

July 10, 1945.

W. H. GILLE

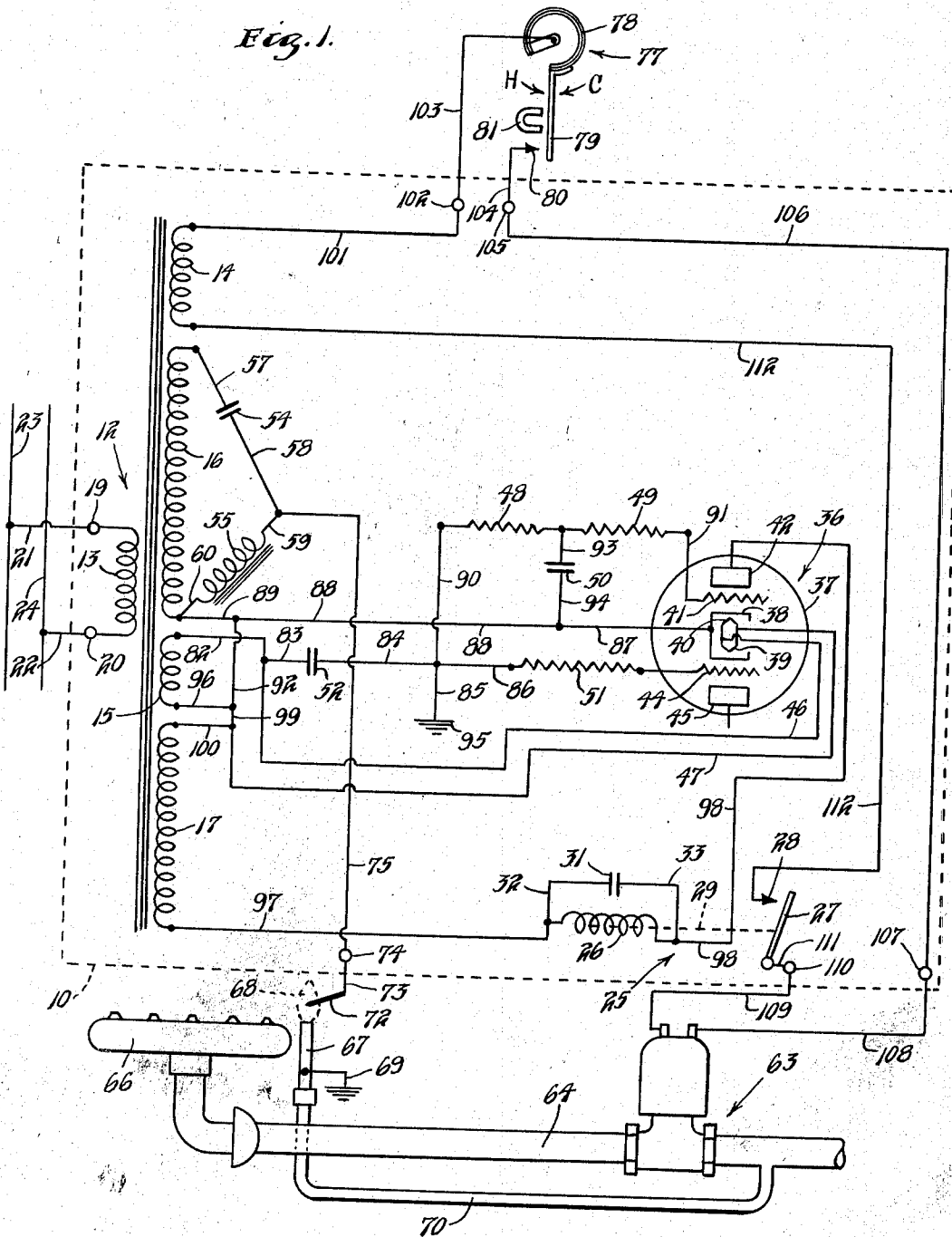
2,379,872

ELECTRONIC CONTROL APPARATUS

Filed Jan. 9, 1943

3 Sheets-Sheet 1

Fig. 1.



Inventor
WILLIS H. GILLE

George H. Fisher
Attorney

July 10, 1945.

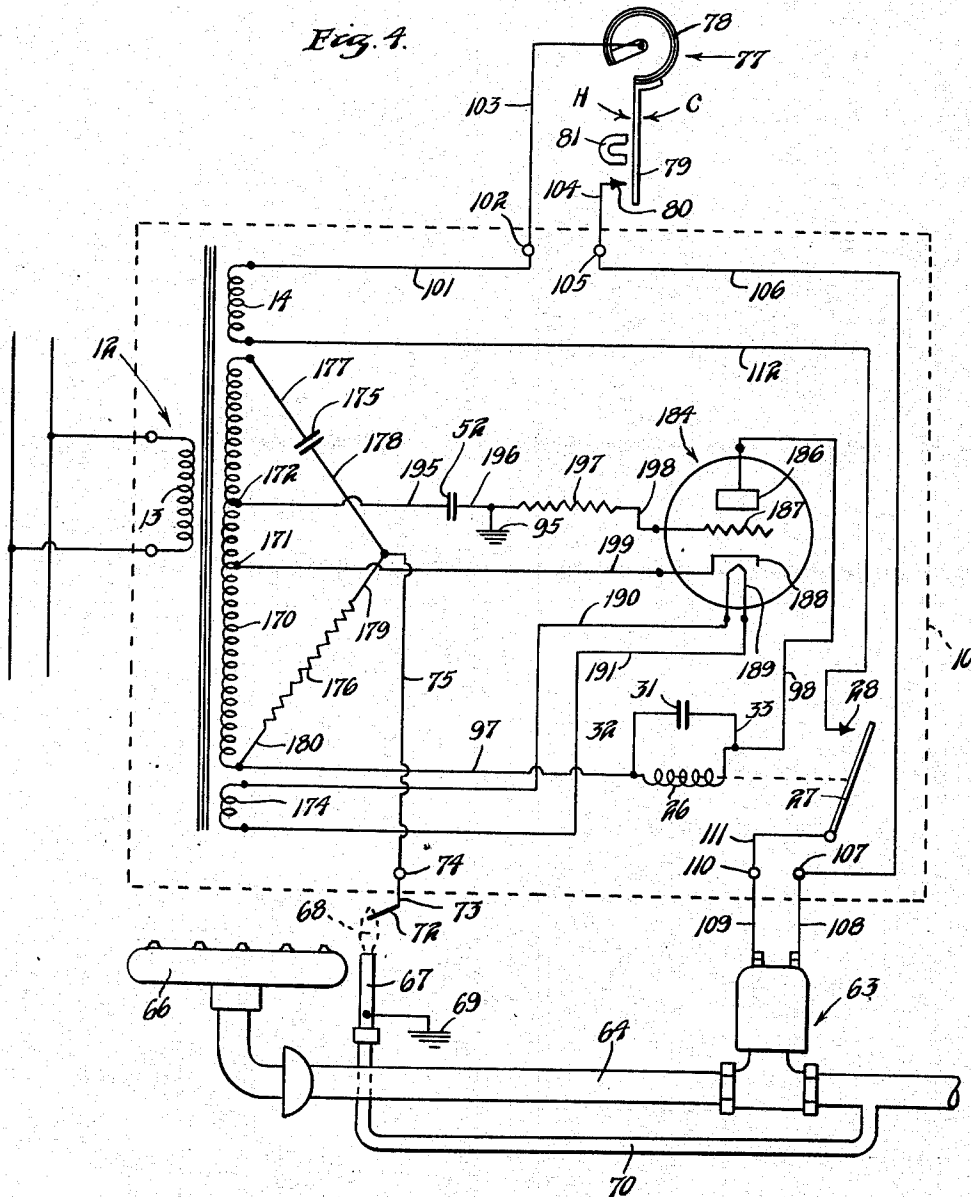
W. H. GILLE

2,379,872

ELECTRONIC CONTROL APPARATUS

Filed Jan. 9, 1943

3 Sheets-Sheet 3



Inventor
WILLIS H. GILLE

George H. Fisher
Attorney

UNITED STATES PATENT OFFICE

2,379,872

ELECTRONIC CONTROL APPARATUS

Willis H. Gille, St. Paul, Minn., assignor to Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., a corporation of Delaware

Application January 9, 1943, Serial No. 471,833

21 Claims. (Cl. 250—27)

The present invention is concerned with electronic control apparatus and more particularly with apparatus designed to detect the presence of a rectifying impedance such as a burner flame bridging a flame gap.

In the co-pending application of Vilynn O. Beam, Serial No. 450,613, filed July 11, 1942, there is disclosed a control device which is adapted to determine whether an impedance connected across a gap is rectifying or not and to act in one manner when the impedance is rectifying and to act in another when the gap is either open circuited or is bridged by an impedance which is non-rectifying. This control device is particularly applicable for the detection of a burner flame where the rectifying impedance is either a flame gap bridged by a burner flame or a photo-electric cell exposed to the illumination of the burner flame. In the control device disclosed in the Beam application, it is necessary to employ two electronic triodes, one of which functions in the usual manner of an electronic amplifier and the other of which appears to function to prevent certain phase shifting tendencies which would make the operation of the apparatus unreliable under certain conditions.

It is a general object of this present invention to provide a control device of the type discussed above in which any tendency towards undesirable phase shifting is counteracted without the use of a second triode.

A further object of the present invention is to provide a control device of the general type discussed above in which a phase shifting bridge is employed to introduce a constant corrective phase shifting action so that the apparatus will under no case give a false indication of the presence of a rectifying impedance.

A still further object of the present invention is to provide a control device in which a single electronic discharge device may be employed without sacrificing any of the advantages of operation obtained with the arrangement disclosed in the aforesaid Beam application.

A still further object of the invention is to provide a burner control system embodying the control apparatus of the previously named objects in which the means responsive to the burner flame is rectifying only when it is exposed to a burner flame.

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 the burner con-

trol system employing my novel control apparatus as a means of detecting a burner flame.

Figure 2 is a modified form of my control apparatus,

Figure 3 is a still further modified form of my control apparatus, and

Figure 4 is another modification of my control apparatus, this modification being shown in connection with a burner control system.

Referring to the drawings, the control apparatus of the present invention is shown as located within a housing 10. This housing may be of any suitable material, being preferably of metal. Disposed within the housing is a step-up, step-down transformer 12 having a line voltage primary 13, low voltage secondary windings 14 and 15, and high voltage secondary windings 16 and 17. The primary winding 13 is connected to terminals 19 and 20 which in turn are connected by conductors 21 and 22 to line wires 23 and 24 leading to any suitable source of power (not shown). The low voltage secondary winding 14 is employed for energizing auxiliary apparatus to be controlled by the control apparatus. The low voltage secondary winding 15 and the high voltage windings 16 and 17 are employed to energize the various elements of the control device. As far as the apparatus of the present invention is concerned, the transformer 12 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 be in turn connected to some primary source of power.

A relay 25 comprises a relay coil 26 and a switch blade 27 adapted to engage a fixed switch contact 28. The switch blade 27 is associated with an armature 29. The switch blade and armature are normally biased by gravity or any other suitable means away from switch contact 28. Upon coil 26 being energized, switch blade 27 is moved against its bias into engagement with switch contact 28.

A condenser 31 is connected by conductors 32 and 33 in parallel with relay coil 26. Condenser 31 acts as a shunt condenser to eliminate any pulsations in the current flowing through relay coil 26.

The energization of relay coil 26 is controlled by an electronic discharge device 36. This device comprises a conventional envelope 37 which encloses the various electrodes. The control device 36 is one which normally comprises two

triodes. A double cathode 38 serves to form a cathode element for each of the two triodes. Associated with this cathode are a pair of heater elements 39 and 40 which are connected in parallel. The first triode comprises cathode element 38, a grid 41, and a plate 42. A second triode is constituted by the cathode 38, a grid 44, and a plate 45. Since the control apparatus of the present invention does not require the use of two triodes, the anode 45 is not employed. This anode is merely shown because in a conventional tube having two control grids such an anode would be present. The triode consisting of cathode 38, anode 42, and grid 41 is preferably of the type which is designed to operate with an anode voltage of such a magnitude that the triode conducts current whenever the grid potential is above a predetermined value negative with respect to the cathode. In other words, this triode is of the conventional type normally operated with a "negative cut off point."

The heater elements 39 and 40 are connected by conductors 46, 47, 48 and 49 across the secondary 15. Secondary 15 thus serves to constantly energize the heater elements 39 and 40.

Resistors 48 and 49, and a condenser 50 form the elements of a filter network between the grid 41 and the cathode 38, as will be more fully explained later. A protective resistor 51 is connected in series with grid 44. The numeral 52 is employed to designate a condenser which is employed to control the potential of grid 41.

The secondary 16, a condenser 54, and a choke coil 55 constitute the elements of a phase shifting network. The condenser 54 and choke coil 55 are connected to secondary 16 by conductors 57, 58, 59, and 60. The voltage between the junction of conductors 58 and 59 and the lower terminal of secondary 16 leads in phase the voltage between the upper and lower terminals of secondary 16 by 90°.

The relay 25 is illustratively shown as controlling an electrically operated gas valve 63. 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 63 controls the flow of gas through a pipe 64 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 reference numeral 68. The pilot burner 67 is connected to ground as indicated at 69. The pilot burner is supplied with gas by a pipe 70 which is connected to the gas supply pipe 64 at a point on the upstream side of valve 63 so that the pilot burner 67 is normally constantly supplied with gas and hence normally constantly burning. A flame electrode 72 is located so as to extend into the path of pilot flame 68. This flame electrode is connected by conductors 73, terminal 74, and conductor 75 to the junction of conductors 58 and 59.

The energization of valve 63 is not only controlled by relay 25 but also by a room thermostat 77. This room thermostat is of conventional construction and comprises a bimetallic element 78 to which is attached a contact arm 79. The contact arm 79 is adapted to be moved by the bimetallic element 78 into and out of engagement with a contact 80. As indicated by the legends "C" and "H," bimetallic element 78 is effective upon a drop in temperature to move the contact arm 79 to the left into engagement with contact 80. Upon a rise in temperature, it is adapted to move the contact arm 79 to the right out of engagement with contact 80. A magnet 81 is

associated with contact arm 79 to impart a snap action to the contact arm and to cause a suitable differential to exist between the temperature at which the contact arm 79 engages contact 80 and that at which it separates from contact 80.

The following are values which can be employed in a specific embodiment of the invention: Windings 16 and 17 may each be designed so that they produce voltages of approximately 300 volts. The secondary 15 can be designed to have a voltage output of approximately 12 volts. The winding 14 is preferably a 24-volt winding. In the same embodiment, the resistors 48 and 49 can be one and two megohm resistors respectively. The condensers 50 and 52 can be .02 microfarad condensers and the condenser 31 is preferably an 0.5 microfarad condenser. The resistor 51 may be a five megohm resistor. The values of condenser 54 and choke coil 55 are so selected as to give substantially equal impedances for current of the available frequency. It is to be understood that these values are merely illustrative values which can be varied over a wide range and that the invention is not in any way limited to the use of elements having these values.

OPERATION OF FIGURE 1

When pilot burner is extinguished

The various elements are shown in the position which they occupy when the pilot burner 67 is extinguished and when the temperature adjacent room thermostat 77 is at or above the desired value so that the thermostat 77 is "satisfied." Under these conditions, the following charging circuit to condenser 52 is active: from the upper terminal of secondary 15 through conductors 82 and 83, condenser 52, conductors 84 and 86, resistor 51, grid 44, cathode 38, and conductors 87, 88, 92 and 96 to the lower terminal of secondary 15. The flow of current through this circuit is only in the direction traced due to the rectifying action of the grid 44 and cathode 38. The effect of the current flow through condenser 52 in the direction traced is to cause a unidirectional voltage to be impressed across condenser 52. The polarity of this voltage is such that the right hand terminal of condenser 52 is negative and the left hand end positive. The right hand terminal of condenser 52 is connected by conductors 84, 86, resistors 48 and 49, and conductor 91 to grid 41. The left hand end of condenser 52 is connected by conductors 83 and 82, the secondary 15, and conductors 96, 92, 88 and 87 to the cathode 38. In other words, the right hand terminal of condenser 52 is a grid terminal and the left hand end a cathode terminal. Since the right hand terminal of condenser 52 is a terminal which is negative, it will be obvious that the result of this unidirectional voltage across condenser 52 is to bias grid 41 negatively.

This action is aided by secondary 16. It is to be noted that the upper terminal of secondary 15 is connected to the grid 41 through condenser 52. The lower terminal is connected to the cathode. The lower terminal is also connected by conductors 98, 99, and 100 to the upper terminal of secondary 17. The lower terminal of secondary 17 is connected by conductor 97, relay coil 26, and conductor 98 to the anode 42. The potential of the upper terminal of secondary 15 is thus displaced 180° in phase with respect to the lower terminal of secondary 17 to which the anode 42 is connected. Hence, the voltage introduced into the connection of the left hand terminal of condenser 52 to grid 41 by cathode 15

is 180° out of phase with respect to the anode voltage. Hence, the tendency of this voltage, to the extent that it is applied to grid 41 through the filter network, is to aid the charge on condenser 52 and to bias grid 41 further negatively. The cumulative result of the charge on condenser 52 and this out of phase voltage introduced by secondary 15 is to bias the grid 41 below the cut off potential or at least sufficiently close to it that insufficient current flows through relay coil 26 to energize the relay effectively. The charging of condenser 52 occurs not only through the circuit traced above but also through the following circuit: from the upper terminal of secondary 15 through conductors 82 and 83, condenser 52, conductors 84 and 90, resistors 48 and 49, conductor 91, grid 41, cathode 38, and conductors 88, 92, and 96 back to the lower terminal of secondary 15. It will be noted that this circuit relies upon the rectifying effect of grid 41 and cathode 38. The current flow through this circuit is somewhat less, however, than that previously traced due to the presence of resistors 48 and 49. Thus, while both the grids 41 and 44 act as elements in rectifying circuits for charging condenser 52, the charging is accomplished principally through the first mentioned circuit including grid 44 and cathode 38.

As previously noted, the resistors 48 and 49 and condenser 50 function as elements of a filter system. It is to be noted that condenser 50 is connected by conductors 93 and 94 between the junction of resistors 48 and 49 connected to the grid 41 and conductor 87 leading to the cathode 38. It will be readily apparent that condenser 50 functions in the usual manner of a shunt condenser of a filter network to tend to filter out any alternating current voltage impulses that might otherwise be applied to grid 41.

It will be seen from the foregoing description that as long as a flame is absent, the grid 41 is biased negatively below the cut off point as the result of a charge impressed on condenser 52. As a result, the triode comprising cathode 38 and anode 42 is not conductive. As will presently be explained, this makes it impossible to cause energization of gas valve 63.

When flame is present

As soon as the pilot burner 67 is ignited so that flame 68 is present, a new charging circuit is established to condenser 52. This charging circuit is as follows: from the junction of conductors 58 and 59 of the phase shifting network through conductor 75, terminal 74, conductor 73, flame electrode 72, flame 68, burner 67, ground connections 69 and 95, conductors 85 and 84, condenser 52, conductors 83 and 82, secondary 15, and conductors 98, 92, and 99 to the lower end of the secondary 15 of the phase shifting bridge. It will be noted that the above circuit was traced through the flame in a direction opposite to flame propagation. It has been found that the on flow through a flame is greatest in the direction of flame propagation. In other words, the conventional current flow through a flame is greater in the direction opposite to flame propagation. Hence, while current may flow through flame 68 in both directions the current flow is much greater in the direction traced. As a result, there is a definite direct current component in the current flowing through condenser 52 with the result that condenser 52 tends to be charged as a result of this current flow. It will be noted

that the last traced circuit was traced through condenser 52 in a direction opposite to that traced in connection with the first circuit. In other words, the effect of the current flow through the last traced circuit is to impress across condenser 52 a charge such as to make the right hand terminal of condenser 52 positive and the left hand terminal negative. As previously pointed out, the right hand terminal of condenser 52 is the grid terminal and the left hand end the cathode terminal. Thus, the tendency of the current flow through the last traced circuit including the flame is to raise the potential of the grid with respect to the cathode. The constants of the circuit are so selected that when a flame is present in the flame gap, this increase in the potential of the grid is sufficient to raise the grid potential appreciably above the cut off value so that the triode including cathode 38 and plate 42 becomes conductive. When this happens, it is possible for a circuit to be established through relay coil 26 as follows: from the lower end of secondary 17 through conductor 97, relay coil 26, conductor 98, anode 42, cathode 38, and conductors 87, 88, 92, 99, and 100 to the upper terminal of secondary 17. The current flow through relay coil 26 as a result of the circuit just traced causes energization of relay coil 26 so as to move switch blade 27 into engagement with contact 28. This makes possible the establishment of a circuit to gas valve 63 under the control of room thermostat 77.

Let it now be assumed that the room thermostat 77 calls for burner operation; that is, that contact arm 79 is moved into engagement with contact 80. When this happens, the following circuit is established to gas valve 63; from the upper terminal of secondary 14, through conductor 101, terminal 102, conductor 103, bimetallic element 78, contact blade 79, contact 80, conductor 104, terminal 105, conductor 106, terminal 107, conductor 108, gas valve 63, conductor 109, terminal 110, conductor 111, switch blade 27, contact 28, and conductor 112, to the other terminal of secondary 14. The energization of gas valve 63 causes it to move to open position permitting gas to flow through pipe 64 to the main burner 66. Since it has already been assumed that the pilot burner 67 is burning, it is certain that main burner 66 will be properly ignited.

Normally the burner 66 will remain ignited until the thermostat 77 becomes satisfied. When this happens, the contact arm 79 separates from contact 80 thus interrupting the energizing circuit to valve 63 and causing valve 63 to close.

If at any time during the operation of the system, the pilot burner 67 is extinguished, the control device of the present invention is effective to cause almost immediate closure of main gas valve 63. As soon as the pilot flame 68 is interrupted, current can no longer flow through the last traced charging circuit for condenser 52. As a result, the only charging circuit for condenser 52 is the one first traced. It will be recalled that the effect of this charging circuit is to produce a charge across condenser 52 which biases the grid 41 below the effective cut off potential. The time required for charging this condenser is extremely small. Thus, almost immediately after the pilot flame 68 is extinguished, the potential of grid 41 is lowered to a value such that the burner relay 25 is deenergized. This causes an interruption of the circuit to main gas valve 63 so as to terminate the flow of gas to the main burner 66.

When flame gap is bridged by high resistance impedance

It occasionally may happen that the flame gap becomes bridged accidentally. One difficulty which is occasionally encountered is that carbon builds up on the flame electrode 68 to the point where the carbon either engages the burner 67 or is separated from burner 67 so slightly that the impedance between the flame electrode and the burner is substantially below the open circuit impedance and may even be very close to the flame impedance. It is obvious that the flame responsive apparatus should not respond to the presence of such an impedance in the same manner as it does to a flame. My present apparatus is particularly designed to distinguish between such a high resistance impedance and a flame.

It will be recalled that the charging of condenser 52 in the direction opposite to that in which it is charged by the biasing circuits depended upon the rectifying effect of flame 68. Any normal impedance bridging the flame gap is not rectifying in effect. Under such circumstances, accordingly, the current flow through the condenser 52 as a result of the last traced circuit is the same in both directions so that the only voltage impressed upon condenser 52 as a result of such current flow is an alternating voltage. Such an alternating voltage in no way affects the direct current potential. Furthermore, this alternating voltage has such a phase relation with respect to the voltage applied to the anode circuit that it tends to further lower the potential of grid 41, as will be pointed out presently. This later effect is more pronounced when the impedance between flame gap 72 and burner 67 is relatively low in magnitude.

When substantial short circuit exists across flame gap

Under certain circumstances, a substantial short circuit condition can exist between the flame gap and the burner 67. A typical condition is that which occurs when the flame electrode becomes unduly heated and softens so as to bend down and touch the burner 67. Under these conditions, the impedance between the electrode 72 and the burner 67 is relatively small. When this happens, the current flow through condenser 52 as a result of the circuit to the flame gap becomes very substantial. Or, viewed in another light, the impedance between the grid terminal of condenser 52 and the junction of conductors 58 and 59 becomes relatively low. The effect of this is to cause grid 41 to tend to assume the potential of the junction of conductors 58 and 59. Several other factors must be considered, however, in determining the potential which is applied to grid 41 under these circumstances. It is to be noted that the junction of conductors 84 and 85 to which grid 41 is connected is also the junction of a connection involving condenser 52 and the impedance between flame gap 72 and burner 67. In other words, the grid is connected to the junction of two conductive legs one of which contains the capacity of impedance of condenser 52 and the other of which contains the resistive impedance of the flame gap. The condenser and the impedance of the flame gap constitute, in effect, a phase shifting bridge. As long as the value of the impedance between flame electrode and burner 67 is comparatively high, the effect of this phase shifting action is not serious. As it becomes lower, however, a more pronounced

phase shifting action takes place. If the grid were connected directly to the upper end of secondary 16 and if the condenser 52 were not present, the grid would be at a potential 180° displaced from the potential of anode 42. This would be desirable but is not possible in view of condenser 52. Due to the presence of condenser 52 and the resultant phase shifting action, the grid 41 would no longer be at a potential 180° displaced from that of the anode unless a phase shifting bridge was provided. The phase shifting bridge including condenser 54 and choke coil 55 operates to cause the voltage between the junction of conductors 58 and 59 and the lower end of secondary 16 to lead that between the upper and lower terminals of secondary 16. This lead in the voltage compensates for the lag in the voltage introduced by the presence of condenser 52. The result is that the two phase shifting actions cancel each other so that grid 41 tends to be maintained at a potential substantially 180° displaced from the anode potential. Thus, as the impedance between flame electrode 72 and burner 67 decreases, the potential of grid 41 is lowered as a result of the out of phase alternating voltage applied to the grid by the connection through the flame gap to the phase shifting bridge.

It will be seen that I have provided a control mechanism which operates under all circumstances to distinguish between a rectifying and non-rectifying impedance without the use of a second triode. In the above operation, the anode 45 plays no part whatsoever and could be omitted in a tube especially designed for applicant's control mechanism.

SPECIES OF FIGURE 2

The species of Figure 2 is similar to that of Figure 1 with the exception of the type of phase shifting bridge that is employed. Since the gas valve 63, the gas burner 66, and the thermostat 77 are all identically the same in structure and in the manner in which they cooperate with the control apparatus, these elements have not been shown in Figure 2. To further enable a more ready comparison of the arrangements of Figure 2 and Figure 1, identical reference characters have been applied in the two figures to corresponding elements. Those elements which correspond to elements of Figure 1 and whose function is readily apparent from the foregoing description of Figure 1 are not described again in connection with Figure 2.

In the present species, the transformer 12 not only comprises the secondaries 14, 15, and 17, but also a center tapped secondary 116 which takes the place of secondary 16 in the species of Figure 1. The cathode 38 is connected by conductors 87, 88, and 89 to the center tap 118 of this secondary 116. Associated with the secondary 116 are a condenser 120 and a resistor 121. The condenser 120 and resistor 121 are connected by conductors 122, 123, 124, and 125 between the opposite terminals of secondary 116. The secondary 116 together with the condenser 120 and the resistor 121 constitutes a phase shifting bridge, the output terminals of which are the center tap 118 and the junction of conductors 123 and 124. The voltage existing between the junction of conductors 123 and 124 and the center tap 118 is displaced 90° in phase from the potential between the upper and lower terminals of secondary 116, the potential difference across the junctions of the phase shifting bridge leading the potential difference between the terminals of secondary 116. In other

words, the voltage between the output terminals of the phase shifting bridge of this species leads the supply voltage by the same amount as the output voltage of the phase shifting bridge of the species of Figure 1. The essential difference between the two phase shifting bridges is that in the species of Figure 1, a condenser and inductance combination is employed, while in that of Figure 2 a condenser-resistor combination is employed. While the condenser-inductance combination gives a greater phase shift, the phase shift resulting from the phase shifting network of Figure 1 is only 90° because of the fact that a center tapped secondary is not employed.

Referring again to Figure 2, the lower terminal of secondary 15 is connected by conductors 126, 127 and 128 to conductor 89 which, as previously noted, is connected to the cathode 38. The upper terminal of secondary 15 is connected through conductors 82 and 83 with condenser 52.

It is believed that the operation of the species of Figure 2 will be readily apparent in view of the foregoing description. When there is no flame, a charging circuit is established through condenser 52 as follows: from the upper terminal of secondary 15 through conductors 82 and 83, condenser 52, conductors 84 and 86, resistor 51, grid 44, cathode 38, and conductors 87, 88, 128, 127, and 126 back to the other terminal of secondary 15. Due to the rectifying action of grid 44 and cathode 38, the current flow takes place through condenser 52 only in the direction traced so that a direct current potential is impressed across condenser 52, the polarity of this potential being such that the right hand end of condenser 52 is negative and the left hand end positive. Since condenser 52 is connected to grid 41 in the same manner as in Figure 1, it will be obvious that the tendency of this charge is to impress a negative voltage on grid 41. This voltage is furthermore aided by the alternating potential across secondary 15. It is to be noted that, as in Figure 1, the voltage phase of this voltage with respect to the cathode 38 is displaced 180° from the voltage applied to the anode by secondary 17. Thus, in the absence of a flame, the grid is biased negatively below the cut off point so that insufficient current can flow through the relay coil 26 to cause energization of the same.

Upon flame being established, an energizing circuit is established from the junction of conductors 123 and 124 through conductor 75, terminal 74, conductor 73, burner electrode 72, burner flame 68, burner 67, ground connections 69 and 95, conductors 85 and 84, condenser 52, conductors 83 and 82, secondary 15, and conductors 126, 127, 128, and 89 to the center tap 118 of the secondary 116. The output voltage of the phase shifting bridge is thus applied to the flame electrode circuit just as in the species of Figure 1. As a result of the application of this voltage and the rectifying action of the flame, a direct current voltage is applied to the condenser 52, which voltage is opposite to the voltage produced by the previously traced charging circuit. Thus, the potential of grid 41 is raised sufficiently to cause energization of relay coil 26 so as to permit the establishment of an energizing circuit to gas valve 63.

In the event of the flame gap being short circuited, the operation is again substantially the same as in Figure 1. In the first place, the impedance bridging the flame gap has no rectifying effect so that there is no tendency for condenser 52 to be charged in a direction opposite to which

it is charged by the biasing circuits. In the second place, the establishment of a non-rectifying impedance connection across the flame gap tends to cause the grid 41 to assume an alternating potential 180° out of phase with the anode potential. As with the species of Figure 1, the phase shifting tendency of condenser 52 and the impedance across the flame gap is compensated for by the phase shifting effect of the phase shifting bridge including condenser 120 and resistor 121.

SPECIES OF FIGURE 3

The species of Figure 3 is similar to that of Figure 1 as far as the phase shifting bridge is concerned. However, in this species, instead of employing the rectifying effect of the grid and cathode of a second triode, a tube having an auxiliary anode, commonly referred to as a diode, is employed. A second condenser connected in series with this diode and the cathode is charged through the rectifying action of the diode and cathode and furnishes a constant source of biasing potential.

The transformer 12 in this case comprises the primary winding 13 and the low voltage secondary windings 14 and 15 as in the case of Figure 1. It also comprises high voltage windings 16 and 17. In addition, a low voltage winding 140 is provided for the purpose of energizing the cathode heater.

As in Figure 1, the secondary 16 is employed as the power supply of a phase shifting bridge. Connected across the terminals of this bridge in series with each other are a condenser 54 and a choke coil 55.

The electronic amplifier in the present species is designated by the reference numeral 145. This amplifier comprises an envelope 146, an anode 147, a grid 148, a cathode 149, and a diode 150. Associated with the cathode 149 is a cathode heater 152 which is connected by conductors 154 and 155 with the terminals of secondary 140.

In addition to the condenser 52 of the species previously described, there is also provided in this species a further condenser 156.

The condenser 156 is charged as a result of the following charging circuit: from the lower terminal of secondary 15 through conductor 158, diode 150, cathode 149, conductors 87, 88, and 159, condenser 156, and conductor 82 back to the upper terminal of secondary 15. Due to the rectifying action of the diode and cathode, the current flow through this circuit takes place only in the direction just traced. This direction of current flow is such as to cause a unidirectional voltage to be built up across condenser 156 of a polarity such that the right hand terminal of condenser 156 is positive and the left hand terminal negative. The right hand terminal of condenser 156 is connected through conductors 159, 88, and 87 to the cathode 149. The left hand terminal is connected through conductor 83, condenser 52, conductors 84 and 90, resistors 48 and 49, and conductor 91 to grid 48. In other words, the right hand end of condenser 156 is the cathode terminal and the left hand terminal the grid terminal. The effect, accordingly, of the charge just referred to is to bias grid 48 negatively with respect to cathode 149. The various elements of the system are so selected that the magnitude of this bias is sufficient to bias the grid below the cut off point or at least sufficiently close thereto that the relay coil 26 is not adequately energized.

Upon the establishment of flame, a charging circuit through condenser 52 is established. This charging circuit is from the junction of conduc-

tors 58 and 59 through conductor 75, terminal 74, conductor 73, flame electrode 72, flame 68, burner 67, ground connections 69 and 95, conductors 85 and 84, condenser 52, conductor 83, condenser 156, conductor 159, and conductor 89, to the lower terminal of secondary 16 of the phase shifting bridge. As was explained in connection with the previous species, due to the rectifying action of the flame, the current flow through the circuit just traced takes place to a greater extent in the direction traced than in the opposite direction. The result of this current flow is that the condenser 52 becomes charged with a voltage of such polarity that the right hand terminal of condenser 52 is positive with respect to the left hand terminal. Furthermore, this positive charge on condenser 52 is sufficient in magnitude to overcome the voltage across condenser 156 sufficiently to raise the potential of grid 148 substantially above the cut off point. As a result, the relay coil 26 is energized through the following circuit: from the lower terminal of secondary 17 through conductor 97, relay coil 26, conductor 98, anode 147, cathode 149, and conductors 87, 88, 159, and 160, to the other terminal of secondary 17.

The action of the phase shifting bridge is substantially the same as with the previous species. Were conductor 75 connected directly to the upper terminal of secondary 16, a definite phase shifting action would exist whenever a non-rectifying impedance were connected in the flame gap. It is to be noted that the grid 148 is connected to the junction of conductors 84 and 85. Conductor 84 is connected through condensers 52 and 156 in series to the lower terminal of secondary 16. Conductor 85 is, on the other hand, connected through ground connections 95 and 69 and through the impedance of the flame gap to the conductor 75. Were conductor 75 connected to the upper end of the secondary 16, the result would be that there would be a phase shifting bridge with the resistive impedance of the flame gap in one leg and the capacitive impedance of condensers 52 and 156 in the other leg. This phase shifting effect becomes particularly marked whenever the flame gap is bridged by a non-rectifying impedance, particularly one with a relatively low impedance value. By interposing the phase shifting bridge consisting of condenser 54 and choke 55, however, this phase shifting action of condenser 156 and the impedance of the flame gap is counter-acted so that the tendency of the connections including the conductor 75 and the flame gap is to maintain the grid at a potential 180° displaced in phase with respect to the anode potential. In this way, it is assured that whenever the flame gap is bridged by a non-rectifying impedance, the potential of grid 148 will be lowered sufficiently that the relay coil 26 will not be energized.

It will be seen that the species of Figure 3 is substantially the same in principle as that of Figure 1 but eliminates the need of a second triode. Furthermore, by reason of the relatively large current capacity of the diode-cathode rectifying path, it is assured that a relatively constant source of biasing potential is available.

SPECIES OF FIGURE 4

The species of Figure 4 differs from that of Figures 1 and 3 in that it employs merely a single triode and depends upon the rectifying effect of the grid and cathode of this single triode to provide the biasing potential.

The transformer 12 in this case comprises a line voltage primary 13, a low voltage secondary 14, a center tapped high voltage winding 170, and a low voltage filament secondary 174. The secondary 170 is provided with a center tap 171 and a tap 172 displaced slightly from the center tap. A condenser 175 and a resistor 176 are connected between opposite terminals of the secondary 170 by conductors 177, 178, 179, and 180.

The electronic amplifier in this species is designated by the reference numeral 184. This amplifier is a conventional type of triode amplifier having an anode 186, a grid 187, and an indirectly heated cathode 188. The heater 189 of the cathode is connected by conductors 190 and 191 to the secondary 174.

A charge is normally maintained on condenser 52, this charge being of such a polarity that the grid 187 is maintained at a potential close to or below the cut off potential. This charge is established by the following circuit: from the tap 172 through conductor 195, condenser 52, conductor 196, resistor 197, conductor 198, grid 187, cathode 188, and conductor 199, to the center tap 171 of secondary 170. Due to the rectifying action of the grid and cathode, the flow of current through the circuit just traced takes place only in the direction traced. This direction is such that the right hand end of condenser 52 becomes charged negatively and the left hand end positively. The result is that the potential of grid 187 with respect to cathode 188 is lowered to a value close to or below the cut off potential. The operation under no flame conditions may be explained in another manner. It is to be noted that the tap 172 is on the opposite side of tap 171 from the lower terminal of secondary 170 to which anode 186 is connected. Thus, when anode 186 is positive with respect to cathode 188, the tap 172 is negative with respect to the cathode 188. The condenser 52 and resistor 197 thus connect the grid 187 with a point of such voltage phase that when the anode is positive with respect to the cathode, this connection tends to render the grid negative. Viewed in either light, the result is that the grid is sufficiently negative with respect to the cathode under no flame conditions so that insufficient current flows through relay coil 26.

Upon the occurrence of a flame, a conductive path is established through condenser 52 as follows: from the junction of conductors 178 and 179 through conductor 75, terminal 74, conductor 73, flame electrode 72, burner flame 68, burner 67, ground connections 69 and 95, conductor 196, condenser 52, and conductor 195 to terminal 172 of secondary 170. Due to the rectifying action of the flame, a greater current flow through condenser 52 takes place in the direction traced so that there tends to be impressed across condenser 52 a voltage of such polarity that the right hand terminal of condenser 52 is positive and the left hand terminal, negative. This positive voltage is in effect connected in series with the alternating potential of that portion of the secondary 170 between taps 171 and 172. The magnitude of the positive voltage across condenser 52 due to flame rectification is large enough to cause the potential of grid 187 to be raised sufficiently above the cut off point. As a result, current flows from the lower end of secondary 170 through conductor 97, relay coil 26, conductor 98, anode 186, cathode 188, and conductor 199 back to the center tap 171 of secondary 170.

The condenser 175 and resistor 176 cooperate with secondary 170 to provide a corrective phase

shifting action as in the previous species. Were conductor 79 connected to the upper terminal of secondary 170, the grid 187 would be connected to the junction of two legs of a phase shifting bridge, one leg of which would include condenser 52 and the other leg the impedance across the flame gap. When this impedance is non-rectifying and of appreciably low value, the shift in phase, due to this phase shifting bridge, would become of importance. By providing the phase shifting bridge consisting of secondary 170, condenser 175, and resistor 176 and by connecting the flame electrode to an output terminal of this phase shifting bridge, it is possible to have a corrective phase shifting action which compensates for the undesirable phase shifting action just referred to.

In a typical embodiment of the invention of Figure 4, each half of secondary winding 170 had an output voltage of 300 volts. The resistor 197 had a resistance value of one megohm. A condenser of approximately .02 microfarad capacity is employed for condenser 52. In the same embodiment, tap 172 is spaced by a voltage of 24 volts from the voltage of center tap 171.

CONCLUSION

It will be seen that I have provided a control mechanism designed for detecting the presence or absence of a rectifying impedance which does not involve the use of two triodes. Furthermore, by the use of a phase shifting network, I am able to obtain a controlled corrective phase shift which does not vary erratically depending upon certain operating conditions, which have no relation to the amount of phase shift necessary.

Although in the illustrated embodiments of my invention, I have shown the rectifying impedance to be a burner flame, it is to be understood that other rectifying impedances may be employed even where the mechanism is controlled as a burner control device. For example, a flame gap may be replaced by a photoelectric cell exposed to the burner flame. Such a photoelectric cell permits current flow in only one direction and allows such current flow to take place only when the photoelectric cell has been exposed to a source of illumination. Accordingly, where the expression "means responsive to a burner flame" is employed in the claims, it is to be understood that this expression is sufficiently broad to cover either a flame gap or a photoelectric cell.

In general, while I have shown certain specific embodiments of my invention, it is to be understood that this is for purposes of illustration and that my invention is to be limited solely by the scope of the appended claims.

I claim as my invention:

1. In combination, a phase shifting network including a source of alternating power, an electronic discharge amplifier having an anode, a cathode, and a control electrode, a connection between said control electrode and said phase shifting network, the potential of the point of connection with said phase shifting network being such that said connection tends to cause said control electrode to be maintained at a value at which said amplifier is effectively non-conductive, said connection having a gap therein adapted to be bridged by an impedance, and means associated with said connection and responsive to the direct current flowing across the terminals of said gap when said gap is bridged by a rectifying impedance to cause the potential of the control electrode to assume a value at which said amplifier is effectively conducting.

2. In combination, a phase shifting network including a source of alternating power, an electronic discharge amplifier having an anode, a cathode, and a control electrode, a connection between said control electrode and said phase shifting network, the potential of the point of connection with said phase shifting network being such that said connection tends to cause said control electrode to be maintained at a value at which said amplifier is effectively non-conductive, said connection having a gap therein adapted to be bridged by an impedance, and a condenser associated with said connection and effective when said gap is bridged by an impedance rectifying in the direction of the control electrode to become charged so as to impress a potential on the control electrode of a value at which said amplifier is effectively conducting.

3. In combination, a phase shifting network including a source of alternating power and two impedance elements of different phase affecting characteristics, an electronic discharge amplifier having an anode, a cathode, and a control electrode, a connection between said control electrode and the junction of said two impedances of said phase shifting network, the potential of said junction being such that said connection tends to cause said control electrode to be maintained at a value at which said amplifier is effectively non-conductive, said connection having a gap therein adapted to be bridged by an impedance, and means associated with said connection and responsive to the direct current flowing across the terminals of said gap when said gap is bridged by a rectifying impedance to cause the potential of the control electrode to assume a value at which said amplifier is effectively conducting.

4. In combination, a source of alternating power, an electronic discharge amplifier having an anode, a cathode, and a control electrode, a connection between said control electrode and said source of power, said connection having a gap therein adapted to be bridged by an impedance, said connection tending whenever the impedance across the gap is non-rectifying to cause said control electrode to assume a value at which said amplifier is effectively non-conductive, reactance means associated with said connection and effective when said gap is bridged by an impedance rectifying in the direction of said control electrode to cause the potential of the control electrode to assume a value at which said amplifier is effectively conducting, and a phase shifting network in said connection compensating for the phase shifting effect of said impedance and said reactance.

5. In combination; an electrically operated control device whose energization is to be controlled in accordance with the presence or absence of a burner flame; a source of alternating power; an electronic discharge amplifier controlling the energization of said control device, said amplifier comprising an anode, a cathode, and a control electrode; a connection between said control electrode and said source of power; said connection having a gap therein adapted to be bridged by a burner flame with the conductive path to said control electrode being opposite to the direction of propagation of said flame; reactance means associated with said connection and effective when said gap is so bridged by a burner flame to assume a value at which said amplifier is effective to energize said control device; said connection tending whenever the gap is bridged by a non-rectifying impedance to cause said control

electrode to assume a value at which said amplifier is effectively non-conductive; and a phase shifting network in said connection compensating for the phase shifting effect of said impedance and said reactance so as to increase said last described tendency of said connection.

6. In combination; a phase shifting network including a source of alternating power, a condenser, and a resistance; an electronic discharge amplifier having an anode, a cathode, and a control electrode; a connection between said control electrode and the junction of said resistor and condenser, the potential of said junction being such that said connection tends to cause said control electrode to be maintained at a value at which said amplifier is effectively non-conductive, said connection having a gap therein adapted to be bridged by an impedance; and means associated with said connection and responsive to the direct current flowing across the terminals of said gap when said gap is bridged by a rectifying impedance to cause the potential of the control electrode to assume a value at which said amplifier is effectively conducting.

7. In combination; a phase shifting bridge including a center tapped source of alternating power, a capacitive reactance, and an inductive reactance; an electronic discharge amplifier having an anode, a cathode, and a control electrode; a connection between the center tap of said source of power and said cathode; a connection between said control electrode and the junction of said two reactances of said phase shifting bridge, the potential of said junction with respect to that of said anode being such that said last named connection tends to cause said control electrode to be maintained at a value at which said amplifier is effectively non-conductive, said last named connection having a gap therein adapted to be bridged by an impedance; and means associated with said last named connection and responsive to the direct current flowing across the terminals of said gap when said gap is bridged by a rectifying impedance to cause the potential of the control electrode to assume a value at which said amplifier is effectively conducting.

8. In combination; a phase shifting network including a center tapped source of alternating power, a capacitive reactance, and an inductive reactance; an electronic discharge amplifier having an anode, a cathode, and a control electrode; a first connection between the center tap of said source of power and said cathode; a second connection between one terminal of said source of power and said anode; a third connection between said control electrode and the junction of said two reactances of said phase shifting bridge, the potential of said junction with respect to the terminal to which said anode is connected being such that said third connection tends to cause said control electrode to be maintained at a value at which said amplifier is effectively non-conductive, said third connection having a gap therein adapted to be bridged by an impedance; and means associated with said last named connection and responsive to the direct current flowing across the terminals of said gap when said gap is bridged by a rectifying impedance to cause the potential of the control electrode to assume a value at which said amplifier is effectively conducting.

9. In combination; an electronic amplifier having an anode, a cathode, and a control electrode; a source of alternating power; two connections between said control electrode and said source of

power, each of which tends to cause said control electrode to assume a potential at which said amplifier is effectively non-conducting; a first of said connections comprising a reactance; a second of said connections having a gap adapted to be bridged by an impedance; said reactance being effective when said impedance is rectifying in the direction of the control electrode to cause the potential of said control electrode to assume a value at which said amplifier is conductive despite both of said connections; and means in said second connection tending to overcome the phase shifting effect of said impedance and said reactance.

10. In combination; an electronic amplifier having an anode, a cathode, and a control electrode; a source of alternating power; two connections between said control electrode and said source of power, each of which tends to cause said control electrode to assume a potential at which said amplifier is effectively non-conducting; a first of said connections comprising a reactance; a second of said connections having a gap adapted to be bridged by an impedance; said reactance being effective when said impedance is rectifying in the direction of the control electrode to cause the potential of said control electrode to assume a value at which said amplifier is conductive despite both of said connections; and a phase shifting network in said second connection compensating for the phase shifting effect of said impedance and said reactance.

11. In combination; an electronic amplifier having an anode, a cathode, and a control electrode; a source of alternating power; two connections between said control electrode and said source of power, each of which tends to cause said control electrode to assume a potential at which said amplifier is effectively non-conducting; a first of said connections comprising a condenser; a second of said connections having a gap adapted to be bridged by an impedance; said condenser being effective when said impedance is rectifying in the direction of the control electrode to become charged in such a manner as to cause the potential of said control electrode to assume a value at which said amplifier is conductive despite both of said connections; and a phase shifting network in said second connection compensating for the phase shifting effect of said impedance and said condenser.

12. In combination; an electrically operated control device whose energization is to be controlled in accordance with the presence or absence of a burner flame; an electronic amplifier controlling the energization of said control device, said amplifier having an anode, a cathode, and a control electrode; a source of alternating power; two connections between said control electrode and said source of power, each of which tends to cause said control electrode to assume a potential at which said amplifier is effectively non-conducting; a first of said connections comprising a condenser; a second of said connections having a gap adapted to be bridged by means responsive to a flame and acting as a rectifying impedance when exposed to a flame; said condenser being effective when said flame responsive means is exposed to a flame and is rectifying in the direction of the control electrode to become charged in such a manner as to cause the potential of said control electrode to assume a value at which said amplifier is conductive despite both of said connections; and a phase shifting network in said second connection compensating for the phase

shifting effect of said impedance and said condenser.

13. In combination; an electrically operated control device whose energization is to be controlled in accordance with the presence or absence of a burner flame; an electronic amplifier controlling the energization of said control device, said amplifier having an anode, a cathode, and a control electrode; a source of alternating power; two connections between said control electrode and said source of power, each of which tends to cause said control electrode to assume a potential at which said amplifier is effectively non-conducting; a first of said connections comprising a condenser; a second of said connections having a gap adapted to be bridged by a burner flame with the conductive path to said control electrode being opposite to the direction of flame propagation; said condenser being effective when said gap is so bridged by a burner flame to become charged in such a manner as to cause the potential of said control electrode to assume a value at which said amplifier is conductive despite both of said connections; and a phase shifting network in said second connection compensating for the phase shifting effect of said impedance and said condenser.

14. In combination; an electronic discharge amplifier comprising an anode, a cathode, and a control electrode; a source of alternating power; a reactance element connected to said control electrode to affect the potential applied thereto; first and second circuits for causing a unidirectional voltage drop across said reactance; said first circuit including a rectifier so disposed as to cause a voltage drop across said reactance element of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said previously named rectifier, so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said reactance and a phase shifting network having a phase shifting effect which compensates for the phase shifting effect present by reason of said reactance when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

15. In combination; an electronic discharge amplifier comprising an anode, a cathode, and a control electrode; a source of alternating power; a condenser connected to said control electrode to affect the potential applied thereto; first and second circuits for charging said condenser; said first circuit including a rectifier so disposed as to cause a charge across said condenser of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said previously named rectifier, so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said condenser and a phase shifting network having a phase shifting effect which compensates for the

phase shifting effect present by reason of said condenser when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

16. In combination; an electronic discharge amplifier comprising an anode, a cathode, and a control electrode; a source of alternating power; a reactance element connected to said control electrode to affect the potential applied thereto; first and second circuits for causing a unidirectional voltage drop across said reactance; said first circuit including a further control electrode and cathode acting as a rectifier and so connected as to cause a voltage drop across said reactance element of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said further control electrode and cathode, so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said reactance and a phase shifting network having a phase shifting effect which compensates for the phase shifting effect present by reason of said reactance when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

17. In combination; an electronic discharge amplifier comprising an anode, a cathode, and a control electrode; a source of alternating power; a reactance element connected to said control electrode to affect the potential applied thereto; first and second circuits for causing a unidirectional voltage drop across said reactance; said first circuit including a diode and said cathode acting as a rectifier and so connected as to cause a voltage drop across said reactance element of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said diode and cathode, so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said reactance and a phase shifting network having a phase shifting effect which compensates for the phase shifting effect present by reason of said reactance when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

18. In combination; an electronic discharge amplifier comprising an anode, a cathode, and a control electrode; a source of alternating power; a first condenser connected between said control electrode and cathode and acting as a filter; a second condenser connected between said control electrode and said source of power to affect the potential applied thereto; first and second circuits for charging said second condenser; said first circuit including a rectifier so disposed as

to cause a charge across said second condenser of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said previously named rectifier, so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said second condenser and a phase shifting bridge having a phase shifting effect which compensates for the phase shifting effect present by reason of said second condenser when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

19. A control device of the electronic type having only one electronic discharge device, said device comprising only one anode, a cathode, and a single control electrode; a source of alternating power; a reactance element connected to said control electrode to affect the potential applied thereto; first and second circuits for causing a unidirectional voltage drop across said reactance; said first circuit consisting entirely of said control electrode, said cathode, resistance connections, and a portion of said source of power of such voltage phase as to cause a voltage drop across said reactance element of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said control electrode and cathode; so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said reactance and a phase shifting bridge having a phase shifting effect which compensates for the phase shifting effect present by reason of said reactance when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

20. A control device of the electronic type having only one electronic discharge device, said device comprising only one anode, a cathode, and a single control electrode; a source of alternating power; a first connection between said anode and said source of power; a second connection between said cathode and said source of power; a condenser; a third connection between said source of power, said condenser, and said control

electrode to cause said condenser to affect the potential applied to said control electrode; first and second circuits for causing a unidirectional voltage drop across said condenser; said first circuit consisting entirely of said control electrode, said cathode, said second and third connections, and a portion of said source of power of such voltage phase as to cause a charge across said condenser of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a gap adapted to be bridged by a rectifying impedance having an effect opposite to that of said control electrode and cathode, so that when said gap is so bridged, the amplifier is rendered conductive; said gap being interposed in a connection between the control electrode terminal of said condenser and a phase shifting bridge having a phase shifting effect which compensates for the phase shifting effect present by reason of said condenser when said gap is bridged by a non-rectifying impedance, said connection being effective when said gap is bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

21. In combination, an electrically operated control device; an electronic discharge amplifier controlling the energization of said control device, said amplifier comprising an anode, a cathode, and a control electrode; a source of alternating power; a reactance element connected to said control electrode to affect the potential applied thereto; first and second circuits for causing a unidirectional voltage drop across said reactance; said first circuit including a rectifier so disposed as to cause a voltage drop across said reactance element of a polarity such that the resulting potential applied to the control electrode assumes a value at which the amplifier is effectively non-conducting; said second circuit including a flame gap adapted to be bridged by a flame in such a direction that the rectifying effect of the flame has an effect opposite to that of said previously named rectifier, so that when said flame gap is so bridged, the amplifier is rendered conductive; said flame gap being interposed in a connection between the control electrode terminal of said reactance and a phase shifting bridge having a phase shifting effect which compensates for the phase shifting effect present by reason of said reactance when said flame gap is accidentally bridged by a non-rectifying impedance, said connection being effective when said gap is accidentally bridged by a non-rectifying impedance to maintain said control electrode at a polarity at which said amplifier is non-conductive.

WILLIS H. GILLE.