Dec. 7, 1948. V. O. BEAM 2,455,350

CONTROL DEVICE

Filed July 11, 1942 2 Sheets-Sheet 1

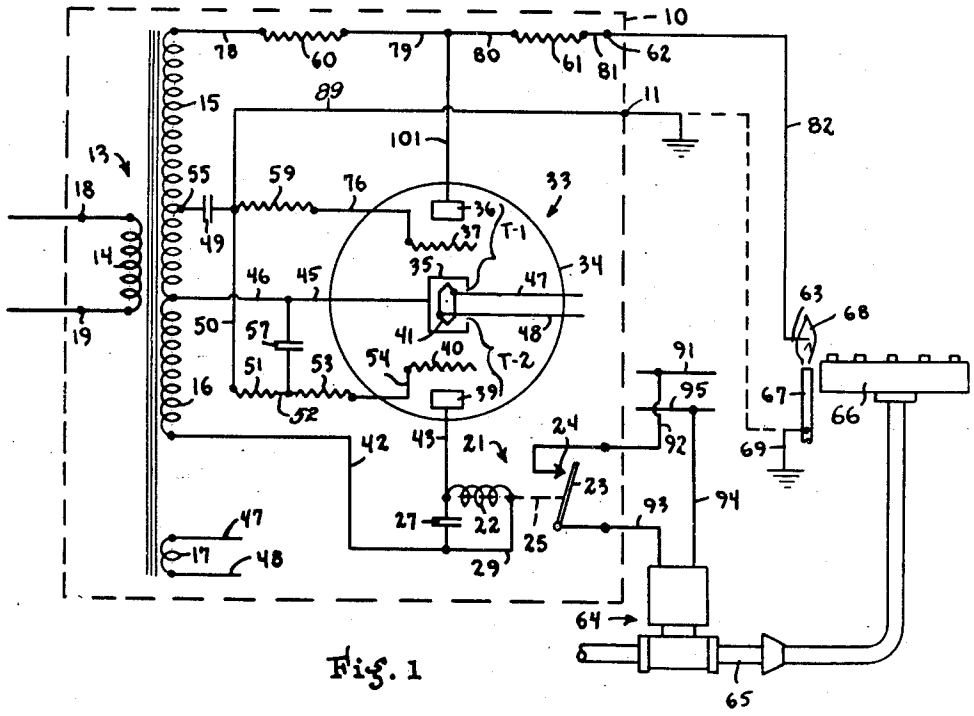


Fig. 1

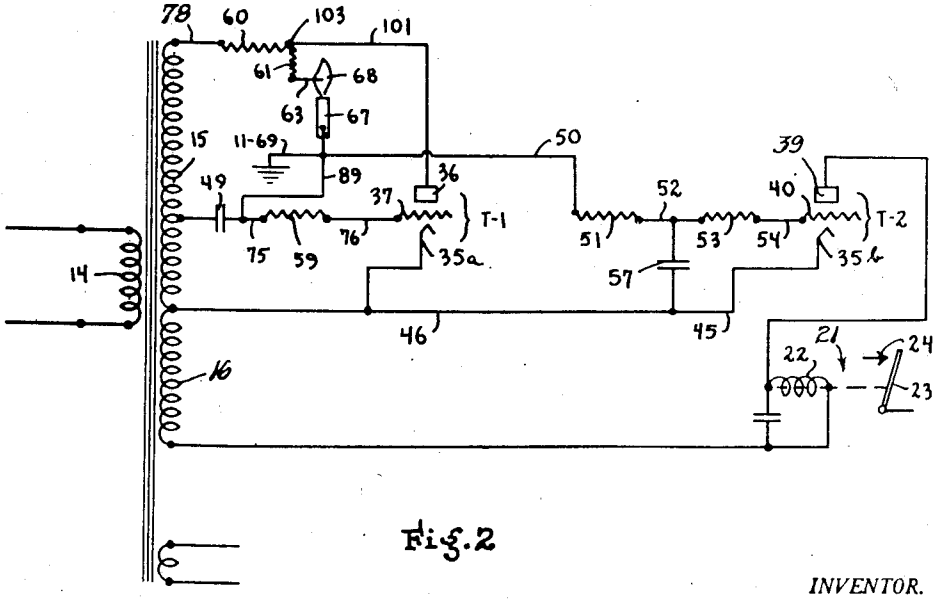


Fig. 2

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Filed July 11, 1942 2 Sheets-Sheet 2

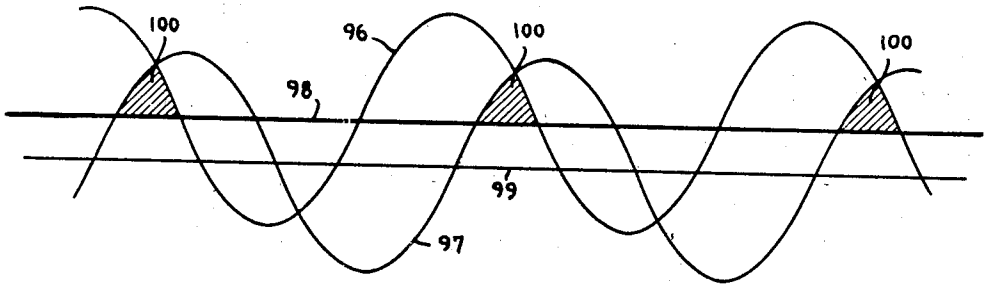


Fig. 3

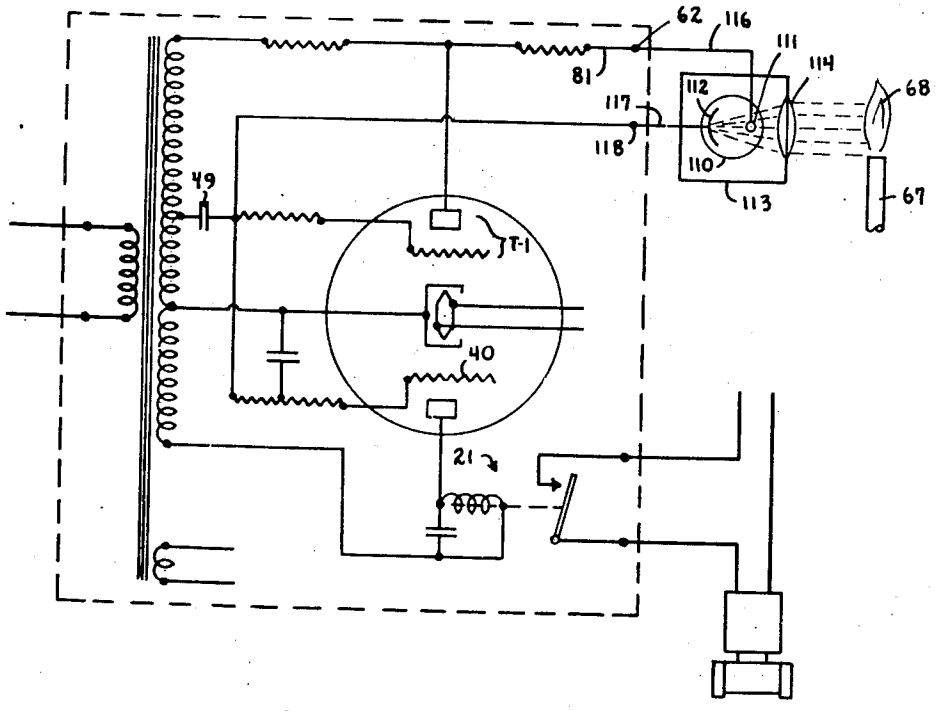


Fig. 4

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UNITED STATES PATENT OFFICE

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CONTROL DEVICE

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Application July 11, 1942, Serial No. 450,613

30 Claims. (Cl. 250—41.5)

1

The present invention relates to a control device and more particularly one designed to control the energization of a current translating device in accordance with a predetermined condition.

An object of the invention is to provide a control device adapted to be associated with an impedance and by which the energization of a current translating device is controlled in accordance with the conductive characteristics of said impedance.

A further object of the invention is to provide such a control device in which the current translating device is energized in one manner when the impedance is more conductive in one direction than in the other and is energized in a different manner when the impedance is conductive to substantially the same extent in both directions.

A still further object of the present invention is to provide a control device such as set forth in the previous objects in which the grid potential of an electronic discharge device is controlled by the charge on a condenser, this condenser being charged normally in one direction and being charged in the opposite direction only when the impedance is appreciably conductive in one direction and is conductive to a substantially lesser degree in the other direction.

A further object of the invention is to provide such a control device employing a grid controlled electronic discharge device in which the grid is connected through a gap to a source of potential at a point such that when the gap is short-circuited or bridged by a non-rectifying impedance, a potential is applied to the grid tending to render the discharge device non-conductive, and in which means associated with said grid connection is operative when the bridging impedance is rectifying to apply a different potential to the grid to render the device conductive.

A still further object of the present invention is to provide a control circuit of the type referred to in the preceding objects in which the controlling impedance is the flame of a burner and in which the current translating device is adapted to be employed to control the delivery of burner fuel.

A still further object of the invention is to provide such a control circuit in which the impedance is a photoelectric cell which becomes more conductive in one direction than in the other upon being exposed to a light source.

Other objects of the invention will be apparent from a consideration of the accompanying specification, claims, and drawings, of which:

Figure 1 is a schematic view of my improved control device associated with a gas burner and a control valve therefor;

Figure 2 is a schematic view of the control circuit of Figure 1 shown in somewhat modified form to aid in an understanding of the operation thereof;

Figure 3 is a view showing the phase and current magnitude relations between certain voltages existing in various portions of the circuit; and

Figure 4 is a schematic view of the control device when employed in connection with a photoelectric cell.

2

Referring specifically to the drawings, the control circuit of the present invention is shown as located within a housing 10. This housing may be of any suitable form. If this housing is of metal, it is desirable that it be connected to ground as at 11.

Disposed within the housing 10 is a step-up, step-down transformer 13 having a line voltage primary 14 and high voltage secondary windings 15 and 16. The transformer also includes a low voltage secondary winding 17 for energizing the cathode heating element. The primary winding 14 is connected to terminals 18 and 19 adapted to be connected to any suitable alternating current source of power (not shown). As far as the apparatus of the present invention is concerned, the transformer 13 constitutes the source of power and elsewhere in the specification and claims, the expression "source of power" is used to designate the means associated with the control device for supplying power at various potentials to the control device, even though this means must in turn be connected to some primary source of power.

A relay 21 constitutes the current translating device in the form of my invention shown for purposes of illustration. This relay comprises a relay coil 22 and a switch blade 23 adapted to engage a fixed contact 24. Switch blade 23 is associated with an armature 25 which in turn is associated with the relay coil 22. Switch blade 23 is normally biased by gravity or other suitable means away from contact 24. Upon energization of relay coil 22, however, the armature 25 is drawn to the left to move switch blade 23 into engagement with contact 24.

A condenser 27 is connected by conductor 29 in parallel with relay coil 22. Condenser 27 acts as a shunt condenser to eliminate any pulsations in the current flowing through relay coil 22.

The energization of relay coil 22 is controlled by an electronic discharge device 33 of the dual triode type. This device includes a conventional envelope 34 which encloses two triodes having a common cathode 35. A first triode includes the cathode 35, an anode 36, and a control grid 37. A second triode includes the cathode 35, an anode 39, and a control grid 40. It is to be understood that this device functions the same as two sepa-

rate triodes having their cathodes connected together.

A heater 41 is associated with the cathode 35 which is of the indirectly heated type. This heater is energized by secondary winding 17 which is connected to the heater by conductors 47 and 48. Only the terminal portion of these conductors are shown in order to simplify the drawing.

The triode consisting of cathode 35, anode 36 and grid 37 will be hereinafter referred to as triode T1 while the triode consisting of cathode 35, anode 39 and grid 40 will be referred to as triode T2. The triode T1 controls in several different manners the grid potential and hence the output of triode T2. The triode T2, in turn, controls the energization of relay coil 22. It is to be noted that relay coil 22 is connected between the anode 39 and cathode 35 of triode T2 in series with the secondary 16 by the following circuit: from the lower terminal of secondary 16 through conductors 42 and 29, relay coil 22, conductor 43, anode 39, cathode 35, and conductors 45 and 46 to the other terminal of secondary 16. During the half cycles in which the lower terminal of secondary 16 is positive and the potential of grid 40 is sufficiently high with regard to cathode 35, current will flow through relay coil 22 over the current conductive path just traced.

A condenser 49 controls the potential of grid 40 of triode T2. This condenser has impressed across it a direct current potential whose polarity and magnitude is determined by various factors. As will be explained in more detail later, the condenser 49 tends to be charged in one direction by the grid current of triodes T1 and T2 and in an opposite direction by the rectified current flowing through the rectifying impedance previously mentioned. It is to be noted that the right-hand terminal of condenser 49 is connected through conductor 50, resistor 51, conductor 52, resistor 53, and conductor 54 to grid 40. The left-hand terminal of condenser 49 is connected through the portion of secondary winding 15 from tap 55 to its lower terminal and through conductors 46 and 45 to cathode 35. Thus the condenser 49 is effectively connected between the cathode 35 and grid 40 and the direct current component of the grid potential is determined by the direct current potential existing across condenser 49.

A condenser 57 is connected between conductor 52 and the junction of conductors 45 and 46. This condenser together with the resistors 51 and 53 acts as a filter network, as will be explained in more detail later.

The circuit further includes current limiting resistors 59, 60 and 61 which serve to limit the current in the various portions of the circuit in which they are connected.

The relay 21 is illustratively shown as controlling an electrically operated gas valve 64. This gas valve is of the type which when energized permits a flow of gas and which upon deenergization interrupts such flow. The gas valve 64 controls the flow of gas through a pipe 65 to a main gas burner 66. Located adjacent to the main gas burner 66 is a pilot burner 67, the flame of which is indicated by the reference numeral 68. The pilot burner 67 is connected to ground at 69.

It will be obvious that whenever the gas valve 64 is energized, gas will flow to main burner 66 and be ignited by the pilot burner 68 if this burner is properly lighted. If the pilot burner is not ignited, however, unignited gas will be admitted into the furnace. If an attempt is made subsequently to light the pilot burner, a violent explosion may result. The control device of the present invention is employed for the purpose of determining when the pilot burner is properly ignited.

In order to more clearly understand certain phases of the operation of the control device of the present invention, the circuit has been redrawn in Figure 2. In this figure, the triode T1 is shown as separate from the triode T2, the cathodes being connected together. The reference characters are all identically the same with the exception that the cathode 36 in connection with triode T1 has been designated by the reference numeral 35a while the cathode in connection with triode T2 has been designated by the reference numeral 35b. Also, a few additional reference characters have been added.

Operation

No flame condition

Referring particularly to Fig. 2, the operation will first be considered when the pilot burner 67 is unignited. Under these conditions, it is desirable that the relay 21 be deenergized. In order for this to be true, it is necessary for the potential of grid 40 to be biased below the cut-off point or at least sufficiently low that the plate current is insufficient to energize relay coil 22. Whether this condition exists depends upon the charge on condenser 49.

As previously indicated, the triode T1 plays a part in determining the charge on condenser 49. During the half cycle in which tap 55 is positive with respect to the lower end of secondary 15, current can flow through condenser 49 and from the grid to the cathode as follows: from tap 55 through condenser 49, resistor 59, conductor 76, grid 37, cathode 35, and conductors 45 and 46 to the lower terminal of secondary 15. During the next half cycle, no current can flow through this circuit because of the inability of current to flow from the cathode to the grid. In other words, the grid-cathode portion of the circuit acts as a rectifier. There is also a conductive path through condenser 49 and the grid and cathode of triode T2 as follows: from tap 55 through condenser 49, conductor 50, resistor 51, conductor 52, resistor 53, conductor 54, grid 40, cathode 35, conductors 45 and 46 to secondary 15. In other words, the grid and cathode of triode T2 are connected in parallel with the grid and cathode of triode T1 to aid in the rectifying action of the latter. As a result, a direct current voltage tends to be impressed across condenser 49. The polarity of this voltage is such that the right-hand end of condenser 49 tends to be negative and the left-hand end positive.

As previously indicated, the resistors 51 and 53 and condenser 57 tend to act as a filter network for reducing the alternating current component that would otherwise be impressed upon grid 40. This action is best indicated in Figure 2 where the circuit has been slightly rearranged to more clearly illustrate these elements in their capacity as a filter network. It will be noted that condenser 57 as is usual in such a filter network acts to shunt out any alternating current component before it would be applied to grid 40. As a result of the voltage applied by condenser 49 through the filter network, the grid is biased sufficiently low with respect to cathode 35b that insufficient current flows through relay coil 22

to cause it to pull in. Thus, as long as the pilot burner is unignited, the relay 21 remains de-energized.

Operation with flame

Let it be assumed that the pilot burner is properly ignited. The condenser 49 now is included in a new circuit path. This circuit is as follows (traced in Figure 1): from the upper terminal of secondary 15 through conductor 78, resistor 60, conductors 79 and 80, resistor 61, conductor 81, terminal 62, conductor 82, electrode 63, flame 68, burner 67, connections 69 and 11, conductor 89, and condenser 49 to tap 55. It will be noted that this current flow through the condenser during the half cycle in which the upper end of secondary 15 is positive with respect to the lower end is in a direction opposite to that through the grid circuit of triode T1. Furthermore, flame 68 conducts current more readily in the direction traced than in the opposite direction. In other words, the ions tend to flow in the direction of propagation of the flame so that the conventional current flow is greater in the direction opposite to flame propagation than in the direction of flame propagation. As a result, the current flow in the next half cycle through condenser 49 and the flame gap is much less due to this rectifying action of the flame. Because of this, the current flowing through the circuit just traced has a pronounced direct current component opposite in polarity to the direct current component of the voltage which is impressed across condenser 49 by reason of the current flow through the grid circuit of triode T1. In other words, the direct current voltage produced by the flow through the flame gap tends to counteract if not completely overcome the direct current voltage introduced by the flow through the grid circuit of triode T1. As a result, the potential of the right hand terminal of the condenser 49 is raised in value to correspondingly raise the potential of grid 40 with respect to cathode 35b. The result is that triode T2 is rendered sufficiently conductive to energize relay coil 22 to cause switch blade 23 to be moved into engagement with switch contact 24. When this happens current will flow from line wire 91 through conductor 92, contact 24, switch blade 23, conductor 93, valve 64 and conductor 94 to line wire 95. Because of the establishment of the circuit just traced, the valve 64 is energized so as to admit gas flow to main burner 66. This gas flowing to main burner 66 is ignited by the pilot burner 68.

If, at any time, the flame is extinguished, the circuit immediately resumes the condition discussed under the heading "No flame operation" with the result that the gas valve 64 is closed and the main burner 66 is extinguished. Inasmuch as the action of the circuit is extremely rapid, there will be no possibility of gas flowing in appreciable volume to the main burner after the pilot burner has become extinguished.

Action in event of high resistance leak between flame electrode and ground

Many prior devices for detecting flame have been faulty in that they behaved the same when there was a high resistance leak between the flame electrode and ground as when a flame itself bridged the gap between ground and the flame electrode. In other words, many of these prior devices measured purely the resistance and were unable to differentiate between flame resistance and an ordinary resistance such as might be caused by the formation of carbon on the burner or by the partial destruction of the insulation isolating the flame electrode from ground. The relay device of the present invention, because of the fact that it detects whether the resistance has any rectifying action, differentiates between a flame resistance and an ordinary resistance.

From the operation described in the previous portion of this specification under the heading "Operation when flame is present," it will be evident that the only reason why the insertion of a flame resistance between burner 67 and electrode 63 causes the negative bias of the grid 40 to be overcome is that the current conduction through the flame is greater in one direction than in the other. The direction of greater current flow is such that the direct current potential across condenser 49 produced thereby overcomes the direct current potential produced by the current flow through the grid circuit of triode T1. Obviously, if the current flow through the condenser and through the flame gap is the same in both directions, there is no direct current component produced by the current flow through the condenser 49 and the direct current voltage across condenser 49 remains exactly the same as before. Hence, the insertion of a high resistance leak has no effect upon the direct current voltage across the condenser 49.

Furthermore, the alternating current voltage component of the voltage produced by current flow through flame 68 is nearly 180° out of phase with the plate voltage of triode T2 and hence tends to bias the grid further negatively. It is to be noted that there is a conductive path from the upper end of secondary 15 through conductor 78, resistor 60, conductors 79 and 80, resistor 61, conductor 81, terminal 62, conductor 82, electrode 63, the resistance between the electrode and ground 69, ground 11, conductors 89 and 50, resistors 51 and 53 and conductor 54 to grid 40. Since the voltage phase of the upper end of secondary 15 with respect to cathode 35 is opposite to the lower end of secondary 16, the point at which anode 39 is connected, it will be obvious that the alternating current voltage impressed on the grid 40 through the conductive path tends to drive it further negative. However, this tendency is relatively slight as long as the resistance between the electrode 63 and ground is relatively high. In any event, tests have proved that the grid potential 40 remains sufficiently low with respect to cathode 35 that triode T2 is incapable of energizing relay 21 under such conditions.

Operation in the event of a low resistance connection between electrode and ground

The present device is designed to distinguish between a flame and a low resistance connection between the electrode 63 and ground. This condition may arise, for example, by the electrode being accidentally engaged with the burner.

As previously indicated, a circuit may be traced directly from the upper terminal of secondary 15 to grid 40. As was noted, this connection tends to cause grid 40 to assume a highly negative value during the half cycle in which plate 39 is positive. Were it not for certain other factors, this connection in itself would insure that the triode T2 would be non-conductive in the event of a short circuit condition such as considered. Obviously, as the resistance across the flame gap decreases, this alternating com-

ponent arising by reason of the connection of grid 40 to the upper end of secondary 15 increases in magnitude and plays a greater part.

In the operation which has been described thus far the anode 36 has not been considered. In other words, in the operation as so far explained, this anode 36 could be disconnected and the apparatus would function just as before. It has been found in actual practice, however, that it is necessary that this anode be connected in the circuit in substantially the manner discussed in order to obtain the desired type of operation under the short circuit conditions now being considered. As a result of various experiments, it is believed that the following explanation correctly accounts for the function of anode 36. In advancing this explanation, however, the applicant is in no way limiting himself to this theory of operation.

Upon referring to Figure 2, it will be noted that the grid 40 and cathode 35b are in effect connected to two terminals of a phase shifting bridge. The grid 40 is connected through conductor 54, resistor 53, conductor 52, resistor 51, and conductor 50 to ground at 11. This ground connection forms a junction between a capacitive impedance provided by the condenser 49 and a resistive impedance constituted by the flame 69 or other resistance between the electrode 63 and ground. This is best shown in Figure 2. The cathode 35b on the other hand is connected to the bottom terminal of secondary 15 and is hence connected through transformer windings to an imaginary intermediate tap between tap 55 and the upper end of winding 15. Because of this connection of grid 40 and cathode 35 across the terminals of a phase shifting bridge, the alternating current component impressed upon grid 40 is less than 180° displaced in phase from the plate voltage.

As long as the resistance across the flame gap is relatively high, this shift in phase of this alternating current component of the grid voltage did not have to be considered. It was not sufficient to overcome the effect of the direct current component. In other words, expressing this in a somewhat different manner, the axis of this alternating current component was sufficiently low in magnitude and the alternating current component was sufficiently small that the positive peaks of the alternating current component did not render the tube conductive when not desired. If the magnitude of this alternating current component is increased because of a decrease in flame gap resistance, a condition such as shown in Figure 3 tends to result. Referring to Figure 3, the plate voltage of triode T2 is indicated by the curve 96 and the grid voltage by the curve 97. The axis of the plate voltage is indicated by the line 98 and the axis of the grid voltage by the line 99. The displacement of the grid current axis 99 from the plate current axis 98 represents the direct current component of the grid voltage which is what has been previously considered. As the alternating current component increases in magnitude, its peaks begin to pass above the axis of the plate voltage so that the grid voltage curve extends into the plate voltage curve as indicated by the said portions 100. For purposes of simplicity, in connection with Figure 3, let it be assumed that the tube is a zero bias cut-off tube, although it is to be understood that normally a tube cutting off with a negative bias is employed. It will be obvious that if the tube is a zero bias cut-off tube, the triode T1 would become conductive over the portion of the cycle marked by the shaded areas 100. Several factors, however, enter to correct this tendency. In the first place, the plate and grid of triode T1 are connected in parallel with the flame gap by the following circuit (referring to Figure 2): from flame electrode 63 through resistance 61, conductor 101, plate 36, grid 37, conductor 76, resistor 59, conductor 75, and conductor 89 to the burner. Because of this connection, the impedance between ground 11 and junction 103 is no longer the purely resistive impedance across the flame gap but also includes the capacitive impedance between the anode 36 and the grid 37. Because of this, the impedance in the branch between ground 11 and junction 103 tends to become somewhat capacitive in character and hence more similar to the impedance introduced by condenser 49 in the other leak of the bridge. Thus, the presence of the plate grid capacity tends to decrease the phase shifting action of the bridge and bring the grid voltage more nearly into a position 180° displaced from the plate voltage.

There is still another effect which tends to prevent the condition of Figure 3, this effect also being due to the presence of anode 36. In the preceding paragraph, a circuit was traced which included anode 36 and grid 37. The only resistance in this circuit consisted of resistors 59 and 61, and the resistance between flame gap 63 and ground. Obviously, as this flame gap resistance decreases, the grid 37 tends to assume a potential more nearly equal to that of anode 36 so that triode T1 passes a very heavy plate current. The resistor 60 is of substantial magnitude and as this plate current increases, a direct current voltage of substantial magnitude exists across resistor 60. This direct current voltage is due to the rectifying action of triode T1 which has now become extremely conductive in one direction but remains substantially non-conductive in the other. The polarity of this direct current voltage is such that the right hand end of resistor 60 tends to be negative and the left hand end positive. It is to be noted (referring to Figure 2) that the right hand end of resistor 60 is connected through resistor 61, flame electrode 63, the flame gap, burner 67, ground connections 11 and 69, conductor 50, resistor 51, conductor 52, resistor 53, and conductor 54 to grid 40. Cathode 35b is connected through conductors 45 and 46 and secondary 15 to the other terminal of resistor 60. Again, the condenser 57 and resistors 51 and 53 act as a filter net work. The result of this direct current component being impressed upon grid 40 is that the axis of grid current 99 tends to be lowered so as to decrease the effect of the peaks of grid voltage curve 97 even if this grid voltage curve still had the same phase relation as grid 53. Moreover, as previously explained, due to the capacitive action of anode 36 and grid 37 of triode T1, the phase displacement is more nearly 180° than that shown in Figure 3. As a result of these effects, the grid 40 is maintained sufficiently negative with respect to the cathode that the current flowing to relay 21 is insufficient to energize the same.

It will be seen from the above description that the only condition to which the present relay responds is to a condition in which the impedance bridging the gap between terminal 62 and ground is rectifying in character. In other words, it is necessary that this impedance be substantially

conductive in one direction and relatively non-conductive in the other direction. If the gap is bridged either by an impedance having the same impedance in both directions or very little impedance, or if the gap is open, the relay circuit will indicate the absence of a flame in the gap. It will thus be seen that my present circuit is an extremely desirable one for detecting impedances of the rectifying type.

While the particular values of the elements employed form no part of the present invention, in one particular embodiment of the invention using a 7N7 tube, a 10,000 ohm resistor was employed for resistor 60, 1 megohm resistors for resistors 51 and 61, a 2 megohm resistor for resistor 53, and .02 microfarad condensers for condensers 49 and 57. In the same embodiment, windings 15 and 16 were each 300 volts windings and tap 55 was spaced by 24 volts from the lower end of winding 15. These values are given solely for illustrative purposes and are in no way critical.

Species of Figure 4

One very important application of the control circuit of the present invention is in connection with photoelectric cells. As is well known, a photoelectric cell has a rectifying action. As long as the photoelectric cell is dark, the impedance in both directions is relatively high. Upon the photoelectric cell being exposed to light, the impedance to current flow from the anode to the cathode is decreased while the impedance in the opposite direction remains substantially unchanged. It will be obvious that by connecting a photoelectric cell across the gap in the circuit connections of the present control circuit, a highly desirable photoelectric relay circuit is obtained in that this circuit will respond only to a decrease in resistance produced by light shining on the photoelectric cell and will not respond to any resistance accidentally connected across the photoelectric cell terminals. Referring to Figure 4, the circuit connections are exactly the same as in Figure 1 with the exception of the connections including the photoelectric cell. The various elements of the circuit with the above noted exceptions have accordingly been given identically the same reference numerals as in Figure 1.

In Figure 4 the photoelectric cell is designated by the reference numeral 110. The photoelectric cell has an anode 111 and a light sensitive electron emmissive cathode 112. The photoelectric cell 110 is shown as housed in a housing 113 having a lens 114 for converging the light rays upon the cathode 112. While the source of light may be any suitable source which it is desired to detect, this source has been illustratively shown as the flame 68 of the pilot burner 67 previously considered.

The anode 111 is connected by a conductor 116 to the terminal 62. The cathode 112 is connected by conductor 117 to a terminal 118 which corresponds to the ground connection 11 in the previously described species. It is, of course, to be understood that cathode 112 may be connected through ground in precisely the same manner as was the burner 67 in the previously described species. In either event, the photoelectric cell 110 is connected across the gap which would otherwise exist between terminals 62 and 118 and corresponding to the gap between terminal 62 and ground in Figure 1.

It is believed unnecessary to describe the operation of the system of Figure 4 in detail. It is sufficient to note that the circuit through the photoelectric cell 110 plays exactly the same function as the circuit through flame 68. Until the light is directed upon the photoelectric cell 110, the impedance of this cell in its current conductive direction is so high that the direct current component on condenser 49 is determined largely by the rectifying action of the grid and cathode of triodes T1 and T2. As soon as a light is directed upon the photoelectric cell 110, its conductivity in its current conductive direction increases so that a direct current voltage of opposite potential tends to be impressed across condenser 49. The result is that the potential of grid 40 is raised to a point such that the relay 21 is energized. Obviously, if a low resistance shunt or a high resistance shunt is established around photoelectric cell 110, the operation will be precisely the same as described in connection with similar situations in the species of Figures 1 to 3.

Conclusion

It will be seen that the improved control circuit is extremely valuable for detecting the presence of an impedance which tends under certain conditions to be more conductive in one direction than in the other. For this reason, it is particularly useful in connection with flame detection either where the gap in the circuit connections are bridged directly by a flame or by a photoelectric cell exposed to the light of the flame. However, it is to be understood that the invention has numerous other applications in connection with other impedances of a rectifying nature. In general, the invention is to be limited only by the scope of the appended claims.

I claim as my invention:

1. In combination, a current translating means, a space discharge amplifier having an anode, a cathode, and a control element, said amplifier controlling the energization of said current translating device and operative to cause either energization or effective deenergization of said device depending upon within which of two ranges of values said control element potential is maintained, a source of alternating potential connected to said amplifier, a connection between said control element and a point on said source such that the connection tends to maintain said control element at an alternating potential within one of said two ranges of values, said connection including a gap adapted to be bridged by a rectifying impedance, a condenser, means connecting said condenser between said connection and said source of potential in such a manner that when said gap is bridged by a rectifying impedance, said condenser is charged with a voltage of a predetermined polarity, and means including a further space discharge amplifier associated with said condenser and effective when said condenser is so charged to maintain said control element at a potential within the other of said two ranges of values.

2. In combination, a photoelectric cell, a current translating means, a space discharge amplifier having an anode, a cathode, and a control element, said amplifier controlling the energization of said current translating device and operative to cause either energization or effective deenergization of said device depending upon within which of two ranges of values said control element potential is maintained, a source of alternating potential connected to said amplifier, a connection including said photoelectric

cell between said control element and a point on said source such that in the event of a low non-rectifying impedance bridging the cell, the connection tends to maintain said control element at an alternating potential within one of said two ranges of values, a condenser, means connecting said condenser between said connection and said source of potential in such a manner that when said cell is subjected to a beam of light so as to be rectifying, said condenser is charged with a voltage of a predetermined polarity, and means including a further space discharge amplifier associated with said condenser and effective when said condenser is so charged to maintain said control element at a potential within the other of said two ranges of values.

3. In flame detecting apparatus, a grid controlled electronic amplifier, a source of alternating potential connected to said amplifier, a connection between said grid and a point on said source such that the connection tends to maintain said grid at an alternating potential at which said amplifier is effectively non-conductive, said connection having a portion thereof responsive to a flame and acting as a rectifying impedance when exposed to a flame, and means associated with said connection and effective when said responsive portion acts as a rectifying impedance to maintain said grid at a different potential such that said amplifier is effectively conductive.

4. In flame detecting apparatus, a grid controlled electronic amplifier, a source of alternating potential connected to said amplifier, a connection between said grid and a point on said source such that the connection tends to maintain said grid at an alternating potential at which said amplifier is effectively non-conductive, said connection having a portion thereof responsive to a flame and acting as a rectifying impedance when exposed to a flame, and means including a condenser associated with said connection and effective by reason of the charging of the condenser when said responsive portion acts as a rectifying impedance to maintain said grid at a different potential such that said amplifier is effectively conductive.

5. In flame detecting apparatus, an electron discharge device having an anode, a cathode, and a control electrode, a source of alternating potential for applying an alternating potential between said anode and cathode, a connection between said control electrode and a point on said source whose voltage phase with respect to the cathode is opposite to that of the point to which the anode is connected so as to tend to maintain said control electrode at an alternating potential at which the device is effectively non-conductive, said connection having a portion thereof responsive to a flame and acting as a rectifying impedance when exposed to a flame, and means associated with said connection and effective when said responsive portion acts as a rectifying impedance to maintain said control electrode at a different potential at which said device is effectively conductive.

6. In flame detecting apparatus, an electron discharge device having an anode, a cathode, and a control electrode, a source of alternating potential for applying an alternating potential between said anode and cathode, a connection between said control electrode and a point on said source whose voltage phase with respect to the cathode is opposite to that of the point to which the anode is connected so as to tend to maintain said control electrode at an alternating potential at which the device is effectively non-conductive, said connection having a portion thereof responsive to a flame and acting as a rectifying impedance when exposed to a flame, and means including a condenser associated with said connection and effective by reason of the charging of the condenser when said responsive portion acts as a rectifying impedance to maintain said control electrode at a different potential at which said device is effectively conductive.

7. In flame detection apparatus, an electron discharge device having an anode, a cathode, and a control electrode, a source of alternating potential for applying an alternating potential between said anode and cathode, means for maintaining said control electrode at a potential at which said device is effectively non-conductive, a connection between said control electrode and a point on said source whose voltage phase with respect to the cathode is opposite to that of the point to which the anode is connected so as to tend to aid said previously named means in maintaining said control electrode at a potential at which the device is effectively non-conductive, said connection having a portion thereof responsive to a flame and acting as a rectifying impedance when exposed to a flame, and means associated with said connection and effective when said responsive portion acts as a rectifying impedance to oppose said first named means so as to cause said control electrode to be maintained at a different potential at which said device is effectively conductive.

8. In combination, an electron discharge device having an anode, a cathode, and a control electrode, a source of alternating potential for applying an alternating potential between said anode and cathode, a condenser connected to said control electrode, means for normally charging said condenser in such a direction as to maintain said control electrode at a potential at which said device is effectively non-conductive, a connection between said control electrode and a point on said source whose voltage phase with respect to the cathode is opposite to that of the point to which the anode is connected so as to tend to aid said condenser in maintaining said control electrode at a potential at which the device is effectively non-conductive, said connection including a gap adapted to be bridged by a rectifying impedance, and means associated with said connection and effective when said gap is bridged by a rectifying impedance to tend to charge said condenser in the opposite direction so as to maintain said control electrode at a different potential at which said device is effectively conductive.

9. In combination, an electron discharge device having an anode, a cathode, and a control electrode, a source of alternating potential for applying an alternating potential between said anode and cathode, a condenser connected to said control electrode, circuit connections between said source of potential and said condenser, said circuit connections including a rectifier so as to charge said condenser and being of such a phase relation that the charge on the condenser tends to maintain the control electrode at a potential at which said device is effectively non-conductive, a connection between said control electrode and a point on said source whose voltage phase with respect to the cathode is opposite to that of the point to which the anode is connected so as to tend to aid said condenser in maintaining said control electrode at a potential at which the device is effectively non-conductive, said connection including a gap adapted to be bridged by a

rectifying impedance, and means associated with said connection and effective when said gap is bridged by a rectifying impedance to tend to charge said condenser in the opposite direction so as to maintain said control electrode at a different potential at which said device is effectively conductive.

10. In combination, an electron discharge device having an anode, a cathode, and a control electrode, an alternating current transformer having windings connected for applying an alternating potential between said anode and cathode, a condenser connected to said control electrode for varying the potential applied thereto, a rectifier, means for connecting said condenser in series with said rectifier between first and second points on said windings so that a direct current potential is impressed across said condenser, the polarity of said potential being such as to bias said control electrode negatively, and further means for opposing said negative bias to render said discharge device effectively conductive, said further means including a connection between said condenser and second and third points on said windings, the voltage phase of said third point with respect to the second point being opposite to that of said first point, said last-named connection having a gap across which a rectifying impedance is adapted to be connected, and said further means being effective to oppose the negative bias only when the impedance connected across said gap is rectifying.

11. In combination, a pair of electron discharge devices, a first having at least an anode and cathode and the other having an anode, a cathode, and a control electrode, an alternating current transformer having windings for supplying an alternating potential, means connecting said cathodes to substantially the same point on said windings, means connecting the anode of said first device to said windings at a second point whose voltage phase with respect to the point of connection of the cathodes is opposite to that of a third point to which the anode of the other device is connected, an impedance connected between the control electrode of the first device and a fourth point on said windings whose voltage phase with respect to the point of connection of the cathodes is the same as that of said second point, and a further connection from said fourth point through said impedance to a point on said windings whose voltage phase with respect to said fourth point is the same as that of said second point, said last named connection having a gap across which a rectifying impedance is adapted to be connected.

12. In combination, a pair of electron discharge devices each having an anode, a cathode, and a control electrode, an alternating current transformer having windings for supplying an alternating potential, means connecting said cathodes to substantially the same point on said windings, means connecting the anode of a first of said devices to said windings at a second point whose voltage phase with respect to the point of connection of the cathodes is opposite to that of a third point to which the anode of the other device is connected, an impedance connected between the control electrode of the first device and a fourth point on said windings whose voltage phase with respect to the point of connection of the cathodes is the same as that of said second point, a further connection from said fourth point through said impedance to a point on said

windings whose voltage phase with respect to said fourth point is the same as that of said second point, said last named connection having a gap across which a rectifying impedance is adapted to be connected, and a further connection between said first named impedance and the control electrode of said second triode.

13. In combination, a pair of electron discharge devices, a first having at least an anode and cathode and the other having an anode, a cathode, and a control electrode, an alternating current transformer having windings for supplying an alternating potential, means connecting said cathodes to substantially the same point on said windings, means connecting the anode of said first device to said windings at a second point whose voltage phase with respect to the point of connection of the cathodes is opposite to that of a third point to which the anode of the other device is connected, a condenser connected between the control electrode of the first device and a fourth point on said windings whose voltage phase with respect to the point of connection of the cathodes is the same as that of said second point, and a further connection from said fourth point through said condenser to a point on said windings whose voltage phase with respect to said fourth point is the same as that of said second point, said last named connection having a gap across which a rectifying impedance is adapted to be connected.

14. In combination, a pair of electron discharge devices each having an anode, a cathode, and a control electrode, an alternating current transformer having windings for supplying an alternating potential, means connecting said cathodes to substantially the same point on said windings, means connecting the anode of a first of said devices to said windings at a second point whose voltage phase with respect to the point of connection of the cathodes is opposite to that of a third point to which the anode of the other device is connected, a condenser connected between the control electrode of the other device and a fourth point on said windings whose voltage phase with respect to the point of connection of the cathodes is the same as that of said second point, and a further connection from said fourth point through said condenser to a point on said windings whose voltage phase with respect to said fourth point is the same as that of said second point, said last named connection having a gap across which a rectifying impedance is adapted to be connected, and a further connection between said first named impedance and the control electrode of said second triode.

15. In flame detecting apparatus adapted to be employed with flame responsive means having rectifying properties in the presence of flame; a condenser, a power source, connections including said power source and said condenser and adapted to be completed by such a flame responsive means and effective when so completed to cause said condenser to assume a charge upon the presence of flame at the flame responsive means, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, a filter having input and output terminals, means connecting said input terminals in a closed circuit independent of the flame responsive means but including said condenser so that the voltage across said condenser is impressed upon the input terminals of said filter, and means for applying

the voltage across the output terminals of said filter to said control element so that the latter controls the current flow to said current responsive means according to the presence or absence of flame at the flame responsive means.

16. In flame detecting apparatus adapted to be employed with spaced electrodes adapted to be bridged by a flame; a condenser, a power source, connections including said power source and said condenser and adapted to be connected to such spaced electrodes and effective when so connected to cause said condenser to assume a charge upon the electrodes being bridged by a flame by reason of the rectifying properties of the flame, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, a filter having input and output terminals, means connecting said input terminals in a closed circuit independent of the electrodes but including said condenser so that the voltage across said condenser is impressed upon the input terminals of said filter, and means for applying the voltage across the output terminals of said filter to said control element so that the latter controls the current flow to said current responsive means according to the presence or absence of a flame bridging the electrodes.

17. In flame detecting apparatus adapted to be employed with flame responsive means in the form of a photocell having rectifying properties in the presence of flame; a condenser, a power source, connections including said power source and said condenser and adapted to be completed by such a photocell and effective when so completed to cause said condenser to assume a charge upon the photocell being exposed to a flame, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, a filter having input and output terminals, means connecting said input terminals in a closed circuit independent of the photocell but including said condenser so that the voltage across said condenser is impressed upon the input terminals of said filter, and means for applying the voltage across the output terminals of said filter to said control element so that the latter controls the current flow to said current responsive means according to whether or not the photocell is exposed to a flame.

18. In flame detecting apparatus adapted to be employed with flame responsive means having rectifying properties in the presence of flame; a condenser, a power source, connections including said power source and said condenser and adapted to be completed by such a flame responsive means and effective when so completed to cause said condenser to assume a charge upon the presence of flame at the flame responsive means, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, a filter network having a plurality of elements, and means for connecting said cathode and said control element in a closed circuit including one element of said filter and said condenser such that any charge on said condenser will be passed through said filter to said control element to control the current flow to said current responsive device according to the presence or absence of flame at the flame responsive means.

19. In flame detecting apparatus adapted to be employed with flame responsive means having rectifying properties in the presence of flame; a condenser, a power source, connections including said power source and said condenser and adapted to be completed by such a flame responsive means and effective when so completed to cause said condenser to assume a charge upon the presence of flame at the flame responsive means, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, and a filter network comprising a resistor connected in a circuit between said first named condenser and said control element, said filter network further comprising a filter condenser connected in a parallel relation with said control element and said cathode such that said filter condenser will assume a charge corresponding to the charge of said first named condenser and will cause said control element to control the current flow to said current responsive device according to the presence or absence of said flame at said flame responsive means.

20. In flame detecting apparatus adapted to be employed with flame responsive means having rectifying properties in the presence of flame; a condenser, a power source, connections including said power source and said condenser and adapted to be completed by such a flame responsive means and effective when so completed to cause said condenser to assume a charge upon the presence of flame at the flame responsive means, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, a filter network, and means connecting said filter network in circuit between said condenser and said control element in such a manner as to prevent any alternating voltages present on said condenser from being impressed to an appreciable extent upon said control element and to provide a path whereby any charge on said condenser is allowed to control said control element and thereby the current flow to said current responsive device according to the presence or absence of flame at said flame responsive means.

21. In flame detecting apparatus adapted to be employed with flame responsive means having rectifying properties in the presence of flame; a condenser, a power source, connections including said power source and said condenser and adapted to be completed by such a flame responsive means and effective when so completed to cause said condenser to assume a charge upon the presence of flame at the flame responsive means, an electron discharge device having an anode, a cathode and a control element, current responsive means connected to said anode and responsive to the current flow through said discharge device, and a filter network having a resistor and a condenser connected in circuit independent of the flame responsive means between said control element and said first named condenser in such a way as to prevent momentary flame fluctuations at the flame responsive means from causing said control element to change the current flow to said current responsive device and cause a false indication of the condition at the flame responsive means.

22. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control

electrode; a current responsive device connected to the anode of said discharge device; a capacitance connected between a first point on said source and said control electrode; an impedance which is rectifying when exposed to a flame connected between said control electrode and a point on said source; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device, said connections being such that when said impedance is bridged by an impedance of less than a predetermined value, said device will be ineffective to energize said responsive device.

23. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a current responsive device connected to the anode of said discharge device; a capacitance connected between a first point on said source and said control electrode; a photoelectric device connected between said control electrode and a point on said source; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device, said connections being such that when said photo-electric device is bridged by an impedance of less than a predetermined value, said discharge device will be ineffective to energize said current responsive device.

24. In combination a discharge device having an anode, cathode, and control electrode, an alternating source of power, means connecting said anode and said cathode in energizing relation to said source of power, a network, including an impedance which is rectifying when exposed to a flame and a condenser, adapted to control the potential of said control electrode, said condenser interconnecting said control electrode and said source at a point which has appreciable voltage magnitude with respect to said cathode connection the effect of said network on said control electrode being substantially unchanged when said rectifying impedance is bridged in parallel by a nonrectifying impedance of greater than a predetermined value and means including said source for rendering said device ineffective when said impedance is bridged by an impedance of less than a predetermined value.

25. In combination a discharge device having an anode, cathode, and control electrode, an alternating source of power, means connecting said anode and said cathode in energizing relation to said source of power, a network including a light-sensitive device and a condenser, adapted to control the potential of said control electrode, the effect of said network on said control electrode being substantially unchanged when said light-sensitive device is bridged in parallel by a non-rectifying impedance of greater than a predetermined value, and means including said source of power for rendering said device ineffective when said light sensitive device is bridged by an impedance of less than a predetermined value.

26. Flame detection apparatus comprising in combination; an electron discharge device having a control electrode for controlling the flow of current in said device; means responsive to the current flow in a path adapted to be bridged by a flame, for affecting said control electrode; said means comprising, a condenser, a rectifier for charging said condenser, means connecting said path in circuit with said condenser to affect the charge on said condenser in accordance with the presence or absence of flame across said path, and means connecting said condenser to said control electrode to cause said control electrode to assume a potential in a first range in the absence of a flame across said path or in the event an impedance of less than a predetermined value is bridging said path and in a second range when flame is present across said path; and current responsive means connected in circuit with said discharge device for indicating the presence or absence of flame in accordance with the potential on said control electrode.

27. Flame detection apparatus comprising in combination; an electron discharge device having a control electrode for controlling the flow of current in said device; means responsive to the current flow in a path adapted to be bridged by a flame, for affecting said control electrode; said means comprising, a condenser, a rectifier for charging said condenser, means connecting said path in circuit with said condenser to affect the charge on said condenser in accordance with the presence or absence of flame across said path, and means connecting said condenser to said control electrode to cause said control electrode to assume a potential in a first range in the absence of a flame across said path and in a second range when flame is present across said path; current responsive means connected in circuit with said discharge device for indicating the presence or absence of flame in accordance with the potential on said control electrode; and a source of voltage adapted to be connected to said control electrode for rendering said device inoperative when said path is bridged by an impedance of less than a predetermined value.

28. Flame detection apparatus, comprising in combination, an electron discharge device responsive to the flow of current in a given path which is adapted to be bridged by a flame, said device comprising an anode, a cathode and a control electrode, and means affecting the flow of current through said device in one manner when a flame is bridging said path and in another manner when said path has no flame thereacross or is bridged by an impedance of less than a predetermined value, said means comprising an asymmetrically conductive device, a resistor, a condenser, an alternating source of power, means connecting said conductive device, said resistor, said condenser and said source of power in a series circuit so that said condenser will be charged by said conductive device, means connecting said path in circuit with said condenser to affect the charge thereon when said path has a flame thereacross, and means connecting said series circuit to said control electrode for controlling the potential thereof in accordance with the response of said series circuit to the conditions existing on said path.

29. An electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a current responsive device connected to the anode of said discharge device; a capacitance connected between a first point on said

source and said control electrode; an impedance which is rectifying when exposed to a flame connected between said control electrode and a point on said source; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device, said point to which the control electrode is connected through said rectifying impedance having a voltage phase with respect to the cathode connection which is opposite the voltage phase of said anode connection and of such magnitude that when said impedance is bridged by an impedance of less than a predetermined value, said device will be ineffective to energize said current responsive device.

30. Flame detection apparatus comprising in combination, an alternating source of power, an electron discharge device having an anode, cathode and control electrode, an impedance which is rectifying when exposed to a flame, a condenser, means connecting said anode and cathode to first and second points respectively on said source, means including said condenser connecting said control electrode to a third point on said source whose voltage magnitude with respect to said cathode connection is of a first value and whose phase is opposite said anode connection, means including said rectifying impedance connecting said control electrode to a further point on said

source whose voltage magnitude with respect to said cathode is of a second value greater than said first value and whose phase is opposite said anode connection, means including a portion of said source and said rectifying impedance when exposed to a flame for charging said condenser, said condenser when so charged maintaining the potential of said control electrode in a first range of values, and means including said source for maintaining said control electrode potential in a second range of values when said rectifying impedance is not exposed to a flame and said first value of voltage is effective on said control electrode or said rectifying impedance is bridged by an impedance of less than a predetermined value and said second value of voltage is effective on said control electrode.

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