June 17, 1947. F. B. MacLAREN, JR., ET AL 2,422,574

CONDUCTANCE-RESPONSIVE ELECTRON TUBE SYSTEM

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Fig. 1.

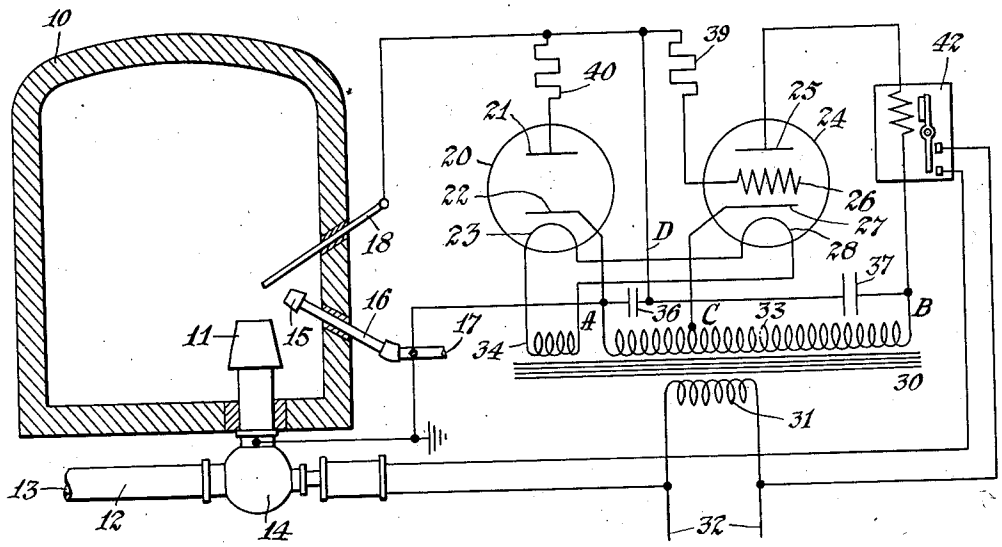


Fig. 2.

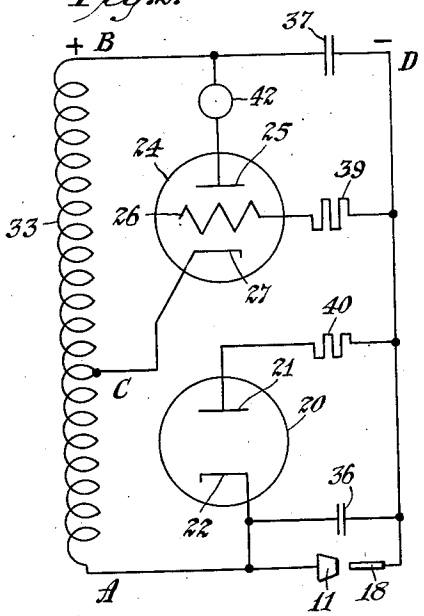
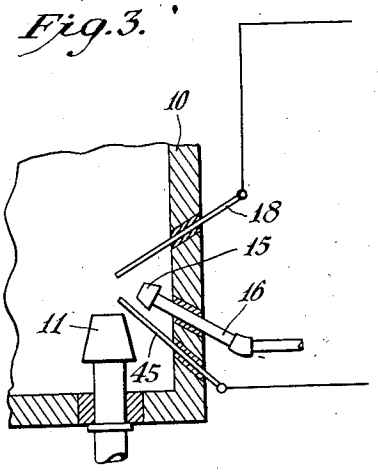


Fig. 3.



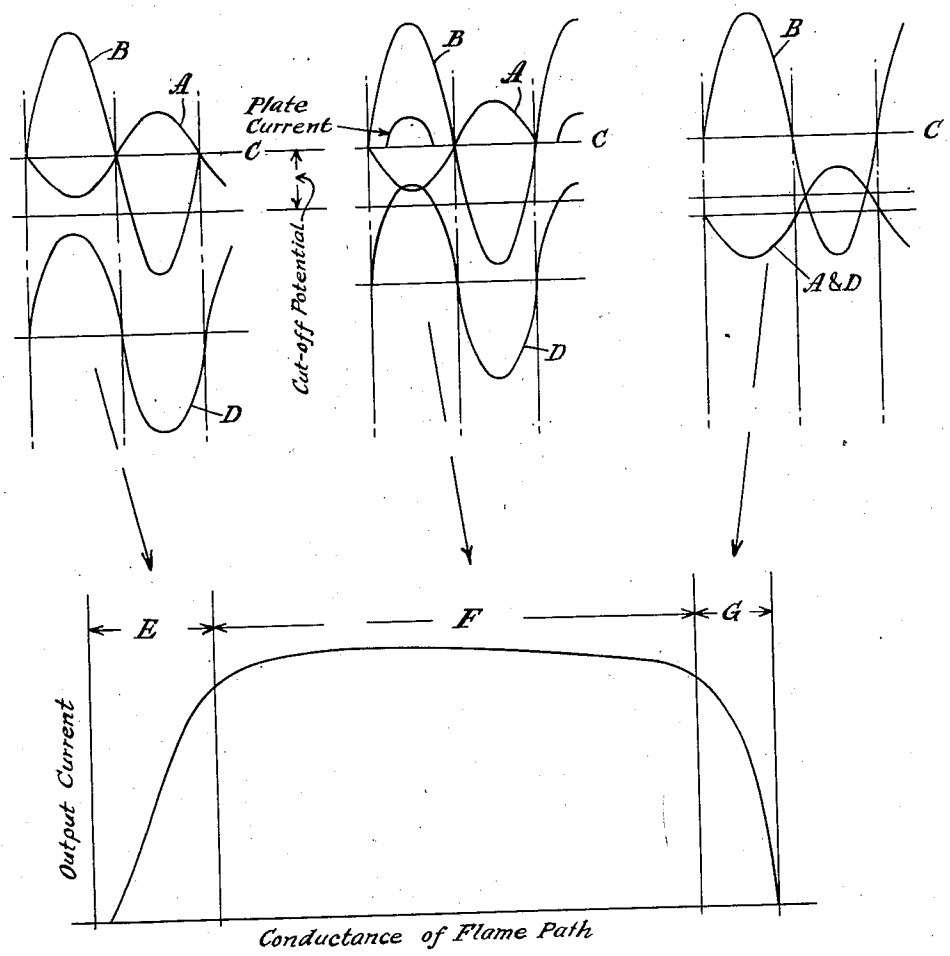
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Fig. 4.



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CONDUCTANCE-RESPONSIVE ELECTRON TUBE SYSTEM

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6 Claims. (Cl. 250—27)

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This invention relates to electrically operated control apparatus for industrial furnaces, more particularly to automatic means embodying a safety shut off, operative to discontinue the supply of fuel in case of extinguishment of the flame.

In industrial furnaces of the gas-, and oil-fired types, it is essential in the interests of safety that there be at no time an accumulation of unburned fuel which may become ignited at one time and cause an explosion. To this end, it is necessary that fuel be not admitted to the combustion chamber unless there be present an igniting agent whereby complete combustion will be assured, and that in the event of accidental extinguishment of the igniting agent, the supply of fuel will be immediately discontinued.

It is a well-known fact that ions in a flame, and the atmosphere immediately surrounding it, are capable of carrying electric charges; and this principle has been made use of in a number of devices for purposes similar to that of the present invention. A well-known example of the application of this principle is found in U. S. Letters Patent No. 1,809,280, issued June 9, 1931, to D. D. Knowles, and wherein a metallic electrode exposed to the flame or to the heated products of combustion in a furnace forms a part of a path for negative electrons, which path may be completed by said flame or said combustion products for the actuation of certain protective devices. It has been found, however, that in apparatus operating upon this principle there exist a number of inherent weaknesses among which may be named that due to the possibility of an alternative conducting path in parallel with the flame being provided by deposited soot or by actual metallic contact due to sagging or breakage of the electrode or its supports, the conductivity of said path tending to simulate the condition of combustion and inhibit the protective function of the device. It has also been found in certain devices of this class that induced conditions in the electrode circuit due to electrostatic or electromagnetic induction from external sources or to eddy currents in nearby conductors or to variation in the electrical characteristics of the electrode circuit have a tendency to interfere with effective and positive operation.

It is an object of this invention to provide means whereby in the event of temporary interruption to the fuel supply or of the extinguishment of the flame or igniting agent for any reason whatsoever, valves controlling the admission of fuel to the furnace will be closed, and may not be reopened until normal conditions are established.

A further object is found in the provision of

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means whereby there is prevented false operation of the device due to formation on the electrode of an accumulation of soot or other conducting material, or a mechanical short circuit, or any condition which might bridge the gap normally essential to proper operation of the device, and thus simulate a condition of combustion without actual combustion taking place.

A further object of the invention is to provide a control circuit of the above nature which shall not be subject to the effects of conditions induced from external magnetic or electrostatic fields in the vicinity of the flame electrode circuit.

It is a further object to provide a device of the above nature which shall not require any form of shielding between the electrode circuit and nearby conducting objects.

It is a further object to provide a device of the above nature which shall be capable of giving satisfactory operation over a wide range of capacitance values in the electrode circuit, such as might be induced by varying the lengths and characteristics of the electrode leads.

It is a further object to provide a device of the above nature which will revert to a safe condition in the event of failure of the line voltage supplying the apparatus, or of the components of the apparatus.

It is a still further object to provide a device of the above nature which shall be simple in its construction and stable in operation.

In carrying out the purposes of the invention it is proposed to utilize an electron tube system embodying a circuit which shall be responsive to the positive ionic conductivity of the flame, and which shall be operative through a range of conductivity values representing those which may be attained by the flame and surrounding ionized gases in combination, but will respond in a sense to avoid hazardous conditions should the conductance of that branch of the circuit which normally includes the flame exceed a predetermined maximum value or become less than a predetermined minimum value.

In the drawings:

Fig. 1 is a diagrammatic representation of a control system utilizing the principles of the invention.

Fig. 2 is a schematic diagram of the electron-tube circuit included in Fig. 1.

Fig. 3 is a representation of an electrode and burner arrangement alternative to that shown in Fig. 1.

Fig. 4 is a graphic representation of the typical relationship existing between certain current and conductivity magnitudes in the system.

Referring to the drawings: The numeral 10 designates a furnace or enclosed space to be

heated by the combustion of fuel at a burner 11 adapted to receive fluid fuel through a conduit 12 from a main supply 13. Inserted in the conduit 12 is an electrically operated valve 14 arranged to be opened when electrically energized and closed when de-energized. A pilot burner 15 receiving fluid fuel through a conduit 16 from an auxiliary supply 17 serves to ignite the fuel at the burner 11. The several objects of the invention hereinbefore referred to are directed to the avoidance of hazardous conditions in the event of the extinction of the pilot flame and the main flame, or of failure of the protective devices associated therewith or of the supply of electric power. Fixedly mounted in a position so as to lie in the path of the flames from both burners is a metallic electrode 18 electrically insulated from the burners and other surrounding structures.

The electrical circuit through which the protective device is rendered operative, and to which this invention is especially directed, is adapted to respond to the electrical conductivity of the path between the electrode and the burners as provided by the flames and the ionized gases surrounding it. This circuit is shown diagrammatically in Fig. 1 and schematically in Fig. 2. A rectifier tube 20 including an anode or plate 21, and a cathode 22 indirectly heated to the emission temperature by filament 23, serves to provide a normal negative bias for a grid-controlled vacuum tube 24, which in turn includes an anode or plate 25, a control grid 26, a cathode 27 and a filament 28 for heating said cathode. A transformer 30 includes a primary winding 31 adapted to receive alternating current from a source of commercial frequency 32, and a secondary winding 33 having terminals A and B and an intermediate tap C, the position of which with respect to the terminals A and B will hereinafter be set forth. While the filaments 23 and 28 may be energized from any convenient source or sources, a practical means of supplying power to them is found in the use of an auxiliary secondary winding 34 on the transformer 31, to which winding both filaments are connected in series. Between the terminals A and B of the windings 33 are connected in series two capacitors 36 and 37, forming an A.-C. voltage divider, the conductor between said capacitors being designated as D. The value of capacitor 37 is much greater than that of 36, so that the A.-C. potential of the conductor D with respect to the terminal A under operating conditions will be substantially that of the terminal B. The grid 26 of the tube 24 is connected to the conductor D through a current-limiting resistance 39, and the electrode 18 is directly connected to the conductor D. The plate 21 of the rectifier tube 20 is connected to the conductor D through a resistor 40. A relay 42, having an actuating winding, and electrical contacts adapted to the control of the valve 14, is connected with said winding in series with the circuit between the plate 25 and the terminal B of the winding 33, so that said relay will respond to changes in the plate current of the thermionic tube 24 in a sense that as the potential of grid 26 with respect to the cathode 27 becomes less negative than the cut-off potential, resulting in a corresponding increase in plate current, said relay will be energized and actuated by said current. The terminal A of the winding 33 is electrically connected to both the burners 11 and 15. The actuating winding of the valve 14 is connected to the source of power 32 (or, if expedient, to a separate source, not shown) in series with the contacts of the relay 42, so that upon closing of said contacts in response to energization of said relay the valve 14 will be opened to admit fuel to the burner 11.

The operation of the circuit as thus far described is represented graphically in Fig. 4, and is treated as being characterized by three more or less distinct conditions, represented by the zones E, F, and G, corresponding, respectively to "E," no flame present; "F," flame present with normal operation; and "G," grounded or short-circuited electrode. In the upper part of Fig. 4 are shown wave representations of the several magnitudes involved, and in the lower part a graph illustrating in a typical manner the variation of plate current as the conductance of the flame path varies through a wide range of values. While the transition from one condition to another is not necessarily abrupt, yet the three conditions may be discussed more or less independently as follows.

Condition "E," no flame present

During that part of the transformer secondary voltage cycle when the conductor D is positive with respect to the cathode 22, electrons will be attracted from said cathode to plate 21 until the maximum instantaneous positive potential of conductor D is neutralized. Since no return path is present for electrons accumulated on the conductor D, a negative potential will be built up across the capacitor 37, and of a value substantially equal to that established between the conductors D and A by virtue of the relative proportioning of the capacitors 36 and 37. This portion of the circuit is equivalent to a half-wave rectifier with a capacitor input filter, having a substantially infinite load resistance. The D.-C. potential of grid 26 with respect to point A is therefore substantially equal to the D.-C. potential across capacitor 37, or the maximum peak value of the A.-C. potential between points A and D. Conductor D, as will be apparent from an inspection of Fig. 2, may then be considered a negative bias. The A.-C. potential of grid 26 with respect to point A is equal to the potential difference between conductor D and point A, or nearly the potential between points A and B. It will therefore be seen that the grid 26 will be maintained negative with respect to cathode 27 by at least the peak value of the potential between points A and C. The tap C on winding 33 is so chosen that the peak value of the potential between points A and C is slightly greater than the cut-off bias for electron-tube 24 at a plate voltage equal to the peak value of the potential between C and B. Under this condition no current will flow in the plate circuit of the tube 24, with the result that the relay 42 will remain de-energized and the valve 14 closed, so that no gas can be admitted to the main burner 11.

Condition "F," flame present

When flame is present between either of the burners and the electrode 18, said flame will constitute a conducting path, due to positive ions between conductors D and A, allowing the charge on capacitor 37 to flow off, and so tending to decrease the D. C. potential existing between the conductor D and the winding 33. There will be no potential drop across resistor 40 as long as no current is flowing through said resistor as is the case as long as the charge on capacitor 37 remains unchanged. A conducting path between

conductors D and A as a result of the presence of a flame between electrode 18 and ground will provide a partial short-circuit across rectifier 20 and resistor 40 in series. The voltage drop across resistor 40 will then cause a reduction in the rectified voltage, thus lessening the D.-C. potential across capacitor 37. This will substantially reduce the bias on the tube 24, with the result that the A.-C. potential between the cathode 27 and the grid 26 will periodically become less than the cut-off value, and plate current will flow through the winding of the relay 42. The operation of the tube is thus brought into the zone designated as F in Fig. 4; and as, with increased conductivity in the flame-path, the grid becomes less negative with respect to the cathode 27, the plate current in the relay 42 will attain sufficient magnitude to actuate said relay, closing its contacts, and energizing the valve 14, whereby fuel may be admitted to the burner 11. So long as combustion continues on either or both of the burners 11 and 15, this condition will be maintained, and the valve 14 will remain open to permit the admission of fuel. By proper proportioning of the circuit constants, the plate current can be kept substantially constant over the region correspoding to ordinary values of flame resistance, and uniform operation of the circuit may be expected. Should both flames be extinguished, the circuit will immediately revert to condition E, the relay 42 will become de-energized, the valve 14 will be closed, and the fuel supply to the burner 11 discontinued. A similar condition will develop in the event of any electrical failure which will cause the actuating current in the relay 42 to be materially reduced in value.

Condition "G," grounded electrode

In the event of a partial or complete ground of the electrode 18 or short circuit between the electrode and either of the burners or associated metal parts, the resistance between conductors A and D will be materially reduced and conductance between them correspondingly increased until they approach a common potential, substantially the whole voltage of the winding 33 being applied across the capacitor 37. Under this condition it will be seen that during the part of the cycle when the plate 25 attains a positive potential with respect to the cathode 27, which is the only time when the tube could become conductive, the grid 26, being substantially at the potential of the conductor A, will be negative with respect to the cathode 27, by a value exceeding the cut-off bias, thus effectually blocking the flow of current through the tube. This corresponds to the zone G in Fig. 4; and as this condition is approached the output current of the tube 24 is reduced to such a value that the relay 42 becomes de-energized, the valve 14 closed, and the supply of fuel discontinued. Obviously, these conditions will affect the plate current of electron-tube 24 as the conductance of the flame path approaches condition G, and will tend to counteract the increase in plate current due to the factors set forth under condition "F."

There has thus been provided a combination in which for extremely high or extremely low values of conductance (or resistance) in the path between the electrode and the burners the fuel supply will be shut off; while for a selected range of intermediate values the fuel supply may be maintained. By proper selection of circuit characteristics the device may be caused to maintain the fuel supply while the resistance of the flame path lies within a range approximating from 1 to 150 megohms; and these may be taken as typical operating values.

As hereinbefore stated, the capacitor 36 is made of a very low value relative to the capacitor 37; and in some cases it is found that the inherent capacitance of the circuit is sufficient, so that the physical embodiment of the capacitor 36 may sometimes be omitted. On the other hand, abnormal lengths of electrode leads will tend to increase the effective value of capacitor 36, thereby reducing the A.-C. potential between points D and A, at the same time reducing the D.-C. potential between said points by the same amount, leaving the minimum bias of control grid 26 unchanged. As a practical example it may be stated that this circuit has been effectively operated with a value of 0.01 microfarad for the capacitor 36, which value corresponds to approximately 150 feet of standard connecting lead. Longer leads may be used with low capacitance cable.

In the event of electrical potentials being induced between the electrode lead and ground, these will increase the A.-C. potential of conductor D above the terminal A, thereby increasing the D.-C. potential across capacitor 37 and the peak A.-C. potential between points D and A by the same amount, leaving the potential between grid 26 and cathode 27 unchanged. Obviously, then, induced voltages in the electrode circuit will then not seriously affect the operation of the system.

While the invention has been shown as embracing both the main burner and the pilot burner in the electrical circuit, so that extinguishment of both flames is essential to cause the safety device to perform its function, it will be obvious that should circumstances render the same desirable, either burner alone may be connected in the electrical circuit without departing from the spirit of the invention. It will also be obvious that the protective device as herein disclosed and claimed is fully applicable to a furnace in which there is only one burner, and in which the pilot flame for ignition is not present.

While for purposes of simplicity the vacuum tube 24 has been shown as of the three-electrode type, it may, without departing from the spirit of the invention, be effectively replaced by a tetrode or a pentode (with corresponding modifications in associated circuits) thus offering the advantage of a more constant value of plate current over the normal range of flame resistance. The grid-controlled tube may also be combined with the rectifier in a single envelope, resulting in one vacuum tube for the entire apparatus.

A further alternative arrangement of electrodes is shown in Fig. 3 in which the burners 11 and 15 are physically related to the furnace 10 exactly as shown in Fig. 1 and the electrode 18 also appears in the form and location as hereinbefore set forth. Instead, however, of having either or both of the burners definitely connected to the electrical circuit there is provided a further electrode 45 positioned in the path of the flame in such a manner that said products will tend to form between the electrodes 45 and 18 a conducting path whenever a flame is present. The electrical connections are identical with those hereinbefore set forth; and the performance also will be identical, except in that neither of the burners forms a definite part of the electrical circuit.

The terms and expressions which we have employed are used as terms of description and not of

limitation, and we have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but recognize that various modifications are possible within the scope of the invention claimed.

We claim:

1. A conductance-responsive system comprising an electron discharge device responsive to ionization currents in a given path, said device having a cathode, an anode, and a control electrode, and means for affecting said control electrode to modify the flow of electrons between said cathode and anode in one sense when the ionic conductance of said path is within a given range and in another sense when said conductance is above or below said range, said means comprising a diode, means for supplying an alternating potential to the anode and cathode of said diode, a capacitor connected to said anode and to said means for supplying alternating potential, and means for connecting the anode and cathode of said diode with said path whereby said diode is placed in parallel with said path.

2. A conductance-responsive system comprising an electron discharge device responsive to ionization currents in a given path, said device having a cathode, an anode, and a control electrode, and means for affecting said control electrode to modify the flow of electrons between said cathode and anode in one sense when the ionic conductance of said path is within a given range and in another sense when said conductance is above or below said range, said means comprising a diode, means for supplying an alternating potential to the anode and cathode of said diode, a capacitor connected to said anode and to said means for supplying alternating potential, connections between said path and the anode and cathode of said diode whereby the latter is placed in parallel with said path, and means connected to said control electrode for controlling the potential thereof in accordance with the response of said diode to the conductance of said path.

3. A conductance-responsive system comprising an electron discharge device responsive to ionization currents in a given path, said device having a cathode, an anode, and a control electrode, and means for affecting said control electrode to modify the flow of electrons between said cathode and anode in one sense when the ionic conductance of said path is within a given range and in another sense when said conductance is above or below said range, said means comprising another electron discharge device having an anode and a cathode, means for supplying an alternating potential thereto, a capacitor connected to the last mentioned anode and to said alternating potential supply means, and connections between said path and said last mentioned anode and cathode for enabling said capacitor to discharge across said path when the conductance of the latter is sufficiently high during those portions of the alternating potential cycles wherein the potential applied to said cathode is positive.

4. A conductance-responsive apparatus comprising an electron discharge device responsive to currents in a given path, said device having a cathode, an anode, and a control electrode, means for supplying an alternating potential to said discharge device, and means for affecting said control electrode to modify the flow of electrons between said cathode and anode in one sense when the conductance of said path is within a given range and in another sense when said conductance is above or below said range, said means including a half-wave rectifier system comprising a diode, resistor, and capacitor in series with each other and connected to said alternating potential supply means, means for connecting a portion of said rectifier system comprising at least said resistor in parallel with said path, and means connecting said rectifier system and said control electrode for controlling the potential of said control electrode in accordance with the response of said diode to the conductance of said path.

5. A conductance-responsive apparatus comprising an electron discharge device responsive to currents in a given path, said device having a cathode, an anode, and a control electrode, means for supplying an alternating potential to said discharge device, and means for affecting said control electrode to modify the flow of electrons between said cathode and anode in one sense when the conductance of said path is within a given range and in another sense when said conductance is above or below said range, said means including a half-wave rectifier system comprising a diode, resistor, and capacitor in series with each other and connected to said alternating potential supply means, and means for connecting a portion of said rectifier system comprising at least said resistor across different points in said path to enable said capacitor to discharge through said path when the conductance of the latter is sufficiently high during those portions of the alternating potential cycles wherein the potential applied to the cathode of said diode is positive.

6. A conductance-responsive system comprising an electron discharge device responsive to ionization currents in a given path, said device having a cathode, an anode, and a control electrode, and means for affecting said control electrode to modify the flow of electrons between said cathode and anode in one sense when the conductance of said path is within a given range and in another sense when said conductance is above or below said range, said means comprising a diode, means for supplying an alternating potential thereto, a resistor, a capacitor connected in series with said diode and with said resistor and said alternating potential supply means, and means for connecting said diode and resistor across different points in said path to enable said capacitor to discharge through said path when the conductance of the latter is sufficiently high during those portions of the alternating potential cycles wherein the potential applied to the cathode of said diode is positive.

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