

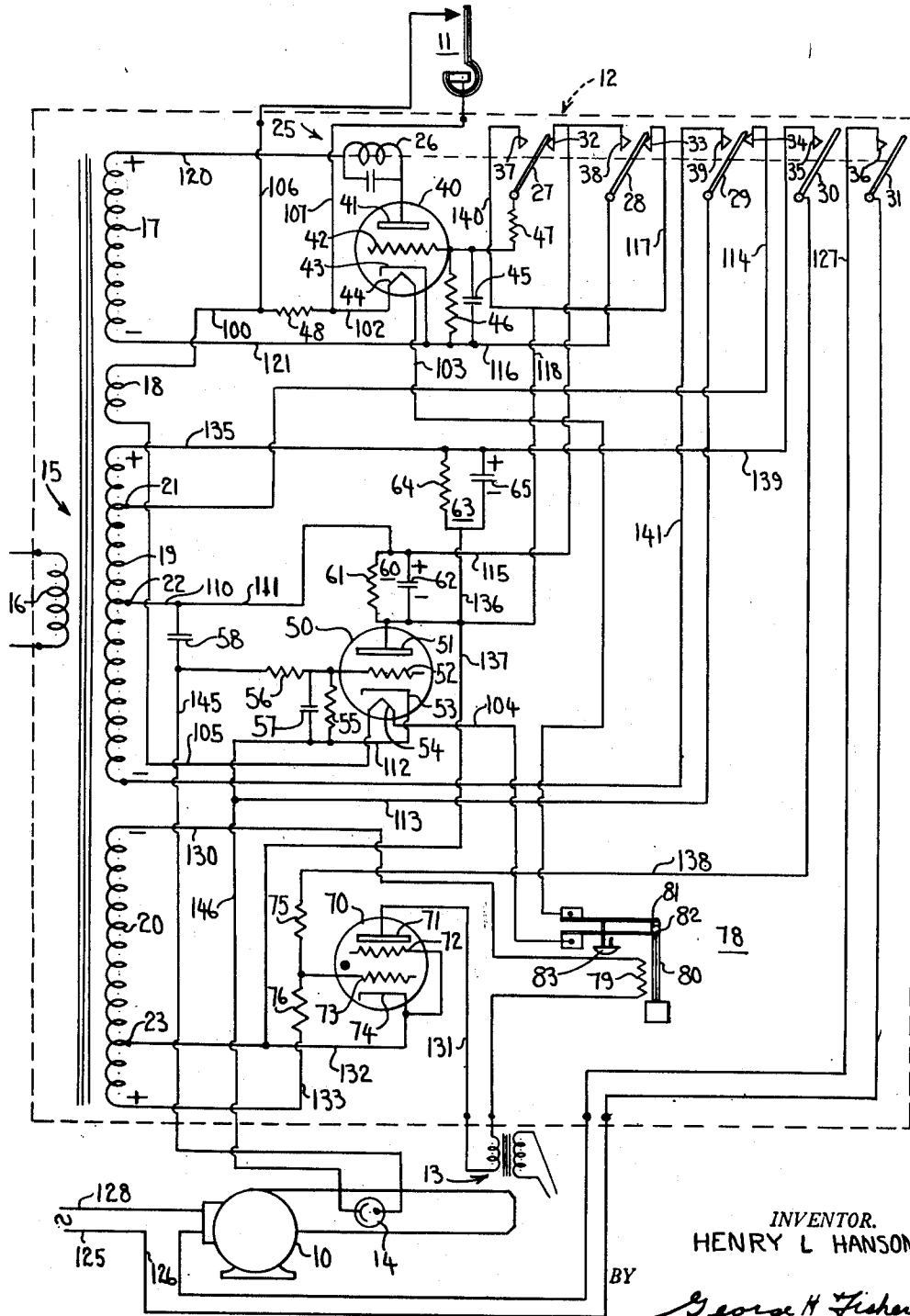
May 11, 1954

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2,678,090

SELF-CHECKING BURNER SAFETY CONTROL APPARATUS

Filed Jan. 14, 1949



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2,678,090

SELF-CHECKING BURNER SAFETY
CONTROL APPARATUS

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Application January 14, 1949, Serial No. 70,946

10 Claims. (Cl. 158—28)

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The present invention is concerned with an electronic fuel burner control apparatus and more particularly with that type of an apparatus which will automatically shut the fuel burner down in the event there is a flame failure and which will maintain the fuel burner inoperative should any portion of the control apparatus not be operating properly.

In present day fuel burner controls, it has been found that electronic devices can be utilized to improve the operation of the burner that is being controlled by responding quickly to flame failure and providing an over-all circuit that is generally more universal and easily controlled. By incorporating electron discharge devices in the present invention, it is possible to utilize a single relay in controlling the operation of the controlled fuel burner and it is further possible to arrange the electrical circuits so that this relay will be deenergized upon a flame failure and will be maintained deenergized if there is a false indication of flame or any part of the control apparatus is not operating properly. This is accomplished by utilizing electron discharge devices of the thermionic type and charging and discharging resistance and capacitance networks associated with these discharge devices in accordance with the operating condition of the burner and the operating conditions of the control apparatus itself.

It is therefore an object of the present invention to provide a control apparatus for a fuel burner which employs a single relay which is adapted to energize the burner, and providing, for energizing this single relay, an electron discharge device which is rendered operative only when the associated components are operating properly and which device will deenergize the single relay should the burner fail to operate.

Another object of the present invention is to provide a control apparatus employing an electronic means for energizing a single relay which is adapted to complete an energizing circuit to the burner and connecting this energizing electronic means with said relay so that said relay cannot be energized unless a predetermined voltage exists on the input of the electronic means.

Still another object of the present invention is to provide a burner control apparatus which includes an electronic control for a single relay where the electronic control is operative to recycle the control relay a predetermined number of times in the event that a flame is not established at the burner.

A still further object of the present invention

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is to provide an improved control apparatus which utilizes a single relay for energizing a control for a burner and a flame detector which will render the control inoperative if the ignition means fails or will maintain the control inoperative if the control apparatus is not operating properly.

A still further object of the present invention is to provide an electronic control apparatus for a fuel burner which has a single relay adapted to energize the fuel burner and further has an electronic ignition apparatus which is operative while the single relay is energized and there is no flame detected at the burner.

These and other objects of the present invention will be understood upon a consideration of the following specification, claims, and drawings of which:

The single figure shows the present invention as employed with an oil burner.

Referring to the single figure, it will be seen that an appropriate fuel burner 10 has been provided. For indicating when there is a demand for operation of the burner 10, a thermostatic device 11 may be provided and this may be located in any suitable space wherein a temperature is being controlled. When the thermostatic device 11 indicates the need for operation of the burner 10, the thermostatic device will close an electrical circuit associated with the controls of the subject invention which are located in a housing indicated generally by the numeral 12. The circuits within the housing 12 are operative to complete an energizing circuit to the burner 10 and to supply energy to an appropriate ignition transformer 13. As soon as the burner flame appears at the nozzle of the burner 10, this flame will be detected by a suitable flame detecting device 14 which may be in the form of a photoelectric cell.

Located within the housing 12 are the control circuits which render the burner 10 operative upon a demand for heat and check the burner operation and these control circuits may be seen to include a main power transformer 15 which has a primary winding 16, connected to a suitable source of power, not shown, and a plurality of secondary windings indicated by the numerals 17, 18, 19 and 20. The secondary winding 19 has a pair of taps thereon indicated by the numerals 21 and 22 while the secondary winding 20 has a tap thereon indicated by the numeral 23.

For completing an energizing circuit to the burner 10, a relay 25 has been provided and this relay comprises a relay winding 26 and a plurality of switch blades 27, 28, 29, 30, and 31. The

switch blades 27, 28, and 29 are normally biased, by means not shown, into engagement with contacts 32, 33 and 34 respectively. Switch blades 30 and 31 are normally biased out of engagement with their associated switch contacts 35 and 36. When the relay becomes energized and the switch blades move into their energized position, the switch blades 27, 28, and 29 will move into engagement with their associated contacts 37, 38, and 39 respectively.

A discharge device 40 is used to control the energization of the relay 25 and this discharge device may be seen to consist of an anode 41, a control electrode 42 and a cathode 43 which is heated to be electron emissive by a suitable filament type of heater 44. Connected in current controlling relation with the discharge device 40 are a condenser 45 and a resistor 46. A further resistor 47 is associated with the input of the discharge device 40 and the condenser 45. A current limiting resistor 48 is associated with the filament heater circuit 44.

The flame detector may be seen to consist of a suitable electron discharge device 50 which device has an anode 51, a control electrode 52, and a cathode 53 which is heated to be electron emissive by a suitable filament type of heater 54. Associated with the input of this discharge device is a biasing resistor 55 and a filter network comprising a resistor 56 and a condenser 57. A further condenser 58 is provided for use in the circuit of the photoelectric cell 14. Located in the output of the discharge device 50 are a pair of electrical networks in a form of parallel connected resistors and condensers. A first network 60 comprises a resistor 61 and a condenser 62 while the other network 63 comprises a resistor 64 and a condenser 65.

For controlling the energization of the ignition transformer 13 a further electron discharge device 70 is provided and this device would preferably be of the gaseous type and will include an anode 71, a suppressor grid 72, a control electrode 73 and a cathode 74 which is heated to be electron emissive by a suitable filament type of heater, not shown. Associated with the input to this discharge device 70 are a pair of resistors 75 and 76. Located in the output circuit of this discharge device, in addition to the transformer 13, is a safety cutout device 78 and this device may be seen to include a heater 79, a bimetallic element 80, and a pair of switch contacts 81 and 82. The heater 79 is operative when energized for a predetermined length of time to warp the bimetal 80 toward the right so that the contacts 81 and 82 will separate. A reset actuator 83 is provided for moving the contacts 81 and 82 back to the closed position after there has been a safety shutdown.

Operation

In considering the operation, it will first be noted that the apparatus as shown upon the drawing is in the deenergized position with the thermostatic device 11 not calling for burner operation and with the burner 10 and ignition transformer 13 deenergized. Further, in considering the following assume the alternating current secondary windings of transformer 15 are, for a particular half cycle, phased as shown upon the drawing. When the apparatus is in the shutdown position, the main control discharge device 40 and the flame detection discharge device 50 are effectively nonconducting since their filament heaters are not receiving full voltage from the secondary transformer winding 18. This

is because the limiting resistor 48 is connected in the series circuit to the filaments of the two discharge devices. This filament circuit may be traced from the upper terminal of secondary winding 18 through conductor 100, resistor 48, conductor 102, filament heater 44, conductor 103, contacts 81 and 82 of the safety cutout device 78, conductor 104, filament heater 54, and conductor 105 back to the lower terminal of secondary 18. The current flowing in the last traced circuit is sufficient to keep the filament heaters 44 and 54 in a partially energized condition so that upon a call for burner operation the filament heaters will not have to change temperature over a wide range, which change tends to deteriorate the filament heaters more quickly than would ordinarily occur if the filaments were left partially energized continuously.

As soon as the space wherein is located the thermostatic device 11 begins to cool, the contacts of the thermostat will close and the closing of these contacts will be effective to shunt out the current limiting resistor 48 in the filament heater circuit for discharge devices 40 and 50. This shunt circuit may be traced from the left hand side of resistor 48 through conductor 106, thermostatic device 11, and conductor 107 back to the right hand side of resistor 48. This shunting of the current limiting resistor will mean that full voltage of the filament secondary winding 18 will be applied to the heaters 44 and 54 and the temperatures of these heaters will increase to a point where the associated cathodes 43 and 53 respectively will become electron emissive.

As soon as the filament heater 54 heats the cathode 53 to be electron emissive, there will be a current flow through the discharge device 50. When the phasing of the secondary transformer 19 is such that the lower terminal of the secondary is positive with respect to the upper terminal, the current flow through the discharge device 50 may be traced from the tap 22 on secondary 19 through conductors 110 and 111, resistor 61, anode 51, cathode 53, conductor 112, conductor 113, switch arm 29, contact 34, and conductor 114 to the tap 21 and the secondary 19. With the current flowing in the last traced circuit, there will be a direct current voltage built up across the condenser 62 since the current flow through the discharge device 50 and the resistor 61 will be unidirectional.

The voltage drop on condenser 62 will be such that the upper terminal is positive and the lower terminal is negative. The charge that has been built up upon the condenser 62 is used to control the potential of the control electrode 42 of the discharge device 40 and this voltage is applied to the control electrode 42 and cathode 43 in a circuit that may be traced from the upper terminal of condenser 62, through conductor 115, switch contact 32, switch blade 27, resistor 47, to the control electrode 42 and from the control electrode 42 through resistor 46 to the cathode 43, from the cathode 43 through conductor 116, switch arm 28, contact 33, and conductors 117 and 118 to the lower terminal of condenser 62. If the voltage on condenser 62 is sufficiently positive on this upper terminal with respect to its lower terminal, a positive voltage will be built up across the condenser 45 on the input of discharge device 40 since this condenser is effectively connected in parallel with the resistor 46. The charge on this condenser 45 will be such that the upper terminal is positive and the lower terminal is negative. If the voltage on the con-

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denser 45 is sufficiently positive on its upper terminal, there will be sufficient current passing through this discharge device 40 to energize the main control relay 25. The energizing circuit for the relay 25 may be traced from the upper terminal of secondary 17 through conductor 120, relay winding 26, anode 41, cathode 43, and conductor 121 back to the lower terminal of secondary 17. The relay 25 is so designed that the relay can become energized only when the current flow through the discharge device 40 is such as to indicate that the control electrode 42 is slightly positive with respect to the cathode 43.

As soon as the relay 25 has become energized, an energizing circuit is completed to the burner 10 and this circuit may be traced in the input power line 125 through conductor 126, switch blade 31, switch contact 36, conductor 127, and burner 10 back to the other input power line 128.

Also energized when the relay 25 becomes energized is the ignition circuit of the subject apparatus. The ignition circuit is normally arranged so that when the relay 25 is deenergized the ignition circuit will be inoperative. This will be understood when it is noted that the control electrode 73 of discharge device 70 is normally connected to a point of the power source which is negative with respect to the cathode 74 when the discharge device has its anode 71 connected to a positive point in the power source. This will be seen when the anode circuit for the discharge device 70 is traced and this may be traced from the upper terminal of secondary 20 through conductor 130, heater 79, ignition transformer 13, conductor 131, anode 71, cathode 74, and conductor 132 to the tap 23 of secondary 20. It will be noted that the control electrode 73 is connected through the resistor 76 and conductor 133 to the lower terminal of secondary 20. Before considering how the discharge device 70 becomes energized upon the energization of the control relay 25, it is also necessary to note that the discharge device 50 is effective to charge the condenser 65 and network 63 so that the upper terminal of the condenser 65 is positive with respect to its lower terminal. This will be understood when the half cycle of the alternating current on secondary winding 19 is such that the upper terminal of secondary 19 is positive with respect to the lower terminal. When the secondary 19 is so phased, it is possible to have a current flow from the upper terminal of secondary 19 through conductor 135, resistor 64, conductor 136, anode 51, cathode 53, conductors 112 and 113, switch blade 29, switch contact 34, and conductor 114 to the tap 21 on secondary 19. Since the current flow in the last traced circuit will be unidirectional there will be a voltage drop across resistor 64 so that the condenser 65 will be charged so that the upper terminal is positive with respect to the lower terminal.

Going back to the ignition circuit again, energization of the relay 25 will cause the discharge device 70 to become conductive if the proper voltages exist in network 63 on the output of the flame detection discharge device 50.

When the relay 25 becomes energized an electrical circuit may be traced from the control electrode 73 of discharge device 70 through the resistor 75, conductor 138, switch blade 30, switch contact 35, conductor 139, network 63, conductors 136 and 137 and conductor 132 to the cathode 74. This last traced circuit, neglecting the effect of the charge on condenser 65 and network 63 is essentially a voltage divider network connected across the lower portion of the second-

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ary winding 20 between tap 23 and the lower terminal of secondary 20. The voltage on the control electrode in this circuit is such that the control electrode will still be sufficiently negative with respect to the cathode 74 so that the discharge device 70 will not become conductive upon the positive half cycle or conductive half cycle of the secondary 20. If, however, there is a positive voltage existing in the network 63, this positive voltage when added to the alternating current voltage in the voltage divider network is effective to bring the control electrode 73 into the range where the discharge device 70 will fire or conduct on every positive half cycle of the secondary 20. When the discharge device does fire there will be a current flowing in the anode circuit that was traced above and this will mean that current will be flowing through the ignition transformer 13 and there will be a resultant sparking across the electrodes of the ignition transformer and this sparking will ignite the fuel that is coming from the burner 10.

When the relay 25 becomes energized the network 60 in the flame detection discharge device circuit is reconnected to the input of the main control discharge device 40 so that now the negative terminal of condenser 62 is connected to the control electrode and positive terminal of condenser 62 is connected to the cathode 43. This circuit may be traced from the upper terminal of condenser 62 through conductor 115, switch contact 38, switch blade 28, conductor 116 to cathode 43 and from cathode 43 through resistor 46, to the control electrode 42, from control electrode 42 through resistor 47, switch blade 27, switch contact 37, conductor 140, and conductor 118 to the lower terminal of condenser 62. At the same time that this last traced circuit comes into effect, the cathode 53 of the flame detection discharge device 50 is connected to the lower terminal of secondary 19 and this circuit may be traced from the cathode 53 through conductors 112 and 113, switch blade 29, switch contact 39, and conductor 141 to the lower terminal of secondary 19.

With the cathode 53 now connected to the lower terminal of secondary 19, the anode circuit for the discharge device 50 may be traced from the tap 22 through conductors 110 and 111, network 60, anode 51, cathode 53, conductors 112 and 113, switch blade 29, switch contact 39, and conductor 141 to the lower terminal of secondary 19. A further anode circuit for this discharge device may be traced from the upper terminal of secondary 19 through conductor 135, network 63, and conductor 136 to the anode 51 and from there through the last traced circuit to the lower terminal of secondary 19. When the discharge device is so connected to the secondary 19, when the upper terminal of the transformer 19 is positive with respect to the lower terminal, there will be current flow in the last traced circuits and the direct current potential built up across the condensers of networks 60 and 63 will remain of the same polarity as they were previously when the cathode 53 was connected to tap 21. With the network 60 reconnected to the input of discharge device 40, the charge on condenser 62 will be such as to tend to bias the control electrode 42 negative to a point where the relay 25 will become deenergized. The time that it will take for this to occur will be dependent upon the size of the resistor 47 which is in the charging circuit for the condenser 45 and also upon the size of the resistor 46 which is in par-

allel with the condenser 45. Normally the presence of flame at the burner will be detected and the charging of the condenser 45 in a negative direction on the control electrode end will be stopped. This will be understood when the operation of the flame detector photocell upon the flame detection discharge device 50 is considered below.

Normally, when no flame is detected on the discharge device 50, the above traced circuits with respect to the discharge device 50 are normally operative as the control electrode 52 is biased to be slightly positive with respect to the cathode 53. This is because the condenser 58, resistor 56 and parallel connected condenser 57 and resistor 55 form a voltage divider network between the anode connection of the discharge device and the cathode 53 as connected to secondary 19. With the control electrode 52 slightly positive with respect to the cathode, on the positive half cycle of the alternating power source, the current flow will be as traced above. When flame is detected by the photoelectric cell 14, a direct current charge is built up across the condenser 58 since the photocell 14 is an asymmetrically conducting device when exposed to the light of the flame. The charge on the condenser will result because of the fact that there is a current flow flowing from the tap 22 through conductor 110, condenser 58, conductor 145, the anode of photocell 14, cathode of photocell 14, conductors 146 and 113, switch blade 29, switch contact 39, and conductor 141 back to the lower terminal of secondary 19.

The charge built up upon the condenser 58 will be such that the lower terminal is negative and the upper terminal is positive and this charge will be effective to bias the control electrode 52 to be negative with respect to the cathode 53. This will mean that the current flow in the discharge device 50 will no longer exist and there will be no further charging of the condensers 62 and 65 in the networks 60 and 63. When there is no longer a direct current potential existing across the network 60, this network will not be tending to bias the control electrode 42 of discharge device 40 to be negative and therefore the control relay will remain energized. When there is no longer a direct current charge existing across the network 63, there will be no direct current voltage maintaining the control electrode 73 of the ignition discharge device 70 positive with respect to the cathode 74 and this will mean that the ignition discharge device 70 will no longer be supplying an energizing voltage to the ignition transformer 13.

The apparatus described thus far is now operating in its normal manner with the ignition device not energizing the ignition transformer 13, the photocell detecting the presence of flame and maintaining the flame detection device 50 inoperative and the potential between the cathode 43 and control electrode 42 of the main control discharge device such as to maintain the relay 25 energized and the burner operative.

As soon as the thermostatic device 11 is no longer indicating a need for further burner operation, the contacts will separate and this will remove the shunt around the current limiting resistor 48 in the filament heater circuit for filament heaters 44 and 54. With the shunt removed from the current limiting resistor 48 the filament heaters 44 and 54 will begin to cool and will cool to a point where the heaters will no longer be effective to heat the cathodes 43 and

53 to be electron emissive. When the cathode 43 is no longer electron emissive the current flow through the discharge device 40 will drop to a value which will no longer be sufficient to maintain the relay 25 energized and therefore the contacts 27 through 31 will move to their deenergized position. When this occurs, the energizing circuit to the burner 10 will be opened with the opening of switch blade 31 from contact 36. Thus, the apparatus will be shut down and the components will return to the positions shown upon the drawing.

In considering the operation upon a flame failure, first assume that a normal operating cycle has started with sufficient voltage on the network 60 being effective to cause the main control discharge device 40 to become operative to energize the relay 25. It will be recalled that when the relay 25 becomes energized an energizing circuit is completed to the burner 10 and the ignition electron discharge device 70 will be effective to energize the ignition transformer 13. Further, with relay 25 energized, the connections of the control electrode 42 and cathode 43 are reversed upon the network 60 so that now the condenser 62 is tending to charge the condenser 45 to be negative on the control electrode side. This circuit may be traced from the lower terminal of condenser 62 through conductor 118, conductor 140, switch contact 37, switch blade 27, resistor 47, to condenser 45, on a control electrode side thereof, and from the other side of the condenser 45 through conductor 116, switch blade 28, switch contact 38, and conductor 115 to the upper terminal of condenser 62.

If a flame is not established within a predetermined time, the condenser 45 will assume a charge which will be sufficiently negative with respect to the cathode that the control electrode will decrease the current flow through the discharge device 40 below the point necessary to maintain relay 25 energized. The time that it will take for this to occur will be dependent upon the size of the resistor 47 which is connected in series with the charging circuit of condenser 45 and the size of the resistor 48 which is connected in parallel with the condenser 45. When the relay 25 becomes deenergized the condenser 45 on the input of discharge device 40 is reconnected across the network 60 so that the condenser will tend to be charged so that the control electrode side is positive with respect to the cathode side. Again, the time that it will take for this positive voltage to appear upon the condenser 45 will be dependent upon the size of the resistor 47 and resistor 48. After a predetermined time the condenser 45 will have charged sufficiently positive on the control electrode side so that the discharge device will become conductive again and will have sufficient current flowing therethrough to energize the relay 25. If flame is not established by the ignition device within a predetermined time, the apparatus will again be shut down since the condenser 45 will be reconnected so that it will tend to charge negative on the control electrode side with respect to the cathode side.

Again, after a predetermined time, the condenser will be recharged so that it will be positive and the control relay 25 will become energized. Each time that the relay becomes energized, the ignition device 70 will be effective to apply an energizing voltage to the ignition transformer and at the same time will be applying an energizing voltage to the heater 79. This heater 79

is so designed that it is capable of storing heat between the succeeding attempts to establish a flame at the burner and, after a predetermined number of times, the heat stored in the heater 79 will be sufficient to move the bimetal toward the right and the contacts 81 and 82 will separate. When they have separated, the filament heater circuit to heaters 44 and 54 will be broken and therefore the discharge devices 40 and 50 will become deenergized and the apparatus will be completely shut down. After the heater 79 has cooled sufficiently, it is possible to depress the actuator 83 and move the contacts 81 and 82 to the closed position. As soon as the circuit is closed the filament circuit will be completed and the discharge devices 40 and 50 will be effective to go through their normal operating cycle in the manner described above. If a flame is not established upon the recycling of the relay a predetermined number of times the apparatus will again shut down in the manner described above.

As soon as the fault causing non-appearance of the flame at the burner has been eliminated, the apparatus will go through its normal operating cycle as described above under "Operation."

Component check

It is necessary in the apparatus to provide as much safety as is possible to insure that the apparatus does not operate the burner when the control apparatus is not functioning properly. Thus, upon the starting up of the apparatus, it will be seen that it is necessary that the filament circuit for filaments 44 and 54 be intact. If not, it is impossible for the filaments to heat the associated cathodes to be electron emissive. Further, it will be realized that upon the starting cycle that it is impossible to energize the control relay 25 until such time as there is a positive voltage applied to the control electrode 42. Thus, if there is a short between the control electrode 42 and the cathode 43 of the main control discharge device 40, it would be impossible to energize the relay 25 because there would not be sufficient current flowing through the discharge device 40. Further assuming that the circuits for the discharge device 40 are functioning properly, since a positive voltage must be applied to the control electrode 42, it will be seen that there must be a positive voltage originating in the network 60 in the output of the discharge device 50. This positive voltage on the network 60 will be of sufficient magnitude only when the control electrode 52 is slightly positive with respect to the cathode 53. Thus, when the control relay 25 is deenergized and the cathode 53 is connected to the tap 21, it will be seen that the control electrode 52 is effectively connected to a point in the power source or secondary 19 which is of a potential slightly positive with respect to the cathode connection 21 since the condenser 56, resistor 55, and resistor 55 and condenser 57 are connected between the anode connection 22 and cathode 53. This, as explained above, is essentially a voltage divider across the corresponding portion of the power source so that the control electrode will be slightly positive. If the control electrode 52 should be short circuited to the cathode 53, the positive voltage existing across the network 60 will not be sufficient to energize the main control relay 40.

In the event that there is a short circuit between the anode 51 and the cathode 53, it will be noted that an alternating current biasing voltage is applied to the condenser 45 which will

be sufficient to maintain the control electrode 42 negative with respect to the cathode 43. The control electrode 42 connection to the secondary winding 19, when this short circuit exists, may be traced from the control electrode 42 through resistor 47, switch arm 27, switch contact 32, conductor 115, and conductors 111 and 110 to the tap 22 of secondary 19. The cathode connection for cathode 43 may be traced from the cathode 43 through conductor 116, switch blade 28, switch contact 33, conductors 117 and 118, anode 51, cathode 53, conductors 112 and 113, switch blade 29, switch contact 34, and conductor 114 to tap 21 on secondary 19. With this connection, and the secondary windings 17 and 19 both phased so that their upper terminals are positive with respect to their lower terminals, it will be noted that the control electrode 42 is connected to a point that is negative with respect to the cathode connection at tap 21. Thus, the discharge device 40 cannot become energized.

Should a similar short circuit occur between the anode 41 and the cathode 43 of the main control discharge device 40, the discharge device would no longer be asymmetrically conductive and since the relay 25 is of the direct current type, this relay will not become energized as there will be no direct current flowing in the anode circuit of the discharge device.

Should a short circuit occur between the control electrode 52 and anode 51 of the flame detection discharge device 50, the above traced circuit wherein the control electrode 42 was connected to a point on transformer 19 which was negative with respect to tap 22 will apply and, while the voltage on this circuit will be less than that originating when there was a direct short circuit between the anode 51 and cathode 53, this alternating current voltage will be sufficient to maintain the discharge device 40 nonconductive. This circuit may be traced from the control electrode 42 through the resistor 47, switch blade 27, switch contact 32, and conductors 115, 111 and 110 to the tap 22. The cathode connection in this situation may be traced from the cathode 43 through conductor 116, switch blade 28, switch contact 33, conductors 117 and 118, anode 51, control electrode 52, parallel connected resistor 55 and condenser 57 to conductor 112 and from there to conductor 113, switch blade 29, switch contact 34, and conductor 114 to tap 21. Since the condenser 58 and resistor 56 form a voltage divider with the parallel connected resistor 55 and condenser 57, it will be seen that the actual voltage existing upon the cathode 43 will not be that which is directly upon the tap 21 but a point that lies between the tap 21 and the tap 22 on secondary 19. As mentioned above, this voltage will be sufficient to maintain the control electrode 42 negative with respect to the cathode 43 and there will be no current flow through the discharge device 40.

Further, if there is any fault in the ignition circuit, the apparatus will shut down after it has recycled a predetermined number of times as was explained above under a flame failure. If there should be any fault in the ignition circuit which would tend to cause an increase in the amount of current flowing in the anode circuit of the discharge device 70, as would occur upon a short circuit across the electrodes of the ignition transformer 13 or upon a short circuit between the anode 71 and control electrode 74, there would be an increased amount of current flowing through the heater 79 and therefore this heater

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will cause the apparatus to shut down much sooner than would ordinarily occur should the apparatus fail to detect the presence of flame at the burner.

Thus it can be seen that the apparatus will not become operative to energize the burner unless all components in the apparatus are in a condition to operate safely.

Conclusion

From the foregoing it can be seen that I have provided an electrical fuel burner control apparatus which will be rendered ineffective if the associated ignition means fails, if the flame fails, or if any component of the apparatus fails to operate in its normal manner. While I have shown specific embodiments of my invention, it is to be understood that it has been for illustrative purposes only and I therefore intend to be limited solely by the scope of the appended claims.

I claim:

1. Burner control apparatus comprising in combination, a source of power, a relay, said relay having a plurality of switch contacts two of which are adapted to complete an energizing circuit to the burner when said relay is energized, a first electron discharge device connected to said source of power, an input circuit for said first discharge device, an output circuit for said first discharge device, said first discharge device being energized upon a demand for burner operation, means connecting said relay in the output circuit of said first discharge device to be energized by the current flow in said output circuit upon a demand for burner operation, flame detecting means responsive to the presence or absence of burner flame, a second electron discharge device connected to said source of power, an input and an output circuit for said second discharge device, means connecting said detecting means to the input circuit of said second discharge device, an electrical impedance network connected in the output circuit of said second discharge device and adapted to have a voltage thereacross of a first value indicative of the presence of a flame at the burner or of a second value indicative of the absence of flame at the fuel burner, a capacitor, means connecting said capacitor to the input circuit of said first discharge device to control the current flow in the output circuit of said first discharge device in accordance with the voltage across said capacitor, means including switch contacts of said relay which are closed when said relay is deenergized and including said network for charging said capacitor in a first sense when said relay is deenergized, said first sense being of a polarity to cause operation of said first discharge device and thereby energize said relay upon a demand for burner operation and further means including switch contacts of said relay which are closed when said relay is energized and including said network for charging said capacitor in a second sense, said capacitor being charged in said second sense only so long as said flame detecting means responds to the absence of burner flame to maintain said voltage of said second value across said network, said second sense being of a polarity to render said first discharge device ineffective to maintain said relay energized after a predetermined time period, said capacitor when charged alternately in said first and second sense by voltage across said network causing recycling of said relay and the

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burner in attempting to establish flame at the burner.

2. Burner control apparatus comprising in combination, a source of power, a relay having a plurality of switch contacts a first of which is adapted to complete an energizing circuit to the burner when said relay is energized, relay energizing means adapted to energize said relay upon a demand for burner operation, electronic ignition means including a grid controlled rectifier having a control grid, means including a second of the switch contacts of said relay to render said ignition means effective when said relay is energized, flame detecting means, an electron discharge device connected to said source of power, a control circuit for said discharge device including said flame detecting means, an output circuit for said discharge device, an electrical impedance network connected to said output circuit, said impedance network thereby being adapted to have a voltage thereacross of a first value indicative of the presence of a flame or of a second value indicative of the absence of a flame, means connecting said network to the control grid of said grid controlled rectifier to control said electronic ignition means in accordance with the presence or absence of flame, and safety cutout means having an actuator in circuit with said ignition means, said cutout means having means to render said relay energizing means ineffective when said ignition means has been energized for longer than a predetermined time.

3. Burner control apparatus comprising in combination, a source of power, a relay including means for completing an energizing circuit to the burner when said relay is energized, a first electron discharge device having a control electrode and an anode and cathode, means connecting said relay in circuit with said anode and cathode, means including said source of power adapted to render said first discharge device operative upon a demand for burner operation, ignition means, a second electron discharge device, an input and an output circuit for said second discharge device, means connecting said ignition means to said output circuit, burner flame detecting means, a third electron discharge device having a control electrode and having an anode and cathode, a first electrical impedance network connected in circuit with the anode and cathode of said third discharge device, a second electrical impedance network connected in circuit with the anode and cathode of said third discharge device, means connecting said flame detecting means to the control electrode of said third discharge device, said first and second networks thereby being adapted to have a voltage thereacross of a first value indicative of the presence of a flame or of a second value indicative of the absence of a flame, means connecting said first network to the control electrode of said first discharge device and said second network to the input circuit of said second discharge device to cause recycling of said relay and said ignition means when a burner flame is not established, and safety cutout means having an operator connected in circuit with said ignition means, said cutout means having means to render said first discharge device inoperative after said ignition means has been recycled a predetermined number of times.

4. Burner control apparatus, comprising in combination, a source of power, flame detection means, an electron discharge device connected to said source, said discharge device having a control electrode connected to said flame detection

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means and having an anode and cathode, an electrical impedance network connected in series with said anode and cathode, said network therefore normally having a voltage thereacross of a first value indicative of the presence of flame or of a second value indicative of absence of a burner flame, a relay, means controlled by said relay adapted to energize the burner when said relay is energized, electronic means connected to said source for energizing said relay upon a demand for burner operation and including a further discharge device having a control electrode to control the current flow therethrough, said electronic means having a main current circuit including said discharge device and said relay to energize said relay in accordance with the voltage applied to said control electrode, first means electrically connecting said network to the control electrode of said further discharge device so that upon demand for heat said further discharge device will initiate energization of said relay to energize the burner if the voltage across said network is of said second value, and second means rendered operative upon a demand for burner operation for electrically connecting said network to the control electrode of said further discharge device so that said further discharge device will maintain said relay energized only for a period of time unless the voltage across said network changes from said second to said first value upon said flame sensing means sensing the presence of flame within said period of time, said first means maintaining said further discharge device inoperative to energize said relay if the voltage across said network does not change from said first to said second value.

5. Burner control apparatus comprising in combination, a source of power, a relay, said relay having a plurality of switch contact pairs, a first pair of which are adapted to complete an energizing circuit to the burner when said relay is energized, a first electron discharge device connected to said source and having an anode, a cathode and a control electrode, means adapted to render said first discharge device operative upon a demand for operation of the burner, means connecting said relay in circuit with said anode and cathode to thereby energize said relay when there is a demand for burner operation, burner flame detecting means, a further electron discharge device connected to said source, said further discharge device having a control electrode connected to said flame detecting means and having an anode and cathode, an electrical impedance network connected in series with the anode and cathode of said further discharge device to cause a voltage to exist across said network which is of a first value indicative of the presence of flame at the burner or of a second value indicative of the absence of flame at the burner, means including a second pair of relay switch contacts which are closed when said relay is energized connecting said network to the control electrode of said first discharge device for rendering said first discharge device ineffective when the burner flame fails, and means including a third pair of relay switch contacts which are closed when said relay is deenergized connecting said network to the control electrode of said first discharge device for maintaining said first discharge device ineffective to energize said relay unless the voltage on said network lies within said second value indicative of the absence of flame.

6. Burner control apparatus comprising in com-

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5 bination, a source of voltage, flame sensing means, electronic flame detection apparatus connected to said source and comprising an electron discharge device having a control electrode connected to said flame sensing means and having an anode and cathode, an electrical impedance network, circuit means connecting said impedance network in series circuit with said anode and cathode, said network normally having a voltage thereacross of a first value indicative of the presence of flame or of a second value indicative of the absence of a burner flame, a relay, means including said relay adapted to energize the burner when said relay is energized, electronic means connected to said source for energizing said relay upon a demand for burner operation, said electronic means including a further discharge device whose current flow is controlled by the voltage on a control electrode thereof, means electrically interconnecting the control electrode of said further discharge device and said network so that said electronic means will maintain said relay energized only for a period of time unless the voltage across said network changes from said second to said first value upon said flame sensing means sensing the presence of flame within said period of time, and means interconnecting said electronic means and said network so that when said first voltage value exists across said network said electronic means will not energize said relay.

7. Burner control apparatus comprising in combination, a relay, said relay having a plurality of switch contacts two of which are adapted to complete an energizing circuit to the burner when said relay is energized, means including an electron discharge device having main electrodes and a control electrode, means connecting said relay in circuit with said main electrodes to be energized when there is a demand for burner operation, a source of power, burner flame detecting means, a further electron discharge device connected to said source of power and having main electrodes, an input circuit for said further discharge device including said flame detecting means, an electrical network, means connecting said electrical network in series with the main electrodes of said further discharge device, said network comprising a parallel connected resistor and condenser and adapted to have a voltage thereacross of a first magnitude indicative of the presence of flame at the burner or of a second magnitude indicative of the absence of flame at the burner, a second resistor, a second condenser, means connecting said second resistor and said second condenser to the control electrode of said first discharge device in current controlling relation to said device, and means including certain of the switch contacts of said relay for connecting said network to said second resistor and said second condenser in one manner when said relay is energized and in another manner when said relay is deenergized, said last named means together with said condensers and resistors rendering said first discharge device ineffective if there is a failure of the burner flame when said relay is energized, said last named means together with said condensers and resistors maintaining said first discharge device ineffective if said further discharge device is not operating properly or a flame is present when said relay is deenergized.

8. Burner control apparatus comprising in combination, a source of power, a relay for completing an energizing circuit to the burner when

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said relay is energized, energizing means for said relay including an electron discharge device connected to said source and having a control electrode, said device being operative upon a demand for burner operation, a main current flow circuit for said discharge device, means connecting said relay in said main current flow circuit, electronic ignition means normally rendered effective by said relay when energized, burner flame detecting means, a further electron discharge device connected to said source, an input circuit for said further discharge device including said flame detecting means, a first and a second electrical impedance network, a current flow circuit for said further discharge device including said first and second impedance network connected in circuit therewith, said first and second network thereby being adapted to have a voltage thereacross of a first magnitude indicative of the presence of a flame or of a second magnitude indicative of the absence of a flame, and means connecting said first network to said control electrode in current controlling relation to said first discharge device and said second network to said electronic ignition means to render said first discharge device inoperative if flame is not established and to render said ignition means inoperative if flame is established at the burner.

9. Burner control apparatus comprising in combination, a source of power, flame sensing means, an electron discharge device having an anode and cathode, an input circuit for said discharge device including said flame sensing means, an electrical impedance network, circuit means connecting said network in series with said anode and cathode, said network thereby being adapted to have a voltage thereacross of a first value indicative of the presence of a flame at the burner or of a second value indicative of the absence of a flame at the burner, a relay, a second electron discharge device energized upon demand for burner operation, means connecting said second device to said source, a control circuit and a current circuit for said second discharge device, means connecting said relay in said current circuit so that said relay will be energized upon a demand for burner operation, means including said relay connecting said network to said control circuit in current controlling relation to said second electron discharge device when said relay is energized so that said relay will be maintained energized only for a period of time unless the voltage across said network changes from said second to said first value upon said flame sensing means sensing the presence of flame within said period of time, and means

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including said relay when deenergized connecting said network to said control circuit in current controlling relation to said second discharge device for checking operation of said detecting means to insure that the voltage across said network is of said second value indicative of the absence of a flame at the burner prior to energizing said relay.

10. Burner control apparatus comprising in combination, an alternating source of power, a relay including means adapted to complete an energizing circuit to the burner when said relay is energized, electronic means connected to said source, said electronic means comprising an electron discharge device having an anode and cathode and having a control electrode, means connecting said relay in circuit with said anode and cathode, flame sensing means, a network having a resistor and capacitor therein, means including said flame sensing means for producing a voltage across said network which is either of a first value indicative of the presence of flame or of a second value indicative of the absence of flame, first circuit means controlled by said relay connecting said network in a first sense to said control electrode of said discharge device when said relay is deenergized so that said discharge device is conductive only when said voltage is of said second value, said network maintaining said first discharge device inoperative to initially energize said relay if the voltage thereon indicates the presence of flame when said relay is deenergized, time delay means, and further circuit means including said time delay means and controlled by the relay for connecting said network to said control electrode in a second sense when said relay becomes energized such that said discharge tends to become sufficiently non-conductive to deenergize said relay after a period of time if said voltage remains at said second value due to the failure of said flame responsive means to sense the presence of flame.

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