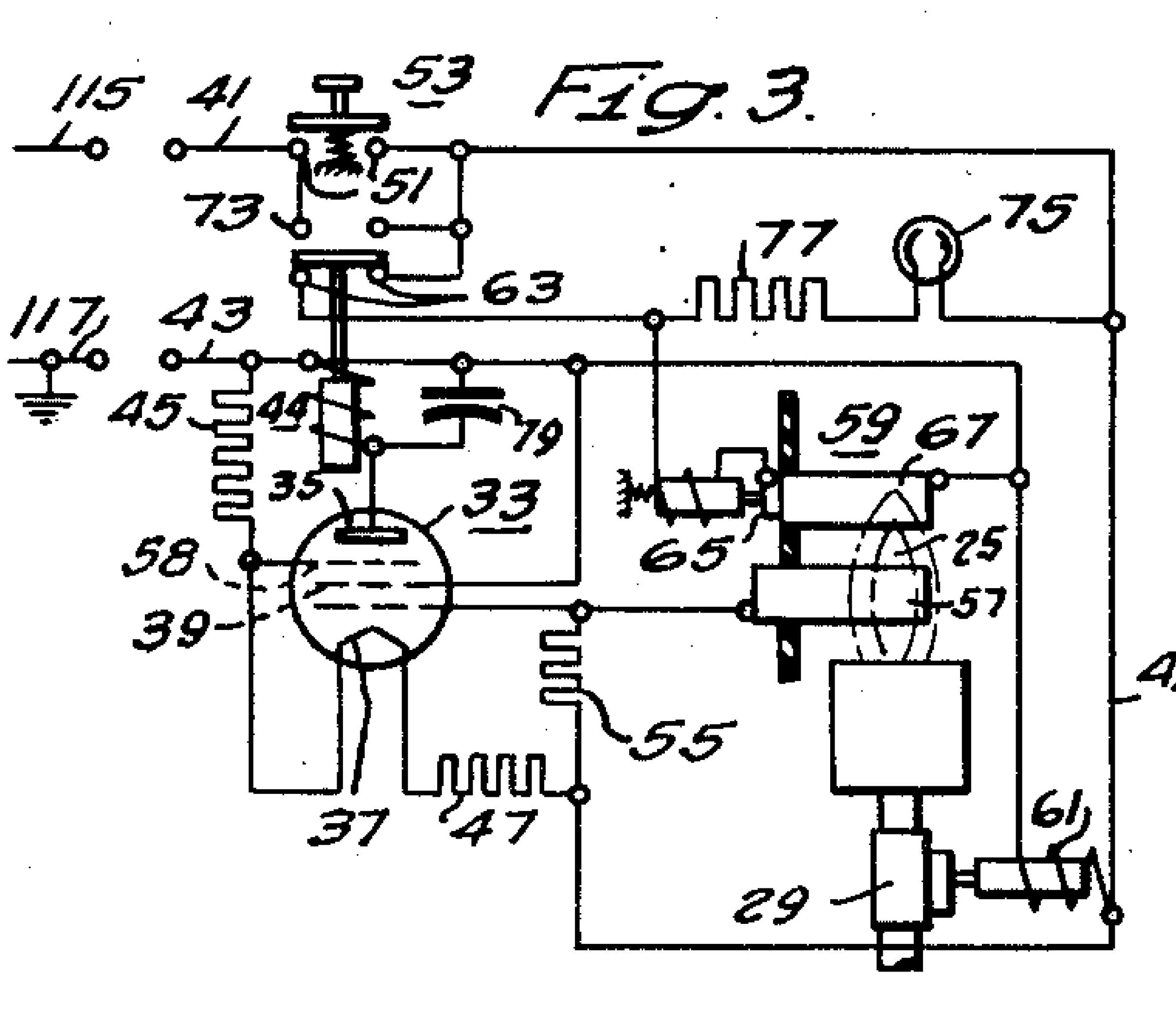


Fig. 3.



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Patented Jan. 23, 1951 **2,539,208**

UNITED STATES PATENT OFFICE

2,539,208

FLAME CONTROL DEVICE

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Application April 1, 1948, Serial No. 18,336

14 Claims. (Cl. 315—107)

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Our invention relates to electric discharge apparatus and it has particular relation to flame-responsive discharge apparatus.

A flame control system constructed and operated in accordance with the prior art of which we are aware is disclosed in an application, Serial No. 792,743, filed December 19, 1947, to George W. Nagel, and assigned to Westinghouse Electric Corporation. This system includes an electric discharge device of the cold-cathode ignition-electrode type which is connected to control the supply of fuel to a burner. The firing electrode of this device is connected to a flame probe which may be connected to the anode terminal of the power supply through the ionized path of a flame. The firing electrode is also connected to the cathode of the device through a high impedance. The device becomes conductive when there is a flame in the burner.

To render the discharge device conductive, a substantial potential of the order of 50 volts must be impressed between its firing electrode and its cathode. This potential is derived from the power supply which ordinarily has a magnitude of the order of 115 volts. The impedance between the firing electrode and the cathode of the discharge device must, therefore, be equal to the flame impedance. The latter is of the order of 20 megohms. If an impedance of this order is to be maintained between the firing electrode and the cathode of the discharge device, the electrode terminals of the discharge device must be properly insulated. The cost of such a discharge device is, therefore, relatively high—exceeding $1.00. The circuit components associated with the discharge device and its socket must also be designed to maintain the 20 megohm impedance. Provisions must also be included to preclude dust deposited on the components or the socket from reducing this impedance. In apparatus such as a clothes dryer to be used in the kitchen of a home in an industrial city like Pittsburgh, these requirements may constitute important cost factors.

It is accordingly an object of our invention to provide a flame control system including an electric discharge device in which the impedance between the control electrode and one of the main electrodes of the discharge device shall be relatively small.

Another object of our invention is to provide a flame control system which shall be substantially less costly than the system including an electric discharge device of the cold-cathode ignition-electrode type, such as disclosed in the above-entitled Nagel application.

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A further object of our invention is to provide a flame control system including an electric discharge device in which the impedance across which the potential is impressed for rendering the discharge device conductive shall be so small as not to require elaborate precautions for insulation.

An ancillary object of our invention is to provide a transformerless flame control system including an electric discharge device of the hot-cathode type.

Another ancillary object of our invention is to provide a flame control system including an electric discharge device wherein the impedance between the control electrode and the cathode of the electric discharge device shall be small compared to the flame impedance.

A further ancillary object of our invention is to provide a circuit including an electric discharge device of the hot-cathode type but not including a heating transformer for the cathode.

Our invention arises from the realization that a grid-controlled hot-cathode tube of the high-vacuum type produces a relatively large variation in anode current in response to a relatively small variation in grid potential. We have found that in such a tube, a swing of approximately 10 to 20 volts in the cathode potential produces a variation of 15 to 25 milliamperes in the plate current. A swing of 20 volts in potential can be produced across a resistor of the order of 5 megohms connected in series with a 20 megohm resistor between the terminals of a 110 volt power supply. Accordingly, in a flame control system including a high-vacuum hot-cathode tube, the grid resistor may be of the order of 5 megohms. In the preferred practice of our invention, we accordingly provide a flame control system including a discharge device of the hot-cathode type.

Our flame control system is particularly designed for use in a clothes dryer. In a dryer it is essential that the discharge device be capable of conducting plate current immediately after the starting switch of the dryer is closed by the operator. We have found that a hot-cathode tube with a directly-heated cathode such as a 3A4, for example, operates satisfactorily in such a drying system. The cathode of such a tube reaches a temperature at which it is properly emissive only one or two seconds after power is applied to it. Accordingly, an important specific feature of our invention is the inclusion in a flame control system of a directly-heated hot-cathode discharge device.

Flame control systems, whether for dryers or for control heaters for homes are ordinarily supplied from a commercial 110 volt source. Since the cathode of a hot-cathode tube operates at a potential substantially lower than that of the supply, the inclusion of a hot-cathode discharge device in a flame control system raises a problem as to cathode heating supply. A cathode transformer should be avoided if practicable because it constitutes an undesirable item of cost. In accordance with another specific aspect of our invention, the cathode of the discharge device in our system is energized from the anode supply, through a drop resistor which absorbs the excessive voltage.

In accordance with a further aspect of our invention, we provide a system including a hot-cathode discharge device of the indirectly-heated type. The time required for heating the cathode of this discharge device in the use of this system is shortened by initially impressing on the cathode a substantially higher potential than its rated potential. This potential is impressed by operation of the initiating push button and the potential is reduced to the rated magnitude by actuation of the relay which is controlled from the discharge device.

Another feature of our invention can be conveniently explained by reference to Yates Patent 2,295,885. In the system shown in Fig. 1 of this patent the power line L_1 is grounded at G' and the gas line to the burner is grounded at G. The grounded gas line constitutes one flame probe and the rod E the other. Yates does not indicate the character of his line L_1. If it is a line of a commercial power supply, such as is used in energizing dryers and domestic burners, the ground G' is provided by the power company and cannot be charged by the operator of a dryer or burner. The operator of a dryer or burner including a flame control system such as Yates', determines the polarity of the electrodes of the discharge device on inserting the power plug. If it is inserted properly the anode is connected to the ground as shown by Yates; if it is inserted improperly the cathode is connected to ground. In the latter circumstance the device T will not become conductive when the flame is ignited since its only affect is to connect the starting anode to ground—that is to impress the same potential on the starting anode and cathode. The provision of asymmetric plugs is not practicable because such plugs would require asymmetric receptacles unavailable in many homes.

In accordance with our invention we provide a system including a pair of flame probes neither of which is grounded—that is neither is at the potential of either of the power company supply lines. The magnitudes and polarities of the potentials of both probes is properly related to the magnitudes and polarities of the potentials impressed on the electrodes of the discharge device regardless of the manner in which the plug of the system is inserted in the power receptacle.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will be understood from the following description of specific embodiments read in connection with the accompanying drawing, in which:

Figure 1 is a view in vertical section showing a clothes dryer including a fuel burner control system in accordance with our invention;

Fig. 2 is a view in section taken along lines II—II of Fig. 1;

Fig. 3 is a circuit diagram of a fuel burner control system in accordance with our invention;

Fig. 4 is a circuit diagram of a modification of our invention; and

Fig. 5 is a circuit diagram of another modification of our invention.

The apparatus shown in Figs. 1 and 2 comprises a container 5 in which a clothes tank 7 is mounted rotatable. The tank 7 is mounted at an angle to the vertical walls of the container and is provided with a neck 9 which extends through an opening 11 in a slanting portion of the top of the container. This opening is covered by a door 15 which may be pivoted to the open position. Clothes may be inserted in the tan 7 after opening the door.

The tank is rotated from an electric motor 17 and as it is rotated, warm air flows over a portion of its surface and in dryers of some designs circulates within the tank 7. This air is derived from a flue 19 in the lower region of the container 5. Near one end of the flue, a fan 21 driven from the motor 17 rotates. The fan draws air from an opening 23 in one side of the flue and passes the air around a gas flame 25. The gas for the flame is derived from a conductor 27 provided with a suitable valve 29. The operation of the valve is controlled from a flame control unit 31.

A circuit diagram of our preferred flame control system is shown in Fig. 3. This system comprises an electric discharge device 33 of the directly-heated hot-cathode type. The discharge device includes an anode 35, a filament 37, and a control grid 39. It may be a triode or a pentode, such as a 3A4.

The discharge device 33 is energized from the line conductors 41 and 43 of a supply which may be of the usual commercial 110 volt, 60-cycle type. Its anode 35 is connected to line conductor 43 through the exciting coil of a relay 44. The filament 37 of the discharge device is connected at one terminal to the line conductor 43 through a potential drop resistor 45; at the other terminal it is connected through a resistor 47, a conductor 49 to one of the normally open contacts 51 of a push button 53. The other of the normally open contacts is connected to line conductor 41. The grid 39 of the discharge device is connected to the junction of the bias resistor and the conductor 49 through a grid resistor 55. The heating current which flows through the filament 37 produces a drop across the bias resistor 47 which is impressed between the grid and the filament through the grid resistor 55 and functions as a bias normally maintaining the discharge device 33 non-conductive.

The control grid 39 is also connected to a flame probe 57. As in the system disclosed in the above-mentioned copending application to Nagel, an ignition assembly 59 functions as a second flame probe.

In accordance with the preferred practice of our invention, the screen grid 58 of the discharge device, if a discharge device having a screen grid is utilized, should be connected to the line conductor 43 to which the anode 35 is connected through the exciting coil of the relay 44 rather than directly to the anode. This connection improves the stability of the operation of the system.

To initiate the operation of the system, the push button 53 is actuated, closing the above-traced circuit through the filament 37 of the discharge device 33. The filament, in a short time interval, rises to a proper temperature for emission. The actuation of the push button 53 also closes an energizing circuit through the solenoid 61 of the gas valve 29. The latter circuit extends from the upper line conductor 41 through the now closed contacts 51, the conductor 49, the solenoid 61 to the lower line conductor 43. The gas valve 29 accordingly opens and gas is supplied to the burner 63. The actuation of the push button also closes the ignition circuit for the burner. This circuit extends from line conductor 41, through now closed contacts 51, normally closed contacts 63 of the relay 44, the exciting coil of the ignitor 59, the vibratory rod 65 and cooperative shell 67 of the ignitor to the lower line conductor 43. The ignitor 29 operates in the same manner as a doorbell—its vibratory rod 65 repeatedly breaking the ignitor circuit at the junction between this rod and the shell 67 and producing an arc at the breach. The arc fires the gas. While the ignitor 29 is operating, it produces a soft buzz which assures the operator that the system is in proper operation.

Once the flame 25 is ignited, the impedance between the ignitor shell 67 and the flame probe 57 connected to the grid 39 decreases to a magnitude of the order of 20 or 30 megohms. A small current flows from line conductor 43 through the flame 25, grid resistor 55, conductor 49, contacts 51 to line conductor 41. A potential drop of the order of several volts appears across the grid resistor 55. The latter potential is of a polarity such that it counteracts the bias potential supplied through the bias resistor 47 and the discharge device becomes conductive. The relay 44 is actuated and its normally-closed contacts 63 are opened and normally open contacts 73 close establishing a shunt across the contacts 51 of the push button 53.

The valve solenoid 61 now remains energized through the now-closed contacts 73 of the relay. Since the normally closed contacts 63 are now open, the operation of the ignitor is interrupted and its buzzing sound stops. The opening of contacts 63 also opens a shunt across an indicator circuit extending from the line conductor 41 through now closed contacts 73 of the relay, indicator glow tube 75, a resistor 77, the exciting coil, rod 65 and shell 67 of ignitor 59 to lower line conductor 43. The tube 75 is ignited indicating that the system is in proper operation. Because the tube 75 and resistor 77 are now in circuit with the ignitor coil, the current flow through the coil is too small to actuate it.

On no longer hearing the buzz and on seeing the light 75, the operator knows that the flame is ignited and the system is otherwise in proper operation. She knows that she may now release the push button 53.

The system now remains in operation so long as the flame continues to burn. Should the flame 25 be accidentally blown out, the discharge device 33 becomes non-conductive, the relay 44 drops out and the gas valve 29 immediately closes. Fluctuations in the flame impedance of short duration do not interrupt the operation of the system. The effect of such fluctuations is suppressed by the condenser 79 connected in parallel with the exciting coil of the relay 44.

A system as shown in Fig. 3 has the advantage that the failure of its major components causes the gas valve to close—that is, the system fails safe. If the filament 37 of the discharge device should open, the flow of heating current to the filament would be discontinued, the flow of plate current through the discharge device 33 would be interrupted and the relay 44 would drop out closing the solenoid valve 29 and shutting off the gas. The solenoid valve 29 also is closed if the relay coil is short circuited or burned out or if the relay circuit is opened at any point. Should one of the flame probes 57—67 contact the other, the control grid 39 would be raised to a potential exceeding anode potential and would deprive the anode circuit of its normal current. Under such circumstances the relay 44 may at once drop out causing the gas valve 29 to close. If it fails to drop out tube 33 burns out within a few seconds dropping out relay 44 and closing valve 29.

In a preferred system in accordance with our invention which we have constructed and found to operate satisfactorily, the following components are included:

Power supply—commercial 110 volt, 60-cycle type
Electric discharge device 33—3A4 tube
Relay 44—standard type having a 5000 ohm impedance
Condenser 79—4 microfarads
Voltage drop resistor 45—1100 ohm, 20 watt
Bias resistor 47—180 ohms, 5 watts
Grid resistor 55—4.7 megohms.

The system shown in Fig. 4 is to a large extent similar to the system shown in Fig. 3. It includes an electric discharge device 81 of the indirectly-heated hot-cathode type in lieu of the discharge device 33. In the preferred practice of our invention, this device 81 is of the 6AQ5 type. To decrease the time interval required to raise the heater 83 of this device to a proper temperature for emission, the heating potential supplied to the heater initially is higher than the rated potential. When the starting push button 85 of the system, shown in Fig. 4, is closed, it closes a supply circuit across the primary 87 of a heating transformer through its upper normally-open contacts 89. Heating current is now supplied from the secondary 91 of the transformer through the normally-closed contacts 63 of the relay 44. The transformer 89—91 is so designed that the potential supplied to the heater 83 during this initial phase of the operation of the system exceeds the rated heater potential. Through the upper now-closed contacts 89 of the push button 85, a circuit is also closed through the valve solenoid 61. Through normally-open lower contacts 93 of the push button, a second circuit is closed through the exciting coil of the ignitor 59.

As in the system shown in Fig. 3, the discharge device (81) is maintained non-conductive. In the Fig. 4 system, the bias is supplied not through a bias resistor but through the secondary 91 of the heater transformer which is connected between the cathode 95 and the control grid 97 through the grid resistor 55. To accomplish this objective, the secondary 91 must be so wound that its terminal which is connected to the cathode is positive when the line conductor 41, which is connected to the anode 99 of the device, is positive.

Because the heater 83 is initially supplied with a potential substantially exceeding the rated potential, it is raised to a properly emissive temperature within a short time interval of the order of five seconds after the push button 85 is closed. During this time interval, a flame 25 is ignited. The resistance between the flame probes 57 and 65 is reduced substantially and a potential is impressed across the grid resistor 55 counteracting the bias. The discharge device becomes conductive and the relay 44 is energized. The solenoid 61 and the primary 87 are now maintained energized through the now-closed contacts 73 of the relay 44 which shunts the contacts 89 of the push button. The push button may now be released and when it is released the ignition circuit is broken. When the relay 44 is energized, its lower normally-closed contacts 63 are opened, opening a shunt across a drop resistor 101 in series with the heater 83. The potential across the heater is now reduced to the proper magnitude for long operating life.

The system shown in Fig. 4 now continues to operate in the same manner as the system shown in Fig. 3. As in the system shown in Fig. 3, the grid resistor 55 may be of the order of 5 megohms and for this reason the electrode terminals of the discharge device and the components of the circuit need not be insulated for high impedance. As is the system shown in Fig. 3, the system shown in Fig. 4 fails safe.

The system shown in Fig. 5 also includes an electric discharge device 81 having an indirectly heated hot cathode 95. In this system the cathode heater 83 of the discharge device is supplied during steady state operation from the secondary 91 of the heater transformer 87—91. When the operation of the system is being initiated, the heater is supplied from the main line conductors 41 and 43 through a parallel network having as one branch the ignitor coil, rod 65 and shell 67; as a second branch the solenoid 61 and if necessary as a third branch a resistor 103. These components function to absorb a portion of the line voltage but the net voltage impressed on the heater 83 is substantially greater than the rated heater potential.

When the initiating push button 105 is actuated, its upper normally-closed contacts 107 are opened and its lower normally-open contacts 109 closed. A circuit is now closed which extends from the upper line conductor 41 through the now-closed contacts 109 of the push button, the secondary 91 of the heater transformer, the heater 83, a resistor 101, the normally-closed contacts 63 of the relay 44, the parallel network consisting of the ignitor coil, the ignitor rod 65 and shell 67, the valve solenoid 61, and the resistor 103, if one is necessary, to the lower line conductor 43. Potential higher than the rated potential is now supplied to the heater 83 and the latter is raised to the proper emissive temperature in a short time interval. The ignitor 59 is, at the same time, energized and produces ignition sparks while emitting a buzzing sound. The gas valve solenoid 61 is also energized opening the valve 29 and permitting gas to flow into the burner. The gas is ignited producing a flame 25. The decreased impedance introduced between the flame probes 57 and 67 by the flame counteracts the bias potential impressed in the grid circuit of the discharge device 81 and the device to become conductive. The relay 44 is now energized opening its normally-closed contacts 63 and closing its normally-open upper contacts 73.

At the now-open contacts 63, the ignitor circuit is broken. The buzzing sound stops.

The gas valve solenoid is now maintained energized in a circuit extending from the upper line conductor 41 through the now-closed contacts 73 of the relay 44, the solenoid 61 to the lower line conductor 43. The overvoltage heater circuit is broken at the now-open contacts 63 of the relay 44. The system is now in complete operation.

When the normally-closed contacts 63 of the relay 44 are opened, a shunt across a pilot lamp 111 is opened and the pilot lamp is energized in a circuit extending from the line conductor 41 through the now-closed contacts 73 of the relay 44, the pilot lamp 111, the exciting coil, rod 65 and shell 67 of the ignitor 59 to the line conductor 43.

When the operator notes that the buzz has ceased and the indicator light is on she knows that the system is in operation and releases the push button 105. The primary 87 of the heater transformer is now supplied with the potential in a circuit extending from the line conductor 41, through the now-closed contacts 73 of relay 44, the normally-closed contacts 107 of push button 105, the primary to the line conductor 43. The heater 83 is now supplied at the rated voltage from the secondary 91 through resistor 101.

The system shown in Fig. 5 fails safe in the same manner as the system shown in Fig. 3. If the heater 83 is burned out, the heater circuit opened, the anode circuit opened, or the relay 44 burned out or its circuit opened, the discharge device 81 becomes non-conductive and the valve 29 closes. If the flame probes become short circuited, substantial current, flows between the grid 97 and the cathode 95 of the discharge device 81. Under such circumstances the anode current may be reduced to a small magnitude such that the relay 44 at once becomes deenergized and the gas valve 29 closes. If this event does not occur then the tube 81 burns out within a few seconds and relay 44 then drops out closing valve 29.

The operation of the modifications of our system is entirely independent of the manner in which the power plug 113 of our system is inserted in the supply receptacles. In explaining this feature of our system we shall assume that the line conductors 41 and 43 are connected through the plug 113 to power company buses 115 and 117 and that bus 117 is grounded.

Consider the system shown in Fig. 3 and assume that the plug is inserted so that line 43 is connected to bus 115 and line 41 to bus 117. At any instant when there is no flame in the burner and bus 115 is positive relative to bus 117, the grid 39 and probe 57 are at ground potential, the cathode 37 at a positive potential relative to ground and the probe 65 at the positive potential of line 115. If a flame 25 is ignited positive current flows from line 115 to ground through the flame and grid resistor 55 producing a positive drop across the resistor to counteract the bias. Now assume that line 43 is connected to bus 117 and line 41 to bus 115 and consider the system when there is no flame in the burner and line 115 is negative relative to line 117. The grid 39 and probe 57 are now at the negative potential of the line 115, the cathode 37 is at a positive potential equal to the bias and the probe 67 is at positive ground potential. When a flame is now ignited positive current flows from line 117 to line 115 through the flame and grid resistor and the bias is again counteracted.

The systems shown in Figs. 4 and 5 also operate in the manner described above.

While we have shown and described certain specific embodiments of our invention, we are fully aware that many modifications thereof are practicable. Our invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. In combination a control circuit including a current-responsive mechanism and an electric discharge device, having a hot cathode, for controlling the flow of current through said mechanism; a first circuit for supplying heating current exceeding the heating current rating of said device to said cathode; a second circuit for supplying heating current of a magnitude substantially equal to the heating current rating of said device; a manually-actuable switch of the type that remains closed only so long as it is manually actuated for closing said first circuit and a switch actuable by said mechanism for opening said first circuit and closing said second circuit and for maintaining said first circuit open and said second circuit closed on release of said manually-actuable switch.

2. In combination, a control circuit including a relay and an electric discharge device, having a hot cathode, for controlling the flow of current through said relay; a first circuit for supplying heating current exceeding the heating current rating of said device to said cathode; a second circuit for supplying heating current of a magnitude substantially equal to the heating current rating of said device; a pushbutton of the type that remains closed only so long as it is actuated for closing said first circuit and a switch actuable by said relay for opening said first circuit and closing said second circuit and maintaining said first circuit open and said second circuit closed on release of said pushbutton.

3. In combination, an electric discharge device having a cathode, a circuit for heating said cathode, a manually-actuable switch for closing said circuit and another switch responsive to the conductivity of said device for shunting out said manually-actuable switch.

4. In combination an electric discharge device having an anode and a cathode, terminals adapted to be connected to a commercial supply of 115 volts nominal rating, connections between said anode, said cathode and said terminals, a circuit for heating said cathode including in series said terminals, a voltage-drop impedance and said cathode, a manually-actuable switch for closing said circuit and another switch responsive to the conductivity of said device for shunting out said manually-actuable switch.

5. In combination an electric discharge device having an anode and a cathode of the directly-heated type, terminals adapted to be connected to a power supply having a potential output of a magnitude exceeding heating potential rating of said cathode, connections between said anode, said cathode and said terminals, a circuit for heating said cathode including in series said terminals, a voltage drop impedance and said cathode, a manually-actuable switch for closing said circuit and another switch responsive to the conductivity of said device for shunting out said manually-actuable switch.

6. In combination, a control circuit including a current-responsive mechanism and an electric discharge device, having a hot cathode for controlling the flow of current through said mechanism; a manually-actuable switch of the type that remains closed only so long as it is manually actuated, having normally-closed and normally-open contacts; a first circuit, including said normally-open contacts, for supplying heating current, exceeding the heating-current rating of said device, to said cathode; a second circuit, including said normally-closed contacts, for supplying heating current to said cathode substantially equal to the heating-current rating of said device; and a switch actuable by the manual actuation of said manually-actuable switch for opening said first circuit, and on release of said manually-actuable switch, closing said second circuit.

7. In combination, a control circuit including a current-responsive mechanism and an electric discharge device, having a hot cathode for controlling the flow of current through said mechanism, an electrically-actuable component for initiating flow of current through said mechanism; a manually-actuable switch of the type that remains closed only so long as it is manually actuated, having a first set of normally-open contacts and a second set of normally-open contacts; a first circuit adapted to be closed by said first set of normally-open contacts, for supplying heating current, exceeding the heating-current rating of said device, to said cathode; a second circuit for supplying heating current to said cathode substantially equal to the heating-current rating of said device; a third circuit including said second set of normally-open contacts for supplying current to said component; and a switch actuable by the manual actuation of said manually-actuable switch for opening said first circuit and closing said second circuit and for maintaining said first circuit open and said second circuit closed on release of said manually-actuable switch.

8. In combination, a control circuit including a current-responsive mechanism and an electric discharge device, having a hot cathode for controlling the flow of current through said mechanism; a manually-actuable switch of the type that remains closed only so long as it is manually actuated, having normally-closed and normally-open contacts; a first circuit, including said normally-open contacts, for supplying heating current, exceeding the heating-current rating of said device, to said cathode; a second circuit, including said normally-closed contacts, for supplying heating current to said cathode substantially equal to the heating-current rating of said device; a third circuit including said normally-open contacts for supplying heating current to said cathode substantially equal to the heating current rating of said device; and a switch actuable by the manual actuation of said manually-actuable switch for opening said first circuit and closing said third circuit so long as said manually-actuable switch remains manually actuated and, on release of said manually-actuable switch, opening said third circuit and closing said second circuit.

9. In combination, a control circuit including an electric discharge device, having a hot cathode, a manually-actuable switch of the type that remains closed only so long as it is manually actuated having normally-closed and normally-open contacts; a first circuit, including said normally-open contacts, for supplying heating current, exceeding the heating-current rating of said device, to said cathode; a second circuit, including said normally-closed contacts, for supplying heating current to said cathode substantially equal to the heating-current rating of said device; and a switch actuable by the manual actuation of said manually-actuable switch for opening said first circuit, and on release of said man-

ually-actuable switch, closing said second circuit.

10. In combination, an electric discharge device of the type having a hot cathode which becomes properly emissive only after it has been heated for a predetermined time interval by heating current of a magnitude equal to its current rating; a pair of terminals; a transformer having a primary and a secondary; a switch having normally-closed and normally-open contacts; a relay responsive to the conductivity of said device having a single movable armature adapted to close normally-closed and normally-open contacts; a first circuit including in series said normally-closed contacts of said switch, said secondary and said cathode; a second circuit including in series said terminals, said normally-open contacts of said switch, said cathode and said normally-closed contact of said relay; and a third circuit including in series said terminals, said normally-open contacts of said relay and said primary.

11. In combination, an electric discharge device of the type having a hot cathode which becomes properly emissive only after it has been heated for a predetermined time interval by heating current of a magnitude equal to its current rating; an electrically-actuable component for initiating a change in the conductivity of said device; a pair of terminals; a transformer having a primary and a secondary; a switch having normally-closed and normally-open contacts; a relay responsive to the conductivity of said device having a single movable armature adapted to close normally-closed and normally-open contacts; a first circuit including in series said normally-closed contacts of said switch, said secondary and said cathode; a second circuit including in series said terminals, said normally-open contacts of said switch, said cathode, said normally-closed contact of said relay and said component; and a third circuit including in series said terminals, said normally-open contacts of said relay and said primary.

12. In combination, an electric discharge device of the type having a hot cathode which becomes properly emissive only after it has been heated for a predetermined time interval by heating current of a magnitude equal to its current rating; a solenoid for initiating a change in the conductivity of said device; a pair of terminals; a transformer having a primary and a secondary; a switch having normally-closed and normally-open contacts; a relay responsive to the conductivity of said device having a single movable armature adapted to close normally-closed and normally-open contacts; a first circuit including in series said normally-closed contacts of said switch, said secondary and said cathode; a second circuit including in series said terminals, said normally-open contacts of said switch, said cathode, said normally-closed contact of said relay and said component; a third circuit including in series said terminals, said normally-open contacts of said relay and said primary; a fourth circuit including in series said terminals, said normally-open contacts of said switch, said cathode and said solenoid; and a fifth circuit including in series said terminals, said normally-open contacts of said relay and said solenoid.

13. In combination, a control circuit including a current-responsive mechanism and an electric discharge device, having a hot cathode, for controlling the flow of current through said mechanism; a transformer having a primary and a secondary for supplying heating current to said cathode; a first circuit in shunt with said primary and including said cathode for supplying heating current exceeding the heating current rating of said device to said cathode; a second circuit including said secondary for supplying heating current of a magnitude substantially equal to the heating current rating of said device; a manually-actuable switch for closing said first circuit and a switch actuable by said mechanism for closing said second circuit.

14. In combination, a control circuit, an electric discharge device having a cathode which becomes properly emissive only after it has been heated for a predetermined time interval by heating current of a magnitude equal to its heating current rating; terminals for connection to a potential supply; a heater transformer for said cathode having a primary adapted to be connected to said terminals and a secondary connected to said cathode; a manually-operable switch for connecting said terminals and said cathode in series and a switch actuable in response to the conductivity of said device for in effect disconnecting said terminals from said cathode and connecting said terminals to said primary.

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