

UNITED STATES PATENT OFFICE

2,440,700

FLUID BURNER SAFETY CONTROL APPARATUS WITH IGNITION TIMING

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Application August 3, 1945, Serial No. 608,751

3 Claims. (Cl. 158—28)

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The present invention is concerned with a fluid fuel burner control apparatus and more particularly with apparatus of the type employing a timer to control certain functions. This application is a continuation in part of my copending application Serial No. 607,631, filed July 28, 1945.

An object of the present invention is to provide an improved burner control system in which a single timer is employed to both time an operation of the blower following the interruption of fuel delivery after a termination of a call for heat and to provide for a safety shut down at the end of a predetermined period of time if combustion is not successfully established.

A still further object of the present invention is to provide such an arrangement in which the timer also functions to time the ignition period.

A still further object of the present invention is to provide such an arrangement in which provision is made if desired for operation of an oil preheater.

A still further object of the present invention is to provide such an arrangement in which the timer is a thermal timer which operates to provide either of two ignition timing periods and a timing period of different length for the operation of the blower following the interruption of fuel.

A further object of the present invention is to provide such an arrangement in which provision is made for delaying the opening of the fuel oil valve after the operation of the blower.

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

Figure 1 is a schematic showing of the improved burner control apparatus associated with portions of the burner apparatus being controlled,

Figure 2 is a schematic view of one relay employed in the apparatus, and

Figure 3 is a schematic view of another relay employed in my apparatus.

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 a pilot burner gas valve 12 which controls flow of fuel to a pilot burner 13. Provided with the pilot burner is some means for igniting the pilot

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burner whenever gas is supplied thereto. This means might well be an electrical ignition means which is energized simultaneously with the pilot burner gas valve. For purposes of simplicity, this ignition means is not shown. An electrical heater 15 is employed for preheating the oil before it is delivered to the burner. The operation of this heater is controlled by a thermostat 21 having a bimetallic element 22 exposed to the oil and adapted upon a drop in temperature to move into engagement with a fixed contact 23.

The main control for the system in 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, 25f, and 25g. In order to simplify the showing of the circuit, switch blades 25f and 25g have been shown in a different portion of Figure 1 than switch blades 25b, 25c, 25d, and 25e. In order to illustrate the normal relationship between the units of relay 25, the relay has been shown with the elements in their normal relation in Figure 2. The relay switch blades 25b, 25c, 25d, 25f, and 25g are biased out of engagement with contacts 25h, 25k, 25m, 25n, and 25p, respectively, and are moved into engagement with those contacts upon energization of relay coil 25a. Switch blades 25c and 25e are biased into engagement with contacts 25s and 25t and are moved out of engagement with these contacts upon energization of the relay coil 25a.

The 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. The latter switch blade is shown in the upper portion of the drawing to simplify the showing of the circuit. The relay is shown with the elements thereof in their normal relationship in Figure 3. The switch blades

40b, 40c, 40d, and 40e cooperate with fixed contacts 40f, 40g, 40h, and 40k. The blades 40d and 40e are normally biased into engagement with contacts 40f and 40k, respectively, being moved out of engagement therewith upon energization of the relay coil 40a. The switch blades 40c and 40d are biased out of engagement with fixed contacts 40g and 40h, being moved into engagement with these contacts upon energization of relay coil 40a.

The relay 40 is controlled by a flame responsive apparatus including an electronic 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 right hand terminal of secondary 61 is connected to relay winding 40a which in turn is connected by conductor 65 to anode 51. The center tapped secondary 61 is connected by conductors 66 and 67 to the cathode 53. Thus, the right hand side of secondary 61 is employed as a source of plate potential for the anode circuit of tube 50.

The left hand side of secondary 61 is employed to control the potential of grid 52. The extreme left hand end of secondary 61 is connected to grid 52 by conductors 68 and 69, resistor 70, condenser 71, conductors 72 and 73, and resistor 74. A further resistor 75 and a further condenser 76 are connected between conductor 67 leading to the cathode 53 and conductor 73 leading to the grid 52. Since condenser 76 and resistor 75 are connected between the grid and cathode, the voltage across these members largely determines the voltage applied to grid 52. As will be explained more fully later, an alternating voltage is normally impressed across condenser 76, this alternating voltage being 180° out of phase with the voltage applied to anode 51. Connected in parallel with resistor 70 and condenser 71 are two flame detecting devices each designed to respond to a different flame and each having a rectifying characteristic when exposed to a flame. The flame responsive device adapted to be associated with the pilot burner 13 is a flame electrode 80 which is connected by resistor 81 and conductor 68 to the left hand terminal of secondary 61. The burner 13 is grounded at 82 and the lower terminals of condensers 71 and 76 are grounded at 83. A burner flame such as that of a gas pilot burner has a rectifying characteristic in that it has a lower resistance to current flowing in a direction opposite to that of propagation of the flame. Consequently, when there is a flame at pilot burner 13 there is, in effect, a rectifying impedance connected between resistor 81 and ground connections 82 and 83. A photoelectric cell 88 is also connected in parallel with this flame gap. This photoelectric cell comprises an anode 89 and a cathode 90. The anode 89 is connected by conductor 91 to the resistor 80. The cathode 90 is connected by conductor 92 to the lower plates of condensers 71 and 76. A photoelectric cell is normally conductive in only one direction and is appreciably conductive in that direction only when illuminated. The photoelectric cell 88 is so mounted

with respect to the burner flame as to be illuminated by it. Consequently, when the burner flame is present, the tube 88 likewise functions as a rectifying impedance.

A third relay is indicated by the reference numeral 100. This relay comprises a relay coil 101 and a plurality of switch blades 102, 103, 104, 105, and 106. Cooperating with the switch blades 102 to 106 are fixed contacts 107, 108, 109, 110, and 111. The blades 102, 103, and 106 are biased out of engagement with contacts 107, 108, and 111, respectively, and are moved into engagement with those contacts upon energization of relay coil 101. Switch blades 104 and 105 are biased into engagement with contacts 109 and 111, respectively, and are moved out of engagement with those contacts upon energization of the relay coil 101.

A thermal timer 120 is employed to terminate the operation of the pilot burner, to maintain the blower in operation after the oil valve is closed following a normal operation of the burner, and to effect a safety shut down of the burner apparatus in the event of a combustion failure. This timer 120, as shown schematically in the drawing, comprises a bimetallic element 121 which normally engages a contact 122, this contact being the "cold contact." Associated with the bimetallic element 121 is a heater 123. Upon energization of the heater, the bimetallic element 121 warps downwardly into engagement with another fixed contact 124, which may be referred to as the "hot contact."

Connected in series with heater 123 are two series connected resistors 130 and 131. A switch blade 133 is adapted to engage with either of two contacts 134 or 135, both of which are connected to the series connected resistors 130 and 131. Contact 134 is connected between resistor 130 and the heater 123 while contact 135 is connected to the junction of resistors 130 and 131. Thus, depending upon the position of switch blade 133, it is connected to either the junction of heater 123 and resistor 130 or to the junction of resistors 130 and 131. As will be pointed out more fully later, the switch blade 133 is employed to control the length of the ignition timing. A resistor 180 is also connected to heater 123 and under certain conditions is in series with it. Power is supplied for operation of relay 25 by a transformer 140. This transformer comprises a primary winding 141 and a low voltage secondary winding 142. The primary winding 141 is connected by conductors 144, 145, and 146 to two line wires 147 and 148 leading to any suitable source of power (not shown).

A transformer 150 is employed to supply power for the energization of thermal timer heater 123 and for relay 100. The transformer 150 comprises a line voltage primary 151 and a low voltage secondary 152.

The energization of primary 151 is controlled by a thermostat 155, which, like thermostat 21, is adapted to respond to the temperature of the oil. This thermostat comprises a bimetallic element 156 carrying a contact 157 adapted to engage with a fixed contact 158. Contacts 157 and 158 are maintained out of engagement by bimetallic element 156 as long as the temperature of the oil is below that desirable for operation of the burner. As soon as the action of pre-heater 15 raises the temperature to the desired operating value, contacts 157 and 158 are closed.

A manually operable switch blade 160 is adapted to be moved into or out of engagement with

a fixed contact 161. Contact 161 is connected to switch blade 104 while the manually operable switch blade 160 is connected to relay switch blade 103. The position of the switch blade in which it is shown in the drawing is identified by the legend "ND" which is an abbreviation of "No delay." The legend "D" appears adjacent contact 161, this legend being an abbreviation of the word "Delay." In the position shown, the blower and oil valve are energized simultaneously; in other words, there is no delay in the energization of the oil valve after the energization of the blower. With the switch blade 160 in engagement with contact 161, the blower is energized before the fuel valve so that there is some delay in the energization of the fuel valve following that of the blower.

While the various elements of the apparatus just described can have a wide range of values, in one particular embodiment, I have found it desirable to employ elements of the following values:

Resistors 130, 131 and 180 had values of 8.8 ohms, 16 ohms, and 18.3 ohms, respectively. The heater 123 had a resistance of 10 ohms. The secondaries 142 and 152 each had output voltages of 24 volts. In the flame discharge apparatus, each half of secondary 61 had an output of 300 volts and secondary 62 had an output of 12 volts. The size of this secondary winding is, of course, dependent upon the voltage rating of the cathode heater of the tube which is employed for tube 50. In the same embodiment of my invention, I employ condensers of 0.02 microfarad and 0.002 microfarad for condensers 76 and 71, respectively. For resistors 70 and 75 I employed resistors having resistance values of 1 and 2 megohms, respectively. I employ a resistor of 3 to 4 megohms for resistor 74 and a resistor of 1 megohm for resistor 81. As previously indicated, however, it is to be understood that all of these values are merely values employed in a particular embodiment of my invention and that the invention is not in any way limited to the use of elements having these particular values.

Operation

Before starting the operation of the system in general, the operation of the flame detecting apparatus will be briefly described.

While the operation of this flame detecting apparatus is briefly set out in the following paragraphs, it is fully set out in the copending application of John M. Wilson, Ser. No. 465,476, filed November 13, 1942, and for a more detailed understanding of the operation of this portion of the apparatus reference is made to that application.

It will be assumed at first that neither the pilot burner nor main burner is ignited. Under these conditions, the only current flowing through condenser 76 is that flowing through the following circuit: from the left hand terminal of secondary 61, through conductors 68 and 69, resistor 70, condenser 71, conductor 72, condenser 76, resistor 75, and conductor 66 to the center tap of secondary 61. It will be noted that all of the impedances in this circuit are symmetrically conductive so that the voltage appearing across condenser 76 is an alternating voltage. Furthermore, since the lower plate of condenser 76, to which grid 52 is connected, is connected to the opposite terminal of secondary 61 than that to which anode 51 is connected, this alternating voltage is 180° out of phase with

that applied to anode 51. The effect of this out of phase alternating voltage is to bias grid 52 negatively during the half cycles in which anode 51 is positive. The tube 50 is therefore non-conductive under these conditions. Now let it be assumed that a flame exists at pilot burner 13. Under these conditions, a new circuit is established through condenser 76, this circuit being as follows: from the left hand terminal of secondary 61 through conductor 68, resistor 81, flame electrode 80, the pilot burner flame, pilot burner 13, ground connections 82 and 83, condenser 76, resistor 75, and conductor 66 to the center tap of secondary 61. The impedance of the pilot burner flame, as pointed out previously, is rectifying in character. That is, current flows through the pilot flame more readily in the direction traced than in the opposite direction. The effect of current flow through the condenser in the direction traced is to tend to cause the lower plate of condenser 76 to become positive with respect to the upper plate. The grid 52, it will be recalled, is connected to the lower terminal of condenser 76. Thus, the effect of the current flow through condenser 76 over the circuit just traced, is to raise the potential of the grid 52 in a positive direction with respect to that of cathode 53. The apparatus is so designed that with a normal pilot burner flame, the potential of grid 52 is raised sufficiently that tube 50 becomes sufficiently conductive to effectively energize relay coil 40a. The current flow through relay coil 40a is as follows: from the right hand terminal of secondary 61 through relay coil 40a, conductor 65, anode 51, cathode 53, and conductors 67 and 66 to the center tap of secondary 61. The result of the energization of relay coil 40a in this manner is to cause switch blades 40b, 40c, 40d, and 40e to move to their energized positions in which switch blades 40b and 40e are separated from contacts 40f and 40k and switch blades 40c and 40d are moved into engagement with contacts 40g and 40h.

The same result is obtained when the photoelectric cell 88 is illuminated by the main burner flame. As pointed out previously, the photoelectric cell 88 is in effect connected in parallel with the flame gap between resistor 88 and ground connection 83. Furthermore, since current tends to flow through the photoelectric cell only from the anode to the cathode, it will be apparent that the tube 88 has the same asymmetrically conductive characteristics as the flame. In fact, since the tube is almost entirely non-conductive in one direction, it is even more rectifying in character than is the flame. As a result, whenever the photoelectric cell is exposed to the illumination of the main burner flame, the condenser 76 becomes charged in the same manner as when a pilot flame is present.

It is to be pointed out that the electronic apparatus which I employ is responsive only to a rectifying impedance so that if either the flame gap or 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 flame or 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. It is also assumed that the oil is above the temperature desired for proper operation of the burner. If the temperature adjacent the bi-

metallic 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 142 through conductor 175, thermostat contact 19, arm 18, contact 20, conductor 176, contact 40k, switch blade 40e, conductors 177 and 178, heater 123, conductor 179, contact 134, switch blade 133, contact 122, bimetallic element 121, conductor 181, switch blade 25c, contact 25s, conductors 182 and 183, push button switch 39, conductor 184, relay coil 25a, and conductor 185, back to the other terminal of secondary 142. 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, 25f, and 25g into their energized positions in which switch blades 25c and 25e are no longer in engagement with contacts 25s and 25t, and in which switch blades 25b, 25c, 25d, 25f, and 25g are in engagement with contacts 25h, 25k, 25m, 25n, and 25p, respectively.

The engagement of switch blade 25d with contact 25m results in the establishment of a holding circuit to relay coil 25a as follows: from the right hand terminal of secondary 142 through conductor 175, thermostat contact 19, blade 18, bimetallic element 17, conductor 187, switch blade 25d, contact 25m, conductor 183, push button switch 39, conductor 184, relay coil 25a, and conductor 185 to the left hand terminal of secondary 142. It is to be noted that the holding circuit just traced is independent of contact 20, the last to be engaged of the thermostat 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 cold contact 122 of the thermal timer 120. The original energizing circuit included this cold contact to insure that the timer was in its cold position before starting operation of the apparatus. The new holding circuit also is independent of the out contact 40k 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 holding circuit for relay 25 also does not include the heater 123. The heater 123 was originally included to insure that the circuit through it was not broken in any way. Since, as will be more apparent later, the safety shut down of the system in the event of flame failure is dependent upon the operation of the thermal timer, it is desirable that the heater be checked before the system is started.

The engagement of switch blade 25b with contact 25h results in the establishment of the following circuit to heater 123, if switch blade 133 is in engagement with contact 134: from the upper terminal of secondary 152 through conductor 186, contact 25h, switch blade 25b, re-

sistor 180, conductor 178, heater 123, conductor 179, contact 134, switch blade 133, contact 122, bimetallic element 121, and conductor 188 back to the lower terminal of secondary 152. When switch blade 133 is in engagement with contact 135 instead of contact 134, as shown, the circuit established to heater 123 upon the engagement of switch blade 25b with contact 25h is as follows: from the upper terminal of secondary 152 through conductor 186, contact 25h, switch blade 25b, resistor 180, conductor 178, heater 123, conductors 179 and 225, resistor 130, contact 135, switch blade 133, contact 122, bimetallic element 121, and conductor 188 back to the lower terminal of secondary 152. It will be noted that this circuit is identical to the one previously traced except for the fact that it includes resistor 130 in series with heater 123. The purpose of this is to slow down the heating of the heater and the time required for the bimetallic element 121 of the timer to move from engagement with cold contact 122 into engagement with hot contact 124. Thus, the position of switch 133 when engaged with contact 135 is said to be the "long" position while the position of switch 133 when in engagement with contact 134 is said to be the "short" position. The switch 133 is manually moved into engagement with one or the other of the two contacts depending upon the length of timing period desired. The resistor 180 is included in these circuits so as to make the total resistance in series with heater 123 substantially the same as when the relay coil 25a was in series with it. These energizing circuits are effective only if the transformer 150 is energized. The upper terminal of primary 151 of transformer 150 is connected by conductor 201 to the line wire 158. The lower terminal of primary 151 is connected by conductor 202 to the contact 158 of oil thermostat 155. For the present, it will be assumed that the operation of the oil preheater is unnecessary and that the oil is at the desired temperature at which thermostat contacts 157 and 158 are closed. Under these conditions, an energizing circuit is established for primary 151 as follows: from line wire 147 through conductor 205, bimetallic element 156, contacts 157 and 158, conductor 202, primary 151, and conductor 201 to the other line wire 148. Since, under the conditions assumed, the transformer 150 is energized the establishment of the circuits traced above through heater 123 results in the energization of that heater to initiate the timing cycle of the time switch 120. The length of this timing cycle will depend upon whether switch blade 133 is in the "short" position shown or in the "long" position in which it engages contact 135.

The engagement of relay switch blade 25f with contact 25n results in the establishment of the following circuit to the pilot burner gas valve 12: from line wire 147 through conductors 205 and 206, contact 25n, switch blade 25f, conductors 207 and 208, gas valve 12, conductor 209, switch blade 105, contact 110, and conductors 213, 196, 197, 198, 199, and 146 back to the other line wire 148. As previously explained, a suitable ignition means is provided for the pilot burner 13 which ignition means is rendered active along with gas valve 12 so that the gas admitted to pilot burner 13 by reason of the energization of gas valve 12 is ignited.

At the same time as the circuit to gas valve 12 is established, a circuit is established to the primary 60 of transformer 59 as follows: from line wire 147, through conductor 190, switch blade

102, contact 107, conductors 192 and 200, primary 60, and conductors 210, 211, 197, 199, and 146 back to the other line wire 148. After a period of time sufficient for the tube 50 to become heated, the flame responsive apparatus is in a position to respond to the establishment of a flame at pilot burner 13. This, as previously explained, will cause energization of relay coil 40a with the resultant movement of switch blades 40b, 40c, 40d, and 40e to their energized positions.

The movement of switch blade 40d into engagement with contact 40h results in the establishment of a circuit to the blower motor 10 as follows: from line wire 147 through conductors 190 and 191, contact 25p, switch blade 25g, conductors 192 and 193, blower motor 10, conductor 194, switch blade 103, conductors 194 and 212, switch blade 40d, contact 40h, and conductors 211, 197, 199, and 146 to the other line wire 148.

Simultaneously with the establishment of the circuit just traced to the blower, a circuit is established to oil valve 11 as follows: from line wire 147, through conductors 205 and 206, contact 25n, switch blade 25f, conductors 207 and 220, oil valve 11, conductor 221, switch blade 40c, contact 40g, and conductors 223, 211, 197, 199, and 146 back to the other line wire 148.

As a result of the establishment of the circuits just traced, both the blower and oil valve are energized simultaneously. This operation has been traced on the assumption that the switch 160 is in the no delay position so that there is no delay in the opening of the fuel oil valve following the energization of the blower. When the switch 160 is in engagement with contact 161, that is, in the delay position, a circuit is established to it at the same time as one is established to the pilot burner gas valve, this circuit being as follows: from line wire 147, through conductors 190 and 191, contact 25p, relay switch blade 25g, conductors 192 and 193, motor 10, conductor 194, switch blade 160, contact 161, switch blade 104, contact 109, and conductors 195, 196, 197, 199, and 146 back to the other line wire 148. With the switch in this position, there is a delay between the energization of the blower motor and the opening of the fuel valve equivalent to the time required for the electronic apparatus to warm up and to respond to the presence of a pilot burner flame. It is often desired to have such an operation of the blower prior to the establishment of fuel flow.

It has also been assumed in the operation considered so far that the oil has been at a temperature at which operation of the preheater 15 is unnecessary. If the installation is one in which an operation of a preheater is never necessary, it will be obvious that the lower terminal of primary 151 of transformer 150 can be connected directly to line wire 147 and that the thermostat 21 and the preheater 15 can be omitted. Where, however, it is necessary to use such a preheater, the switch 160 is maintained permanently in the delay position, that is, in engagement with contact 161. Thus, upon energization of relay 25, the blower 10 is immediately placed into operation. At the same time, assuming that the thermostat 21 is calling for heating of the oil, a circuit is established to the oil preheater 15 as follows: from line wire 147 through conductors 190 and 191, contact 25p, switch blade 25g, conductor 192, bimetal element 22, contact 23, conductor 240, preheater 15, conductors 241 and 194, switch blade 160, contact 161, switch blade 104, contact 109, and conductors 195, 196, 197, 199, and 146 to the other line wire 148. The oil is then heated until

a temperature has been reached at which thermostat 155 closes its contacts 157 and 158. Shortly above this temperature, the thermostat 21 is satisfied. When thermostat 155 closes its contacts, it is possible for the circuit to timer heater 123 to be established. During the time that the preheater 15 was warming the oil, this timer heater 123 has been completely deenergized. While the original thermostat energizing circuit included the timer heater 123, this circuit through timer 123 included contact 25s. As soon as relay 25 became energized, however, the switch blade 25c separated from contact 25s to interrupt this circuit. This is obviously desirable since the oil preheater may require longer to heat up the oil than is safe to allow for the timing operation of the time switch. With thermostat 155 satisfied, however, the timer heater 123 is energized to initiate the timing cycle. At the same time, the circuit previously traced to the pilot burner gas valve can be established so that relay 40 can be energized to cause the energization of oil valve 11.

It will be noted that the operation of the preheater requires that the switch 160 be in continual engagement with contact 161, in other words, in the delay position. Since the operation of the oil preheater inherently delays the opening of the oil valve a considerable period of time after the operation of the blower, the only action which can possibly be obtained where an oil preheater is used is one in which the opening of the oil valve is delayed after the energization of the blower. Hence, the fact that switch 160 must be in the delay position under these conditions in no way lessens the flexibility of the apparatus.

It will be apparent that regardless of the position of the switch 160, or regardless of whether the oil preheater 15 is used, by the time that the flame responsive device has responded to the presence of the pilot flame and completed the energization of relay 40a, both the oil valve and the blower are in operation. Thus, all of the conditions necessary to the establishment of a burner flame are present.

At the end of a predetermined period of time following the energization of relay 25, which period of time is determined by the position of switch blade 133 and is normally considerably greater than that required for the operation previously described to take place, the heating effect of the heater 123 on the bimetal element 121 has been sufficient to move the element from engagement with contact 122 into engagement with contact 124. This results in the interruption of the previously traced energizing circuit for heater 123. The heater is maintained energized, however, by the following circuit: from the upper terminal of secondary 152 through conductor 186, contact 25h, switch blade 25b, resistor 187, conductor 178, heater 123, conductors 179 and 225, resistors 130 and 131, conductor 226, contact 25k, relay switch blade 25c, and conductors 181 and 188 back to the other terminal of secondary 152. This circuit, while traced for the first time, is established upon energization of relay coil 25b. Due, however, to the fact that it includes resistors 130 and 131, one or both of which are shorted out as long as bimetal element 121 engages contact 122, most of the current flowing through heater 123 is due to that flowing through the circuit first traced. As soon as the timer moves away from its cold contact 122, however, all of the current must travel through resistors 130 and 131. This reduces the heating effect of the thermal timer to in turn reduce the amount of time required for

the thermal timer to move back to its cold position following its deenergization upon a termination of the call for heat. The utility of this will be more fully set out later.

The movement of the bimetal blade 121 of thermal timer 120 into engagement with contact 124 also results in the establishment of an energizing circuit to relay coil 101 as follows: from the upper terminal of secondary 152 through conductor 227, relay coil 101, conductor 228, contact 124, bimetal element 121, and conductor 188 to the lower terminal of secondary 152. The establishment of this circuit causes relay 100 to be energized with the result that the switch blades 102, 103, 104, 105, and 106 are moved to their energized positions.

The movement of switch blade 105 out of engagement with contact 110 results in the interruption of the previously traced circuit to the pilot burner gas valve so that the operation of the pilot burner is terminated. This will result in the interruption of the circuit traced through the pilot burner flame and through condenser 76. In the meantime, however, the main burner has presumably been ignited so that the photoelectric cell 88 is now exposed to the main burner flame. As a result, the relay 40 remains energized despite the extinguishment of the pilot burner flame. The operation in the event that the main burner flame has not been established will be discussed in a subsequent paragraph.

The system has now gone through a normal starting cycle and is operating normally. Presumably, it will continue to operate until such time as the thermostat 16 is satisfied; that is, until the thermostat blade 18 has separated from both contacts 19 and 20. When this happens, the holding circuit for relay 25 is interrupted so that this relay becomes deenergized. As a result, the oil valve is immediately closed. At the same time, the transformer 59 which supplies power to the flame detecting apparatus is also deenergized. The energizing circuit to the timer heater 123 is likewise interrupted. Thus the burner flame is extinguished and relay 40 moves to its deenergized position. The blower 10 is maintained in operation, however, by reason of the following circuit: from line wire 147 through conductor 190, switch blade 102, contact 107, conductors 230 and 193, blower 10, conductor 194, relay switch blade 103, contact 108, conductor 230, relay switch blade 253, contact 257, and conductors 231, 199, and 146 to the other line wire 148. As a result of the establishment of the circuit just traced which is dependent upon the deenergization of relay 25 and the energization of relay 100, the blower motor continues in operation until the timer 120 has cooled sufficiently for blade 121 to move from engagement with contact 124 into engagement with contact 122. When this happens, relay 100 becomes deenergized with the result that switch blade 102 moves out of engagement with contact 107 to deenergize the blower 10. The apparatus is now all in the starting condition shown in Figure 1.

It will be noted from the above that the blower 10 continued in operation after closure of fuel oil valve 11 for a period of time equal to the cooling time of timer 120 to provide "blowout" operation. As previously explained, this cooling time is reduced by resistors 130 and 131. As will be noted from the above circuit traced following the separation of timer switch blade 121 from cold contact 122, the circuit maintained through heater 123 under these conditions includes both

resistors 130 and 131 regardless of the position of switch blade 133 which, as previously explained, determines whether the ignition timing period is relatively short or relatively long. Thus, by reason of resistors 130 and 131, it is possible to have a "blowout" operation whose length is independent of the ignition timing.

In the foregoing operation, it was assumed that both the pilot burner and main burner ignite normally, as is usually the case. It was also assumed that the main burner continued to operate until the thermostat 16 was satisfied. Provision is made with my apparatus to take care, without the inclusion of a separate safety switch, of contingencies such as the main or pilot burner not igniting or the main burner becoming extinguished during a call for heat.

Let it be assumed at first that the pilot burner 13 did not originally become ignited. Under these conditions, relay 40 would never become energized. As a result of this, the oil valve 11 would never be energized. The thermal timer, however, would continue to heat until the bimetal blade 121 moved from engagement with the cold contact into engagement with the hot contact 124. As previously explained, the energization of heater 123 is continued despite the separation of bimetal blade 121 from contact 122. Also under these conditions the relay 100 would become energized by the same circuit as traced above. This would result in the switch blades 102 to 106 moving to their energized position. If the selector switch 160 were in the no delay position, the blower 10 is not energized until the relay 40 is energized. Since, under the conditions assumed, relay 40 has never been energized, blower 10 likewise has never been energized. The energization of relay 100 with the resultant movement of switch blade 105 out of engagement with contact 110 causes deenergization of the pilot burner gas valve, previously explained. Thus, all of the burner equipment is deenergized under the conditions just considered. The thermal timer is maintained in its hot position and the relay 25 is maintained energized.

In order to inform the attendant of the failure to start, an alarm circuit is established under the conditions just considered. This alarm circuit extends from line wire 147 through conductors 205 and 206, contact 257, switch blade 257, conductors 207 and 235, alarm 24, conductor 236, switch blade 405, contact 407, conductor 237, relay switch blade 106, contact 111, and conductors 106, 196, 197, 198, 199, and 146. It will be noted that the above alarm circuit is dependent upon the deenergization of relay 40 and the energization of relays 25 and 100. This is the condition which exists under the conditions just being considered.

From the above, it will be clear that when the pilot burner is not initially ignited, the thermal timer which normally operates to time the ignition and to time the blow out cycle functions to place the apparatus in such a condition that none of the burner equipment is energized and at the same time to sound the alarm to warn the attendant of the condition.

Let the condition now be considered in which the pilot burner is successfully ignited but despite this, the main burner is not ignited. Under these conditions, the blower 10, the oil valve 11, and gas valve 12 continue in their energized conditions until the bimetallic element 121 moves into engagement with the hot contact 124. When this happens, the relay 100 is energized. The ener-

gization of relay 100, it will be recalled, causes the deenergization of the pilot burner gas valve 12 so as to extinguish the pilot burner. Since the main burner has not been ignited, neither the photoelectric cell 90 nor the flame gap provided by electrode 80 is acting as a rectifying impedance so that relay 40 becomes deenergized. A condition now exists in which relays 25 and 100 are energized and relay 40 is deenergized. This is the same condition as treated in the previous paragraph. In other words, the blower, the pilot burner gas valve, and the oil valve are all deenergized. The alarm 24 is, however, energized to let the attendant know of the failure to establish combustion.

If main burner combustion is initially established but fails during a call for heat, relay 40 becomes deenergized. This again creates a condition in which relays 25 and 100 are energized and relay 40 is deenergized. Again, the blower motor, the pilot burner gas valve, and the oil valve are deenergized, the alarm being energized.

It will thus be seen that the timer which provides for ignition timing and for a blow out cycle operation of the motor following closure of the fuel oil valve, also functions to place the system in condition where all of the burner apparatus is deenergized. In any of the three cases referred to above, the system will remain shut down until either there is a power failure, the thermostat ceases to call for heat, or until the push button switch 39 is opened. If there is a power failure, if the thermostat 16 becomes satisfied, or if the push button switch 39 is opened by the attendant after the difficulty has been corrected, the relay 25 will become deenergized. The reclosure of thermostat 16 or of push button switch 39 or the reestablishment of power cannot cause immediate reenergization of relay 25 since the holding circuit established by switch 25d has been opened and it is necessary to again establish the original energizing circuit for relay coil 25 which, it will be recalled, included the cold contact of timer 120. Thus, the system remains shut down until the timer 120 has cooled sufficiently to cause reengagement of bimetallic element 121 with contact 122. When this happens, the entire cycle is repeated, and if the operation of the burner is still not satisfactory, the system will again go "on safety."

In discussing the various contingencies, one possible contingency has been neglected. Where the operation of the preheater 15 is necessary to bring the oil up to temperature and for some reason the oil preheater is ineffective to bring it up to temperature, the system will continue to operate as far as blower 10 and the oil preheater 15 are concerned. It is necessary to make this operation independent, however, of any thermal safety switch timing since it is often necessary to operate the oil preheater as much as five minutes before the oil reaches the desired temperature. A condition in which the oil preheater 15 does not operate to bring the oil up to temperature is highly unlikely. If it is desired, a conventional thermal safety switch can be employed in the motor circuit with the heater of the safety switch in series with the preheater 15. Normally, this precaution is not necessary.

It will be seen from the above that I have provided an improved oil burner circuit in which provision is made for the use of a timer to not only provide a safety shut down of the system but also to time the ignition and to produce a timed blow out cycle following the interruption of the

fuel. This has been accomplished without sacrificing any of the necessary safety features. Furthermore, the system despite the use of the thermal timer for all of the functions named, has a high degree of flexibility and can be used to provide either two lengths of ignition timing, delay the operation of the fuel oil valve following the initiation of blower operation, or simultaneously energize the fuel oil valve and the blower. Furthermore, despite the combined use of the thermal safety switch, the system is capable of being utilized where it is necessary to preheat the oil.

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

I claim as my invention:

1. Burner control apparatus including a fuel control, a burner blower, a burner ignition means, a thermal timer movable from a cold to a hot position, a main control switch, means operative as a result of closure of said main switch to cause energization of said burner ignition means, said burner blower, said thermal timer, and said fuel control, means controlled by said thermal timer for interrupting energization of said ignition means upon said timer moving to its hot position, means including said timer operable upon deenergization of said timer and fuel control as a result of opening of said main switch to continue operation of said blower until said timer moves to its cold position, and means operative upon said main switch being closed and upon a failure of combustion to deenergize said blower and maintain said timer in its hot position.

2. Burner control apparatus including a fuel control, a burner blower, a burner ignition means, a thermal timer movable from a cold to a hot position, a main control switch, means operative as a result of closure of said main switch to cause energization of said burner ignition means, said burner blower, said thermal timer, and said fuel control, means controlled by said thermal timer for interrupting energization of said ignition means upon said timer moving to its hot position, means including said timer operable upon deenergization of said timer and fuel control as a result of opening of said main switch to continue operation of said blower until said timer moves to its cold position, and means operative upon said main switch being closed and upon a failure of combustion to deenergize said blower immediately and to maintain said timer in its hot position under the control of said main switch.

3. Burner control apparatus comprising a fuel control for a burner; a heater for the fuel; a burner blower; burner ignition means; means including a main control device for initiating operation of said burner ignition means, said fuel heater, and said burner blower; means including a timer for rendering said ignition means inoperative at the end of a timing period of said timer; means including a device responsive to the temperature of the fuel for initiating operation of the timer when the fuel is at a predetermined temperature; means including said fuel temperature responsive device and a device responsive to the operation of the ignition means for energizing said fuel control when said ignition means is operative and said fuel is at a predetermined temperature; and means operative in the event of the burner not being ignited when said timer is at the end of said timing period to cause the operation of said blower, said fuel control, and

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said ignition means to be terminated while maintaining said timer in its hot position.

4. Burner control apparatus for controlling a burner fuel control, a burner blower and a burner ignition means; said apparatus comprising; a first relay adapted to be connected to a main control switch and a source of power so as to be energized when said main control switch is closed; a second relay; means adapted to be associated with a burner and with the ignition means therefor and to energize said second relay when either said ignition means is operative or there is combustion at the burner; a thermal timer having an electrical heater; means for energizing said heater when said first relay is energized; a third relay, means for energizing said third relay when said thermal timer is in its hot position; first circuit means controlled by said first and third relays and adapted to be connected to a burner ignition means to energize the latter when said first relay is energized and said third relay is deenergized; second circuit means controlled by said first and second relays and adapted to be connected to a burner fuel control to cause operative energization of the latter when both said first and second relays are energized; third circuit means adapted to be connected to a burner blower and controlled by said first and second relays in such a manner that said blower is maintained in operation when said first relay is energized only if said second relay is also energized so that said blower immediately ceases operation upon said second relay becoming deenergized due to a combustion failure while said first relay is energized.

5. Burner control apparatus for controlling a burner fuel control, a burner blower and a burner ignition means; said apparatus comprising: a first relay adapted to be connected to a main control switch and a source of power so as to be energized when said main control switch is closed; a second relay; means adapted to be associated with a burner and with the ignition means therefor and to energize said second relay when either said ignition means is operative or there is combustion at the burner; a thermal timer having an electrical heater; means for energizing said heater when said first relay alone is energized; a third relay, means for energizing said third relay when said thermal timer is in its hot position; first circuit means controlled by said first and third relays and adapted to be connected to a burner ignition means to energize the latter when said first relay is energized and said third relay is deenergized; second circuit means controlled by said first and second relays and adapted to be connected to a burner fuel control to cause operative energization of the latter when both said first and second relays are energized; third circuit means adapted to be connected to a burner blower and controlled by said first, second, and third relays in such a manner that said blower is maintained in operation only if said second relay is energized or if said third relay is energized and said first relay is deenergized so that upon said first relay being deenergized said blower continues in operation until said third relay is deenergized but upon said second relay being deenergized due to a combustion failure, said blower and said fuel control immediately cease operation.

6. Burner control apparatus for controlling a burner fuel control, a burner blower and a burner ignition means; said apparatus comprising; a first relay adapted to be connected to a main control switch and a source of power so as to be energized when said main control switch is closed;

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a second relay; means adapted to be associated with a burner and with the ignition means therefor and to energize said second relay when either said ignition means is operative or there is combustion at the burner, a thermal timer having an electrical heater; means for energizing said heater when said first relay is energized; a third relay, means for energizing said third relay when said thermal timer is in its hot position; first circuit means controlled by said first and third relays and adapted to be connected to a burner ignition means to energize the latter when said first relay is energized and said third relay is deenergized; second circuit means controlled by said first and second relays and adapted to be connected to a burner fuel control to cause operative energization of the latter when both said first and second relays are energized; third circuit means adapted to be connected to a burner blower and controlled by said first and second relays in such a manner that said blower is maintained in operation when said first relay is energized only if said second relay is also energized so that said blower immediately ceases operation upon said second relay becoming deenergized due to a combustion failure while said first relay is energized; and fourth circuit means controlled by said second and third relays and adapted to extend to an alarm to energize the same when said third relay is energized and said second relay is deenergized.

7. Burner control apparatus for controlling a burner control and a burner ignition means; said apparatus comprising: a first relay adapted to be connected to a main control switch and a source of power so as to be energized when said main control switch is closed; a second relay; means adapted to be associated with a burner and with the ignition means therefor and to energize said second relay when either said ignition means is operative or there is combustion at the burner, a thermal timer having an electrical heater; means for energizing said heater when said first relay is energized; a third relay; means for energizing said third relay when said thermal timer is in its hot position; first circuit means controlled by said first and third relays and adapted to be connected to a burner ignition means to energize the latter when said first relay is energized and said third relay is deenergized; and second circuit means controlled by said first and second relays and adapted to be connected to a burner control to cause operative energization of the latter when both said first and second relays are energized so that said burner control ceases operation and said timer heater remains energized under the control of said first relay when said second relay becomes deenergized due to a combustion failure while said first relay is energized.

8. Burner control apparatus for controlling a burner control and a burner ignition means, said apparatus comprising a first relay adapted to be connected to a main control switch and a source of power so as to be energized when said main control switch is closed; a thermal timer movable from a cold to a hot position in response to energization thereof; means for energizing said thermal timer when said first relay is energized; a further relay; means for energizing said further relay when said thermal timer moves to its hot position; first circuit means controlled by said first and said further relay and adapted to be connected to a burner ignition means to energize the latter when said first relay is energized

and until said further relay is energized; second circuit means controlled by said first and said further relay and adapted to be connected to a burner control to cause operative energization of the latter when said first relay is energized and until said further relay is energized; and means adapted to be associated with a burner and to be effective upon the establishment of combustion at the burner to establish a further energizing circuit means for said burner control which is adapted to maintain said burner control energized while said first relay is energized despite the energization of said further relay.

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