

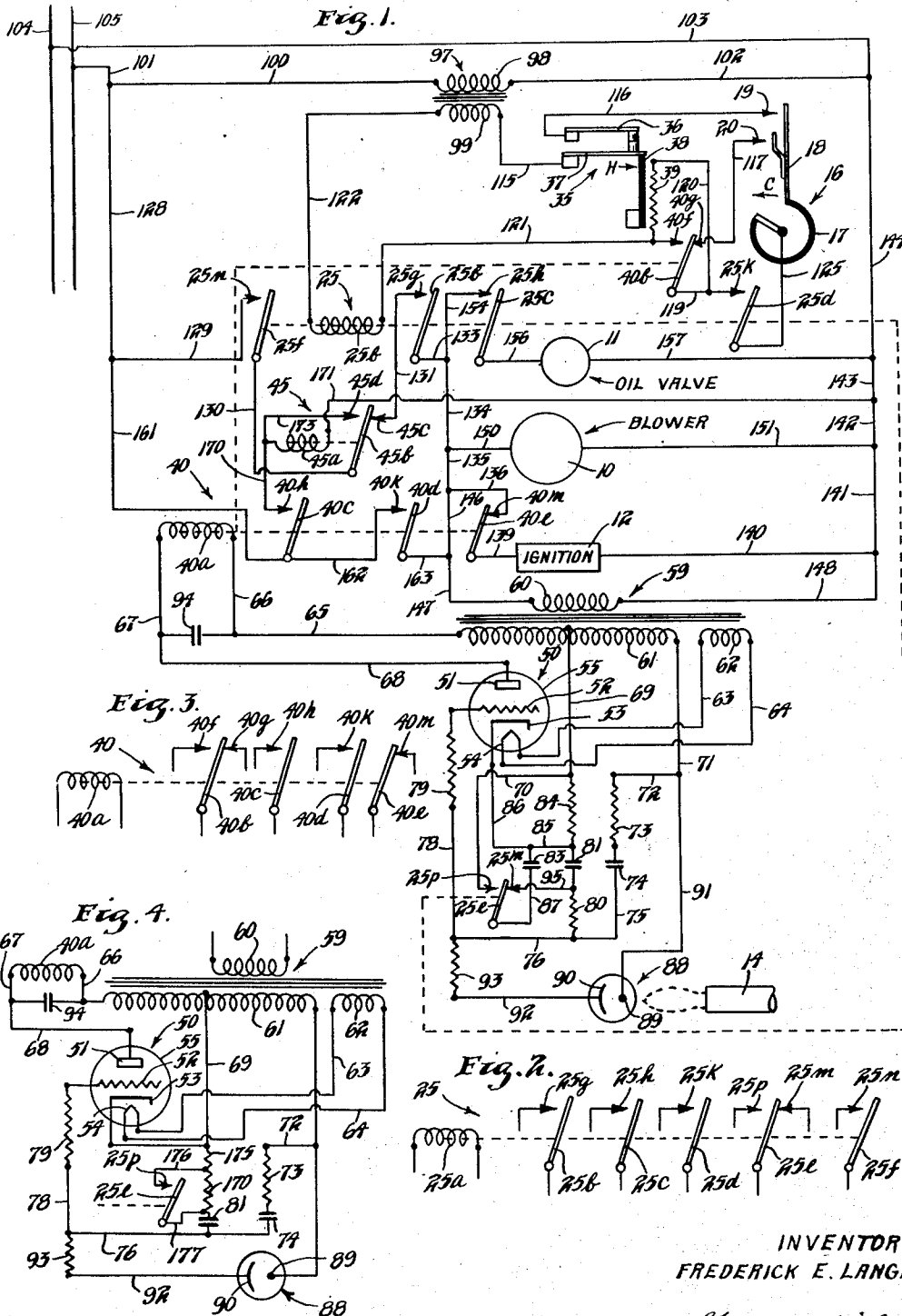
Jan. 3, 1950

F. E. LANGE

2,493,412

BURNER SAFETY AND SCAVENGING CONTROL

Filed Aug. 11, 1945



INVENTOR
FREDERICK E. LANGE

BY *George H. Fisher*
ATTORNEY

UNITED STATES PATENT OFFICE

2,493,412

BURNER SAFETY AND SCAVENGING
CONTROL

Frederick E. Lange, Minneapolis, Minn., assignor
to Minneapolis-Honeywell Regulator Company,
Minneapolis, Minn., a corporation of Delaware

Application August 11, 1945, Serial No. 610,264

12 Claims. (Cl. 158—28)

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The present invention is concerned with burner control apparatus and more particularly apparatus of the type in which provision is made for operating a burner blower for a period of time after interruption of the fuel.

In many types of oil burner it is desirable that the blower or other means for delivering air to the burner be continued in operation for a period of time after the delivery of fuel is terminated. Such a period of blower operation is often referred to as a "blow out cycle." The reason for such a blow out cycle is that otherwise a few drops of oil tend to remain on the burner and due to the rather high temperature conditions existing in the furnace following a termination of burner operation, this oil becomes carbonized. When the process is repeated as often as the burner is placed in operation, carbon tends to accumulate to a point where operation of the burner may be impaired. In order to provide for such continued operation of the blower after the fuel has been interrupted, various timing arrangements have been proposed. While satisfactory, these additionally complicate the control apparatus and add to the expense thereof. It has also been suggested that the flame responsive device can be employed to provide a timed period of blower operation following the interruption of fuel, such timed period of blower operation being equivalent in length to that required for the flame responsive apparatus to detect the presence of flame. The difficulty with such an arrangement is that in order to obtain a sufficiently long period of blower operation, it is necessary to have such a slow rate of response of the flame responsive apparatus that dangerous conditions may arise in the case of an abnormal flame failure.

An object of the present invention is to provide burner control apparatus in which the timing of the blow out cycle is performed by the flame responsive apparatus and in which the speed of response of the flame responsive apparatus is relatively rapid in the event of an abnormal flame failure.

A further object of the present invention is to provide burner control apparatus in which a safety cut out is provided, this safety cut out being operative only when the flame responsive apparatus does not indicate the presence of combustion. The flame responsive apparatus also normally being effective to maintain the blower in operation a predetermined period of time after the oil valve has closed following a termination of a call for heat, and in which the speed of re-

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sponse of the flame responsive apparatus is much greater in the event of an abnormal flame failure than in the event of a normal flame failure following a termination of the call for heat.

A further object of the present invention is to provide an arrangement such as set out in the previous object in which the flame responsive apparatus is effective to quickly terminate operation of both the blower and the fuel control in the event of an abnormal flame failure.

A further object of the present invention is to provide burner control apparatus such as set out in the previous objects in which the speed of response of the flame responsive apparatus is much more rapid during a call for heat by a main control device than upon a termination of the call for heat by the main control device.

A further object of the present invention is to provide an arrangement in which the flame responsive device employs electronic means.

A further object of the present invention is to provide an arrangement such as set out in the immediately preceding object in which the timing of the flame responsive means is changed by varying the time constant of a capacitive circuit in the flame responsive means.

Other objects of the present invention will be apparent from a consideration of the accompanying specification, claims, and drawings, in which Figure 1 is a schematic view of one form of my invention.

Figures 2 and 3 are schematic views of relays employed in the apparatus of Figure 1, and

Figure 4 is a schematic view of a portion of a modification of my invention.

Referring to Figure 1, the burner apparatus to be controlled comprises a blower 10 employed to supply air under pressure to an atomizing type of oil burner, the nozzle of which is shown in the lower part of the figure and designated by the numeral 14. The numeral 11 is employed to indicate an oil valve which controls the flow of fuel to the burner. This valve may, for example, be of a solenoid type which is open whenever energized and closed when deenergized. Also included in the burner apparatus being controlled is an ignition means 12 which is associated with the burner nozzle 14 in such a manner as to ignite the oil mixture issuing from the nozzle. This ignition means may, for example, take the form of a high voltage transformer and spark electrodes adapted to produce a spark in the path of the mixture issuing from the nozzle.

The main control for the system with which my apparatus is employed is a thermostat 16.

This thermostat may, for example, be a room thermostat located in the space whose temperature is to be controlled or it may be a boiler water thermostat responsive to the temperature of the boiler water. The thermostat is shown as comprising a bimetallic element 17 to which is attached a contact arm 18 adapted to sequentially engage with two contacts 19 and 20. As indicated by the legend adjacent the thermostat, the bimetallic element 17 moves contact arm 18 to the left upon a drop in temperature. The contact arm 18 is so spaced from contacts 19 and 20 that it first engages contact 19 and then upon a further drop in temperature engages contact 20.

The thermostat 16 controls the energization of a relay indicated in its entirety by the reference numeral 25. This relay comprises a relay coil 25a and a plurality of switch blades 25b, 25c, 25d, 25e, and 25f. In order to simplify the showing of the circuit, switch blade 25e has been shown in a different portion of the drawing than switch blades 25b, 25c, and 25d. Moreover, switch blade 25f has been shown on the opposite side of the relay coil from switch blades 25b to d. In order to illustrate the normal relationship between the elements of relay 25, the relay has been shown with the elements in their normal relation in Figure 2. The relay switch blades 25b to 25f are adapted to cooperate with contacts 25g, 25h, 25k, 25m and 25p, and 25n, respectively. The switch blades 25b, c, d, e, and f are biased out of engagement with contacts 25g, h, k, p, and n, respectively, and are adapted upon energization of the relay coil 25a to be moved into engagement with those contacts. The switch blade 25e is biased into engagement with contact 25m and is adapted upon energization of relay coil 25a to move out of engagement with that contact.

A thermal safety switch 35 also controls the energization of relay 25. This safety switch may be of any type which at the end of a period of time moves to a circuit interrupting position and remains in that position until manually reset. A typical switch of this type which may be employed is that shown in the patent to John M. Wilson 2,290,399. As shown schematically in the drawing, the switch consists of a pair of switch blades 36 and 37, the switch blade 37 being held in engagement with the switch blade 36 against its bias by a bimetallic element 38. An electric heater 39 is located adjacent bimetallic element 38 and is effective when energized to heat bimetallic element 38 to cause it to warp to the right, as indicated by the legend adjacent the element 38. Upon continued energization of heater 39 beyond a predetermined period of time the bimetallic element 38 moves out from under switch blade 37, permitting switch blade 37 to drop away from switch blade 36. When this happens, the switch blades 36 and 37 must be manually reengaged.

Reference numeral 40 is employed to generally designate a further relay. This relay comprises a coil 40a and four switch blades 40b, 40c, 40d, and 40e. Switch blade 40b is shown as separated from the remaining switch blades. The units of the relay are shown in their normal relationship in Figure 3. The switch blade 40b cooperates with contacts 40f and 40g, being biased into engagement with the latter contact and being moved into engagement with the former contact upon energization of relay coil 40a. The switch blades 40c and 40d cooperate with contacts 40h and 40k, respectively, being biased out of engagement with those contacts and moved into engagement there-

with upon energization of the relay coil. The switch blade 40e cooperates with a contact 40m, being biased into engagement with the contact and moved out of engagement with it upon energization of relay coil 40a.

The relay 40 controls the energization of a further relay 45 having a relay coil 45a and a single relay switch blade 45b. This switch blade cooperates with two fixed contacts 45c and 45d, being biased into engagement with the former contact and moved into engagement with the latter upon energization of the relay coil 45a.

The energization of relay 40 is controlled by flame responsive apparatus including an electron discharge tube 50. This tube comprises an anode 51, a grid 52, and a cathode 53. Associated with the cathode is a cathode heater 54. The three electrodes together with the cathode heater are enclosed in an envelope 55 which may, for example, be evacuated. The tube 50 is supplied with power by a transformer 59, this transformer comprising a primary winding 60, a high voltage center tapped secondary winding 61, and a low voltage secondary winding 62. The secondary winding 62 is connected by conductors 63 and 64 to the filament heater 54. The extreme left hand terminal of secondary 61 is connected by conductors 65 and 66 to the right hand terminal of relay winding 40a, the left hand terminal of which is connected by conductors 67 and 68 to anode 51. The center tapped secondary 61 is connected by conductor 69, resistor 84, and conductors 85 and 86 to the cathode 53. Thus, the left hand side of secondary 61 is employed as a source of plate potential for the anode circuit of tube 50.

The right hand side of secondary 61 is employed to control the potential of grid 52. The extreme right hand end of secondary 61 is connected to grid 52 by conductors 71 and 72, resistor 73, condenser 74, conductors 75, 76, 77 and 78, and resistor 79. A further resistor 80 and a further condenser 81 are connected between conductor 85 leading to the cathode 53 and conductor 76 leading to the grid 52. A third condenser 83 is connected in parallel with condenser 81 under certain conditions and in parallel with resistor 84 under other conditions. When the relay 25 is deenergized so that switch blade 25e is in engagement with contact 25m as shown, the condenser 83 is in parallel with condenser 81. When, however, relay 25 is energized as during a normal burner operation, the condenser 83 is in parallel with resistor 84. The capacity of condenser 83 is relatively large as compared with that of condenser 81.

Connected in parallel with resistor 73 and condenser 74 is a photoelectric cell 88 having an anode 89 and a cathode 90. The anode 89 is connected by conductors 91 and 72 to the upper terminal of resistor 73. The cathode 90 is connected by conductor 92, resistor 93, and conductors 76 and 75 to the lower terminal of condenser 74. The photoelectric cell 88 is mounted with respect to the flame of burner 14 in such a manner as to be illuminated by it. The photoelectric cell 88, when so illuminated, acts as a rectifying impedance.

A condenser 94 is connected in parallel with relay coil 40a by conductors 66 and 67. The function of condenser 94 is to by-pass the A. C. component of the pulsating current flowing through tube 50 when the latter is conductive.

Power is supplied for energization of relay 25 by a step down transformer 97. This trans-

former comprises a line voltage primary winding 98 and a low voltage primary winding 99. The line voltage primary 98 is connected by conductors 100, 101, 102, and 103 to line wires 104 and 105 leading to any suitable source of power (not shown).

Operation

Before proceeding with the description of the apparatus as a whole, the operation of the flame responsive portion of the apparatus will first be considered. The operation of the flame detecting apparatus is fully set out in the copending application of John M. Wilson, Serial No. 465,476, filed November 13, 1942, issued as Patent No. 2,448,503, Aug. 31, 1948. While the operation is explained in the following paragraphs in sufficient detail to enable a full understanding of the same as far as its application to the present apparatus is concerned, reference is made to the above mentioned Wilson patent for a more detailed understanding of the operation.

It will be assumed at first that the main burner is not ignited. Under these conditions, the current flowing through condenser 81 is that flowing through the following circuit: from the right hand terminal of secondary 61 through conductors 71 and 72, resistor 73, condenser 74, conductor 75, resistor 80, condenser 81, resistor 84, and conductor 89 to the center tap of secondary 61.

It will be assumed at first that the relay 25 is energized so that switch blade 25e is in engagement with cathode 25p. Under these conditions, the condenser 83 is connected in parallel with resistor 84 by a circuit extending from the upper terminal of resistor 84 through conductor 70, contact 25p, switch blade 25e, conductor 87, condenser 83, and conductor 85 to the lower terminal of resistor 84. Since, as indicated above, the resistor 84 is in series with the cathode, the condenser 83, being in parallel with resistor 84, is likewise in series with the cathode. Thus, when current flows through the anode circuit, the condenser 83 assumes a charge equivalent to the voltage drop across resistor 84. When relay 25 is energized as is now being assumed, condenser 83 does not in any way affect the operation of condenser 81. Thus, the voltage across condenser 81 is due solely to that of the circuit just traced. It will be recalled that the impedances in this circuit are all symmetrically conductive so that any voltage across condenser 81 is an alternating voltage. Since the lower terminal of condenser 81, which is the terminal connected to grid 52, is connected to the right hand terminal of secondary 61 which is 180° out of phase with respect to the left hand terminal, to which the anode is connected, it will be obvious that the alternating voltage across condenser 81 is 180° out of phase with the anode voltage. In other words, during the half cycles in which the anode 51 is positive with respect to the cathode, the voltage impressed across condenser 81 under the conditions being considered is of such polarity as to bias the grid 52 negatively with respect to the cathode 53. The tube 50 is thus sufficiently non-conductive as not to effectively energize relay coil 40a.

Let it now be assumed that the photoelectric cell 88 is illuminated by a flame issuing from burner 14. Under these conditions, the photoelectric cell 88 is conductive so that a new circuit is established to condenser 81 as follows: from the right hand terminal of secondary 61 through conductors 71 and 91, anode 89, cathode

89, conductor 92, resistor 93, conductors 77 and 76, resistor 80, condenser 81, resistor 84, and conductor 69 to the center tap of secondary 61. Due to the rectifying characteristic of photoelectric cell 88, there is an appreciable current flow through the circuit just traced only in the direction in which it was traced. As a result, a charge tends to be impressed upon condenser 81 which is of such polarity as to cause the lower terminal of condenser 81 to tend to become positive with respect to the upper terminal. As previously pointed out, it is the lower terminal of condenser 81 which is connected to the grid 52. Hence, the effect of this charge is to raise the potential of grid 52 with respect to the cathode 53. The photoelectric cell and the constants of the circuit are such that with a normal burner flame the potential of grid 52 is raised to a point such that sufficient current flows through tube 50 to cause effective energization of the relay 40a. The current flowing through the relay 40a flows through the following circuit: from the left hand terminal of secondary 61 through conductors 65 and 66, relay coil 40a, conductors 67 and 68, anode 51, cathode 53, conductors 86 and 85, resistor 84, and conductor 69 to the center tap of secondary 61. The effect of the establishment of this circuit is to cause the effective energization of relay 40 so as to cause switch blades 40b, 40c, 40d, and 40e to move to their energized positions in which switch blades 40b, 40c, and 40d are in engagement with contacts 40f, 40h, and 40k and in which switch blades 40b and 40e are out of engagement with contacts 40g and 40m.

In tracing the above circuit, it is to be noted that the circuit included the resistor 84. With relay 25 energized as has been assumed, condenser 83 is connected in parallel with resistor 84. Thus, with relay 25 energized and with the photoelectric cell 88 exposed to a flame, the condenser 83 becomes charged with a voltage equal in magnitude to that across resistor 84 and of a polarity such that the upper terminal of condenser 83 is negative with respect to the lower terminal. Upon relay coil 25 becoming deenergized, the condenser 83 is connected in parallel with condenser 81 by a circuit extending from the upper terminal of condenser 81 through conductor 85, condenser 83, conductor 87, switch blade 25e, contact 25m, and conductor 95. When the condenser 83 is so connected, the positive terminal of the condenser is connected to the lower terminal of condenser 81 which, as previously explained, is connected to the grid 52. Thus, the effect of this is to increase the charge across the condensers connected to the grid 52. This is effective following a normal shut down to maintain the grid at a raised potential with respect to the cathode 53 longer than would otherwise be the case since it is necessary for both condensers 81 and 83 to lose the unidirectional component of the voltages across them.

It is to be pointed out that the electronic apparatus which I employ is responsive only to a rectifying impedance so that if the terminals of the photoelectric cell are bridged by a non-rectifying impedance, even though it may have the same value of impedance as the illuminated photoelectric cell, the apparatus will not falsely indicate the presence of a flame.

Turning now to the operation of the apparatus in general, it is assumed that the thermostat 16 is satisfied so that the entire system is shut down. If the temperature adjacent the bimetallic element 17 of thermostat 16 now drops,

the arm 18 will be moved to the left so as to engage first contact 19 and then contact 20. Nothing happens until both sets of contacts are engaged, at which time a circuit is established to relay coil 25a as follows: from the right hand terminal of secondary 99 through conductor 115, safety switch blades 37 and 36, conductor 116, contact 19, contact arm 18, contact 20, conductor 117, contact 40g, switch blade 40b, conductors 119 and 120, safety switch heater 39, conductor 121, relay coil 25b, and conductor 122 to the left hand terminal of secondary 99. The result of the establishment of this circuit is to cause the energization of relay coil 25a with the resultant movement of switch blades 25b, 25c, 25d, 25e, and 25f into engagement with contacts 25g, 25h, 25k, 25p, and 25n, respectively. At the same time, switch blade 25e is moved out of engagement with contact 25m.

The engagement of switch blade 25d with contact 25k results in the establishment of a holding circuit to relay coil 25a as follows: from the right hand terminal of secondary 99 through conductor 115, safety switch blades 37 and 36, conductor 116, contact 19, contact arm 18, bimetallic element 17, conductor 125, switch blade 25d, contact 25k, conductor 120, heater 39, conductor 121, relay coil 25a, and conductor 122 to the left hand terminal of secondary 99. It is to be noted that the circuit just traced is independent of contact 20, the last to be engaged of the thermostatic contacts. This insures that the relay 25 will remain energized until there has been a rise in temperature sufficient to separate thermostat blade 18 from contact 19. In this way, provision is made for a differential in temperature between the energization and deenergization of relay 25. It is also to be noted that the holding circuit just traced is independent of the out contact 40g of relay 40. It was desirable that the original energizing circuit include such an out contact to protect against the system being accidentally brought into operation with relay 40 in its energized position. If it were possible to initiate operation of the system with the relay in this position, there would be no assurance that the relay was not accidentally retained in this position even though flame were not present. There would thus be no provision for checking the establishment of flame.

The engagement of switch blades 25f and 25b with contacts 25n and 25g, respectively, results in the establishment of the following energizing circuit to the ignition 12: from line wire 105 through conductors 101, 128 and 129, contact 25n, switch blade 25f, conductor 130, switch blade 45b, contact 45c, conductor 131, contact 25g, switch blade 25b, conductors 133, 134, 135, and 136, contact 40m, switch blade 40e, conductor 139, ignition 12, and conductors 140, 141, 142, 143, 144, and 103 to the other line wire 104. A circuit is also established to the primary winding 60 of the transformer 59 as follows: from line wire 105 through conductors 101, 128, and 129, contact 25n, switch blade 25f, conductor 130, switch blade 45b, contact 45c, conductor 131, contact 25g, switch blade 25b, conductors 133, 134, 146, and 147, primary winding 60, and conductors 148, 141, 142, 143, 144, and 103 back to the other line wire 104. The establishment of the circuit just traced results in energization of the electronic apparatus with the result that the cathode heater 54 starts to warm up to place the apparatus in condition to check the operation of the flame. The movement of switch

blade 25e out of engagement with contact 25m, as a result of the energization of relay 25, results in condenser 83 being disconnected from condenser 81. Since condenser 81 has a relatively small capacitance, the time required for charging the condenser is relatively small as compared with that when condensers 81 and 83 were in parallel. Thus, instead of from one to three minutes being required, the charging time may be a matter of only a comparatively few seconds. Thus, as soon as the cathode heater is warmed up, electronic apparatus is capable of detecting very rapidly the establishment of combustion at the main burner.

At the same time as the circuits are established to the ignition means 12 and the primary of the transformer 59, circuits are also established to the blower 10 and the oil valve 11. The circuit to blower 10 is as follows: from line wire 105 through conductors 101, 128, and 129, contact 25n, switch blade 25f, conductor 130, switch blade 45b, contact 45c, conductor 131, contact 25g, switch blade 25b, conductors 133, 134, and 136, blower 10, and conductors 151, 142, 143, 144, and 103 to the other line wire 104. The circuit established to oil valve 11 is as follows: from line wire 105 through conductors 101, 128, and 129, contact 25n, switch blade 25f, conductor 130, switch blade 45b, contact 45c, conductor 131, contact 25g, switch blade 25b, conductors 133 and 154, contact 25h, switch blade 25c, conductor 156, oil valve 11, and conductors 157, 144, and 103 to the other line wire 104.

As a result of the circuits traced above, the oil valve is energized to deliver oil to the burner, the blower is in operation, the ignition means is functioning, and the flame responsive apparatus is capable of detecting the presence of flame. Normally, the burner ignites almost immediately so that as soon as the flame responsive apparatus has warmed up, a matter requiring considerably less than a minute, the flame responsive apparatus responds to the presence of flame by causing energization of relay 40a with the movement of switch blades 40b, 40c, 40d, and 40e to their energized positions previously referred to.

The movement of switch blade 40b into engagement with contact 40f results in a shunt being established around the heater 39 of the safety switch 35, this shunt extending from the upper terminal of heater 39 through conductors 120 and 119, switch blade 40b, and contact 40f to the lower terminal of heater 39. The effect of the establishment of this circuit is to terminate the operation of the safety switch 35. If heater 39 were allowed to remain energized sufficiently long, safety switch 35 would eventually open to cause deenergization of relay 25 and as a result the rest of the apparatus. By establishing the shunt around heater 35, however, the bimetal element cools down so that it is not effective to interrupt operation of the system.

The movement of switch blade 40e out of engagement with contact 40m interrupts the circuit to the ignition 12. Since the main burner has been ignited, the continued operation of the ignition is no longer necessary.

The movement of switch blade 40d into engagement with contact 40k results in the establishment of the following circuit to blower 10: from line wire 105 through conductors 101, 128, 161, and 162, contact 40k, switch blade 40d, conductors 163, 146, 135, and 150, blower 10, conductors 151, 142, 143, 144, and 103 back to the

other line wire 104. It is to be noted that the new circuit parallels switch blades 25f, 45b, and 25b and is not dependent upon either relay 25 or relay 45. In other words, the closure of switch blade 40d with contact 40k results in the establishment of a shunt circuit between conductor 128 and switch blade 25b as follows: from conductor 128 through conductor 161 and 162, contact 40k, switch blade 40d, and conductors 163, 146, 135, 134, and 133. Since the left hand terminal of ignition transformer 60 is connected to conductor 146, it will be apparent that the ignition transformer is now also energized through switch blade 40d and contacts 40k independently of relays 25 or 45. Similarly, since the oil valve 11 is connected through switch blade 25c and contact 25h to conductor 133, it will be apparent that this device is now also energized independently of relay 45. Since, however, it includes in its circuit switch blade 25c, its energization is dependent upon the continued energization of relay 25.

The movement of switch blade 40c into engagement with contact 40h results in the establishment of an energizing circuit to relay coil 45a as follows: from line wire 105 through conductors 101, 128, and 161, switch blade 40c, contact 40h, conductor 170, relay coil 45a, and conductors 171, 143, 144, and 103 to the other line wire 104. The energization of relay coil 45a results in switch blade 45h moving out of engagement with contact 45c and into engagement with contact 45d.

The movement of switch blade 45b out of engagement with contact 45c interrupts the previously traced circuits under the control of relay 25 to the blower, oil valve, and ignition transformer. Since, however, new circuits under the control of relay 40 have already been established, this does not terminate energization of these devices.

The movement of switch blade 45b into engagement with contact 45d results in a holding circuit being established for relay coil 45a as follows: from line wire 105 through conductors 101, 128, and 129, contact 25n, switch blade 25f, conductor 130, switch blade 45b, contact 45d, conductor 173, relay coil 45a, and conductors 171, 143, 144, and 103 to the other line wire 104. This holding circuit is independent of relay 40 and insures that the relay 45 will remain energized as long as relay 25 is energized.

The apparatus is now operating normally. The oil valve and blower are both energized and the safety switch heater 39 and the ignition 12 are deenergized. The flame responsive apparatus is not only energized, but due to the disconnection of the condenser 83 from the condenser 81, the speed of the response of the flame detecting apparatus is relatively rapid. Under normal conditions, the burner will continue to operate until the temperature surrounding the thermostat 16 rises to a point where thermostat contact arm 18 has moved out of engagement with not only contact 20 but also contact 19. When this happens, the relay 25 is immediately deenergized so as to cause movement of the switch blades thereof to their deenergized positions.

The movement of switch blade 25c out of engagement with contact 25h results in the immediate deenergization of the oil valve 11. This interrupts the delivery of fuel to the burner. At the same time, switch blade 25e moves out of engagement with contact 25p and into engagement with contact 25m. This results in condenser 83 being disconnected from resistor 84 and being con-

nected in parallel with condenser 81. Since, as previously explained, the condenser 83 has by reason of its parallel connection with resistor 84 assumed a charge of such polarity that the lower terminal of condenser 83 is positive with respect to the upper terminal, the total capacitive charge existing in the circuit connections between the grid and cathode has been greatly increased. As a result of the closure of the oil valve, the main burner is almost immediately extinguished. This in turn results in the photoelectric cell being no longer illuminated so that the conductive path through it is interrupted. The voltage across condenser 81 now tends to assume the alternating value originally considered. This tendency is resisted, however, by the inclusion of condenser 83 in parallel with it, which condenser is of relatively large capacity and has a substantial positive voltage across its terminals. Because of the inclusion of condenser 83 in parallel with condenser 81, the apparatus requires a substantial period of time, for example, a minute, in order to cause deenergization of relay 40a.

As long as relay 40 is energized, the blower continues in operation. Due to the delay in the response of the flame responsive apparatus by reason of the connection of the condenser 83 in parallel with condenser 81, this operation of the blower continues for a substantial period of time after deenergization of the fuel oil valve 11. This period of time is adequate to remove any traces of oil remaining at the burner.

The movement of switch blade 25f out of engagement with contact 25n results in the interruption of the holding circuit to relay coil 45a. When relay 40 becomes deenergized the circuit to coil 45a is broken at 40h and relay 45 moves to the deenergized position shown in the drawing. As soon, therefore, as relay 40 is deenergized as a result of the flame responsive apparatus detecting the extinguishment of combustion, all of the elements have returned to the position shown in the drawing in which the apparatus is again in condition for the initiation of a new cycle of operation as soon as the thermostat 16 calls for heat.

In considering the operation above, it was assumed that combustion was established at the main burner in the normal manner and continued throughout the call for heat by the room thermostat. Let it be assumed first, however, that combustion is never established. Under these conditions, the flame responsive apparatus does not cause energization of relay 40 with the result that the shunt circuit around heater 39 is not established by the movement of switch blade 40b into engagement with contact 40f. Accordingly, the heater 39 continues to heat the bimetallic element 38 of safety switch 35 until the element 38 moves to the right beyond switch blade 37 allowing switch blade 37 to separate from switch blade 36. This results in the interruption of the circuit to relay 25 and the resultant deenergization of that relay to cause complete deenergization of the entire system. Before it can again be placed into operation, it is necessary for the switch blade 37 to be manually raised into engagement with switch blade 36. Before doing so, the attendant can inspect the apparatus to determine the cause of the failure to establish combustion.

Let it be assumed now that combustion is properly established but that for some reason or other a combustion failure occurs before the termination of the call for heat. Under these conditions, the photoelectric cell 88 becomes non-conductive

so that the only energizing circuit for condenser 81 is that which was first traced and which, it will be recalled, includes only symmetrically conductive impedances. Thus, in a very short period of time, for example, a matter of only a few seconds, the condenser 81 loses the positive charge resulting from the action of photoelectric cell 58 so that the only voltage across it is the alternating voltage first considered. It will be recalled that this alternating voltage biases the grid negatively to such an extent that the relay 40a is non-conductive. It is to be noted that under these circumstances condenser 83 is not in parallel with condenser 81 but rather is in parallel with resistor 84. Since resistor 84 is not connected between the cathode and grid, the condenser 83, when connected in parallel with resistor 84, does not appreciably affect the voltage applied to grid 52. It certainly does not affect the operation of condenser 81. Thus, the response of the condenser 81 to the extinguishment of the burner flame is extremely rapid under these conditions.

As soon as relay 40 is deenergized, the oil valve, the blower, and the transformer 59 are all immediately deenergized. This is due to the fact that relay 45 is still energized so as to hold switch blade 45b out of engagement with contact 45c. Thus, the originally traced circuits under the control of relay 25 are interrupted so that the only circuits which would otherwise exist would be those resulting from the closure of switch blade 40d with contact 40k. Thus, when switch blade 40d separates from contact 40k, all of the circuits to the burner apparatus are interrupted.

The separation of switch blade 40b from contact 40f as a result of the deenergization of relay 40 interrupts the shunt circuit around heater 39 so that the heater 39 again starts heating the safety switch. This operation will continue until the safety switch opens its contacts to deenergize relay 25. When this happens, switch blade 25f will separate from contact 25n to interrupt the holding circuit for relay coil 45a to cause deenergization of relay 45. Again, all of the apparatus will be completely deenergized and a manual resetting of the safety switch 35 will be required before the system can again be placed into operation.

It is to be noted from the above operation that the response of the flame apparatus following a termination of a call for heat is relatively slow so as to maintain the blower in operation for a predetermined period of time following the closure of the fuel oil valve. When, however, there is a flame failure while the main burner control is in operation, the flame responsive apparatus responds quickly to the extinguishment of flame and causes an immediate closure of both the oil valve and the blower. Thus, the apparatus of my invention utilizes a flame responsive apparatus to provide a timed period of blower operation following the fuel interruption without in any way reducing the sensitivity of the flame responsive apparatus to an abnormal flame failure. This is obviously highly desirable since when there is an abnormal flame failure, it is imperative that the delivery of oil be interrupted immediately.

Species of Figure 4

In the modification of Figure 4, I have shown a slightly different way of varying the sensitivity of the flame responsive apparatus. Since the main portion of the burner control apparatus is identical to that of Figure 1, it has not been illustrated in Figure 4. Furthermore, to facilitate

a comparison of Figures 1 and 4, the same reference characters have been used in Figure 4 to indicate elements which are identical to those of Figure 1. The primary difference between Figure 4 and Figure 1 is that the change in response is accomplished by varying the amount of resistance connected in series with condenser 81. In the present case, two resistors 170 and 175 have been connected in series with condenser 81 in lieu of resistor 80 of the species of Figure 1. The resistor 170 has a relatively large resistance as compared with that of resistor 175. The "out" contact 25m of relay 25 has been eliminated so that the switch blade 25e cooperates only with contact 25p which it engages when the relay 25 is energized. When the relay 25 is energized, the relatively large resistor 170 is shunted out by conductor 176, contact 25p, switch blade 25e, and conductor 177. Thus, whenever the relay 25 is energized, resistor 170 is effectively out of the circuit. Since resistor 84 is not employed in the present species, the shunting of resistor 170 results in resistor 175 being the only resistor between condenser 81 and the center tap of secondary 81. Furthermore, the total resistance now in series with condenser 81 is equal to the resistances of resistors 73 and 175, both of which have very small resistance values as compared with that of resistor 170. As is well known, the time required for a condenser to discharge is dependent upon the time constant of the circuit which is proportional to the product of the resistance and capacitance in the circuit. By shunting out a large portion of the resistance, the time constant of the circuit is reduced so that the apparatus is able to respond quickly to the presence or loss of flame.

It will be apparent that the operation of the flame responsive apparatus is generally similar to that of Figure 1 as far as the operation of the burner system is concerned. As long as relay 25 is energized as is the case when thermostat 18 is calling for heat, switch blade 25e is engaged with contact 25p and shunts out resistor 170 to render the apparatus quickly responsive to the presence or absence of combustion. As soon, however, as the thermostat is satisfied, the switch blade 25e moves out of engagement with contact 25p, interrupting the shunt circuit around resistor 170 so that the time constant of the circuit including condenser 81 is increased to such a point that the response of the flame responsive apparatus is relatively slow. By proper choice of constants, the apparatus can be designed to require at least a minute to respond to the absence of a flame under these conditions. This results in the blower continuing in operation for a substantial period of time following the closure of the fuel oil valve.

While I have shown certain specific embodiments of my invention for purposes of illustration, it is to be understood that the scope of the invention is to be limited only by the appended claims.

I claim as my invention:

1. Burner control apparatus including a fuel control; a burner blower; a safety cut-out; means adapted to respond to the presence of combustion at the burner being controlled; means including a main control device for initiating operation of said fuel control, said burner blower, and said safety cut-out; means including said safety cut-out effective at the end of a timed period to terminate operation of said fuel control and burner blower unless the operation of

said safety cut-out is previously interrupted; means including said combustion responsive means for interrupting operation of said safety cut-out upon the establishment of combustion and for again starting its operation if combustion is terminated; means effective upon the operation of said fuel control being terminated due to said main control device assuming a position in which fuel is not demanded to continue the operation of said blower until said combustion responsive means responds to the termination of combustion; and means controlled by said main control device for causing said combustion responsive means to respond more quickly when said main control device is calling for burner operation than when it is not.

2. Burner control apparatus including a fuel control; a burner blower; means including a main control device for initiating operation of said fuel control and burner blower when said main control device is in a position demanding burner operation; means effective when said main control device assumes a position in which burner operation is not desired to cause said fuel control to assume a fuel interrupting condition; means including flame responsive apparatus for continuing operation of said blower until said flame responsive apparatus has responded to the termination of burner flame; means including said flame responsive apparatus effective in the event of a flame failure while said main control device is calling for burner operation to cause said fuel control to assume a fuel interrupting position; and means to cause said flame responsive apparatus to respond more quickly to the termination of flame when said main control device is calling for burner operation than when it is not.

3. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; means including a flame responsive apparatus for interrupting delivery of fuel while said control device is in its fuel demanding position upon the occurrence of a flame failure; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until said flame responsive apparatus has responded to the extinguishment of the burner flame; and means to decrease the speed of response of said flame responsive apparatus upon said main control device becoming satisfied.

4. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; means including a flame responsive apparatus for interrupting delivery of fuel and air while said control device is in its fuel demanding position upon the occurrence of a flame failure; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until said flame responsive apparatus has responded to the extinguishment of the burner flame; and means to decrease the speed of response of said flame re-

sponsive apparatus upon said main control device becoming satisfied.

5. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; means including a safety controller effective after a timed period of operation of said safety controller to interrupt delivery of fuel to said burner; means including flame responsive apparatus for interrupting operation of said safety controller upon the establishment of combustion within said timed period; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until said flame responsive apparatus has responded to the extinguishment of the burner flame; and means to decrease the speed of response of said flame responsive apparatus upon said main control device becoming satisfied.

6. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; means including a safety controller effective after a timed period of operation of said safety controller to interrupt delivery of fuel and air to said burner; means including flame responsive apparatus for interrupting operation of said safety controller upon the establishment of combustion within said timed period; further means including said flame responsive apparatus for interrupting delivery of fuel while said control device is in its fuel demanding position upon the occurrence of a flame failure; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until said flame responsive apparatus has responded to the extinguishment of the burner flame; and means to decrease the speed of response of said flame responsive apparatus upon said main control device becoming satisfied.

7. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; flame responsive apparatus including a condenser, a flame responsive element, and means including a charging circuit for charging said condenser in accordance with the presence or absence of combustion adjacent said flame responsive element; means including said flame responsive apparatus for interrupting delivery of fuel while said control device is in its fuel demanding position upon the charge of said condenser assuming a predetermined value as a result of flame failure; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until the charge of said condenser assumes said predetermined value due to the extinguishment of the

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burner flame; and means to increase the time constant of said charging circuit to decrease the speed of response of said flame responsive apparatus upon said main control device becoming satisfied.

8. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; flame responsive apparatus including a condenser and means for charging said condenser in accordance with the presence or absence of combustion adjacent said flame responsive element; means including said flame responsive apparatus for interrupting delivery of fuel while said control device is in its fuel demanding position upon the charge of said condenser decreasing below a predetermined value as a result of flame failure; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until the charge of said condenser assumes said predetermined value due to the extinguishment of the burner flame; and means effective upon said main control device moving to satisfied position to connect a further charged condenser in parallel with said first named condenser to increase the time required for said first named condenser to discharge.

9. In a burner control apparatus; a burner; a main control device movable between heat demanding and satisfied positions; means for initiating delivery of fuel and air to said burner when said main control device is in heat demanding position and for interrupting said delivery of fuel when said control device assumes a heat satisfied position; flame responsive apparatus including a condenser, a flame responsive element, and means including a charging circuit for charging said condenser in accordance with the presence or absence of combustion adjacent said flame responsive element; means including said flame responsive apparatus for interrupting delivery of fuel while said control device is in its fuel demanding position upon the charge of said condenser decreasing below a predetermined value as a result of flame failure; means including said flame responsive apparatus effective upon said control device assuming its satisfied position to continue delivery of air to the burner until the charge of said condenser assumes said predetermined value to the extinguishment of the burner flame; and means effective upon said main control device becoming satisfied to increase the resistance of said charging circuit to increase the time required for said condenser to discharge.

10. Burner control apparatus adapted to be connected to a burner fuel control, a burner blower, and a main control switch movable between heat demanding and satisfied positions; said apparatus comprising: switching means; combustion responsive means adapted to be responsive to combustion conditions at a burner to operate said switching means; fuel control circuit means effective when said apparatus is so connected to maintain said fuel control in fuel supplying position only while said main control switch is in heat demanding position; blower circuit means controlled by said switching means and adapted when said apparatus is so connected to initiate energization of the blower as a result

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of movement of said main control switch to heat demanding position and to maintain said blower energized until said combustion responsive means has responded to the termination of combustion adjacent the burner; means controlled by said switching means and connected in said fuel control circuit means for interrupting said fuel control circuit means when said combustion responsive means responds to the termination of combustion; and means effective when said apparatus is so connected to such a main control switch to cause said combustion responsive means to respond more quickly to the termination of combustion when said main control switch is in heat demanding position than when it is in its satisfied position.

11. Burner control apparatus for controlling a burner fuel control and a burner blower; said apparatus comprising: a relay; energizing circuit means for said relay adapted to be connected to a main control switch and to energize said relay when so connected and when said main control switch is closed; further switching means, combustion responsive means adapted to be responsive to combustion conditions at a burner to operate said switching means; fuel control circuit means controlled by said relay and adapted to be connected to a fuel control for the burner for maintaining said fuel control in fuel supplying position only while said relay is energized, blower circuit means controlled by said relay and said further switching means and adapted to be connected to a burner blower for initiating energization of the blower as a result of energization of the relay and for maintaining said blower energized until said combustion responsive means has responded to the termination of combustion adjacent the burner, means controlled by said further switching means and connected in said fuel control circuit means when said combustion responsive means responds to the termination of combustion, and means controlled by said relay to cause said combustion responsive means to respond more quickly to the termination of combustion when said relay is energized than when said relay is deenergized.

12. Burner control apparatus adapted to be connected to a burner fuel control, a burner blower, and a main control switch movable between heat demanding and satisfied positions; said apparatus comprising: switching means; combustion responsive means including a condenser for operating said switching means when the charge across said condenser assumes a predetermined value; a flame responsive element, and a charging circuit for charging said condenser in accordance with the presence or absence of combustion adjacent said flame responsive element; fuel control circuit means effective when said apparatus is so connected to maintain said fuel control in fuel supplying position only while said main control switch is in heat demanding position; blower circuit means controlled by said switching means and adapted when said apparatus is so connected to initiate energization of the blower as a result of movement of said main control switch to heat demanding position and to maintain said blower energized until said combustion responsive means has responded to the termination of combustion adjacent the burner; means controlled by said switching means and connected in said fuel control circuit means for interrupting said fuel control circuit means when said combustion responsive means responds to the

termination of combustion; and means effective when said apparatus is so connected to such a main control switch to increase the time constant of said charging circuit to decrease the speed of response of said combustion responsive means when said main control switch moves from its heat demanding position to its satisfied position.

FREDERICK E. LANGE.

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