Jan. 3, 1961 D. L. GRAVES ET AL 2,966,940

FUEL BURNER PROGRAMMING APPARATUS

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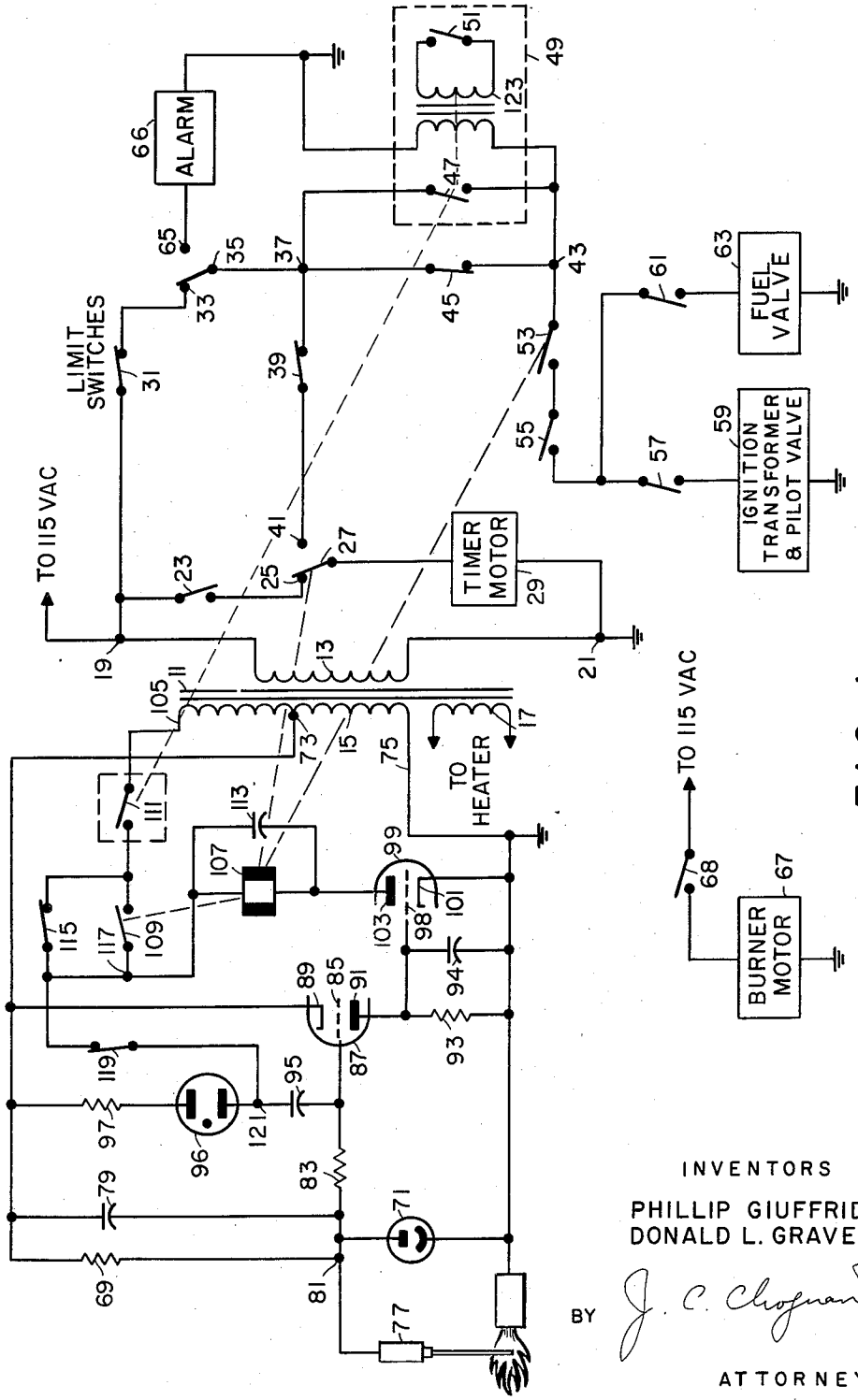


FIG. 1

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FUEL BURNER PROGRAMMING APPARATUS

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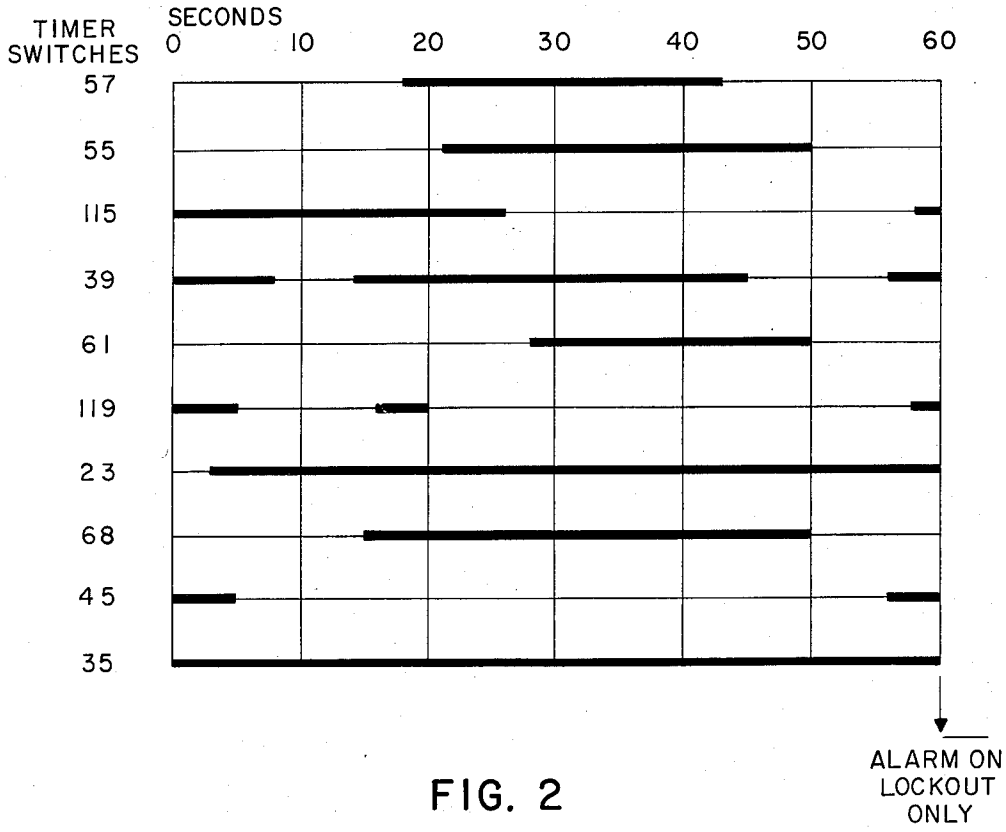


FIG. 2

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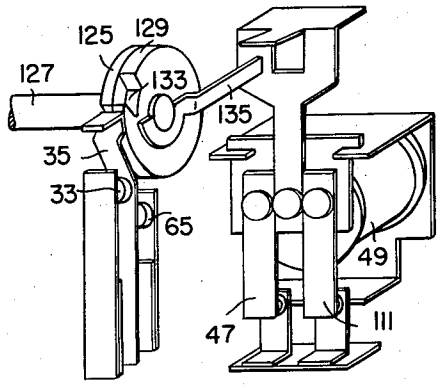
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FUEL BURNER PROGRAMMING APPARATUS

Filed Jan. 10, 1958 3 Sheets-Sheet 3

FIG. 3



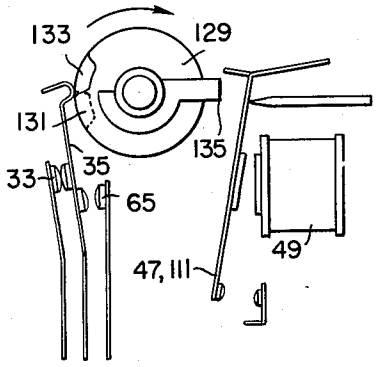


FIG. 4

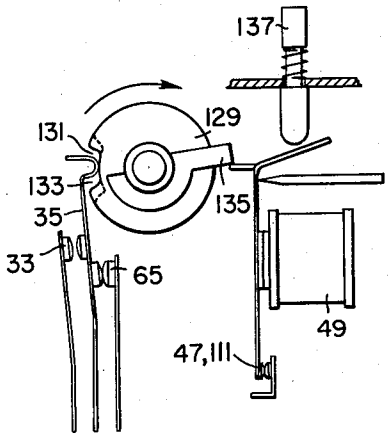


FIG. 5

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2,966,940

FUEL BURNER PROGRAMMING APPARATUS

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1 Claim. (Cl. 158—28)

This invention relates to electrically controlled fuel burners and particularly to controls suitable for fully automatic industrial furnaces in which the lighting of the burner at the beginning of each heating period is entirely controlled by an automatic timing device.

Fully automatic industrial furnaces burning oil, pulverized fuel or gas may employ either spark electrodes or a pilot burner to ignite the main burner. A pilot, if used, is ordinarily ignited by spark electrodes. The heating period is initiated by the closing of contacts in a thermostat or similar control. In order to put the burner into operation at the beginning of each heating period the ignition and fuel supply systems must be turned on in the proper sequence. This is frequently accomplished by a programming relay or automatic timer which closes and opens contacts in the various control circuits at predetermined intervals. The entire starting operation is known as the starting cycle. On a typical burner, the burner motor is first turned on. The ignition follows. If a pilot is used, the pilot valve is opened at the same time. After a certain interval during which the ignition or pilot flame becomes established, the main fuel valve is opened. After another interval, during which the main flame becomes established, the ignition is turned off leaving the burner in normal running condition. When the space or vessel to be heated reaches the desired temperature, the contacts of the thermostat open, shutting down the burner. When the thermostat contacts close again, the starting cycle is repeated. Because of the explosion hazards associated with industrial burners of large capacity, a flame failure device is usually provided to shut down the burner in case of failure of the main flame or of the pilot or of both, in order to prevent accumulation of unburned fuel in the combustion chamber. Since flame failure is usually an indication of faulty operation, it is essential that a burner shutdown from this cause, as distinguished from the normal shutdown at the end of a heating period, result in some action requiring the attention of an operator before the burner can again be operated. For this purpose a lock-out device is ordinarily provided, such as a switch or push-button located in the vicinity of the burner, which must be manually reset whenever it has opened.

The sequences and the delay periods between starting operations best suited for safe and efficient operation of different types of burners may vary widely. For example on an oil-fired burner with a gas pilot it is desirable that the flame failure device be put into control of the system immediately upon the opening of the main fuel valve, whereas on an oil furnace ignited by spark electrodes it is necessary to maintain the flame failure device ineffective to shut down the burner for some period after opening of the fuel valve in order to allow sufficient time for the main flame to ignite.

In flame failure devices using electronic detectors and amplifiers it is common practice to use circuitry and components to delay de-energization of the flame-responsive relay for a short period following loss of flame

signal, thus avoiding nuisance burner stoppage as a result of normal flame fluctuations. Were the delay system to fail in such a manner as to extend greatly this delay, the effectiveness of the flame-sensing system would be nullified by the failure of the flame-responsive relay to respond to flame failure. Since the ultimate safety function of a combustion safety control rests on the flame-responsive relay, the design and construction of the delay circuit should be such as to insure utmost reliability.

It is the principal object of this invention to provide an improved burner control device of relative simplicity and outstanding safety.

It is another object of this invention to provide a new burner safety control in which there are provided means to check the satisfactory operation of the flame-responsive relay before the start of each programming cycle.

In accordance with one feature of the illustrated embodiment of this invention, a checking signal capable of closing the flame relay is applied to the flame relay. Means, which are responsive to the closing of the flame relay by the checking signal, are provided to remove the checking signal. Means responsive to the opening of the flame relay (due to the removal of the checking signal) are provided to ignite the fuel burner. Thus, the closing and opening of the flame relay are tested at the start of each programming cycle.

In accordance with another feature of the illustrated embodiment of this invention, the checking signal is used to hold the flame relay closed (after its closing and opening have been satisfactorily tested) for a predetermined time while the burner is ignited to allow sufficient time for the main flame to become established.

Other and incidental objects of this invention will be apparent to those skilled in the art from a reading of the specification and an inspection of the accompanying drawings in which:

Figure 1 is a circuit diagram of a fuel burner programming apparatus in accordance with this invention.

Figure 2 is a time chart showing the sequence and relative duration of the closing of timer contacts of the circuit of Figure 1.

Figure 3 is a perspective drawing showing the lock-out switch and timer cam assembly of the circuit of Figure 1 in relation to the control relay.

Figure 4 is a side-view of the lock-out switch in its normal position, and

Figure 5 is an illustration of the lock-out switch in its tripped position.

Referring now to Figure 1, there is shown a transformer **11** having a primary winding **13**, a secondary winding **15**, and an auxiliary heater winding **17**. One terminal **19** of the primary winding **13** is connected to the ungrounded side of an A.C. power line, while the other terminal **21** of the primary winding **13** is connected to the grounded side of the power line. The terminal **19** is connected through the timer switch **23** and through contact **25** of the single-pole double-throw flame relay switch **27** to the timer motor **29** back to the ground terminal **21**. The terminal **19** is connected through limit switches **31** and contact **33** of the single-pole double-throw timer switch **35** to a point **37**. Point **37** is connected through the timer switch **39** to the contact **41** of the single-pole double-throw flame relay switch **27**. Point **37** is also connected to point **43** through the timer switch **45**. The control relay switch **47** is connected in parallel with the timer switch **45** between points **37** and **43**. The control relay switch **47** is part of the control relay **49** which is operated by the thermostat **51**. Point **43** is connected through the flame relay switch **53**, the timer switch **55** and the timer switch **57** to the ignition transformer and pilot valve **59**. Point **43** is also connected through the flame relay switch **53** and timer

switches 55 and 61 to the fuel valve 63. The contact 65 of the single-pole double-throw timer switch 35 is connected to the alarm 66. The burner motor 67 is connected across the A.C. power line through a timer switch 68.

The flame detection portion of the fuel burner safety control apparatus comprises a resistor 69 and a photocell 71 connected in series between the center tap 73 and the grounded terminal 75 of the secondary winding 15. A flame electrode 77 is connected in parallel with the photocell 71 and a capacitor 79 is connected in parallel with the resistor 69. The junction 81 of the resistor 69 and the photocell 71 is connected through resistance 83 to the control grid 85 of a triode 87. The cathode 89 of triode 87 is connected to the center tap 73 and the anode 91 is connected to the grounded terminal 75 through a load resistor 93. A capacitor 94 is connected in parallel with the resistor 93. A capacitor 95, a neon lamp 96 and a resistor 97 are connected in series between the control grid 85 and the cathode 89 of triode 87. The anode 91 is connected to the control grid 98 of a triode 99. The cathode 101 of triode 99 is connected to terminal 75 and the anode 103 of triode 99 is connected to the terminal 105 of secondary winding 15 through a relay coil 107, relay contact 109 and control relay switch 111. A holding capacitor 113 is connected across the relay coil 107. A timer switch 115 is connected in parallel with the relay contacts 109. The junction 117 of the relay coil 107 and the relay contacts 109 is connected through a timer switch 119 to the junction 121 between the capacitor 95 and the neon lamp 96.

Operation of the flame detection circuit

Let us assume that the transformer 11 is energized, that the triodes 87 and 99 are at operating temperature, that the control relay switch 111 and the timer switch 115 are closed, and that relay contacts 109 and timer switch 119 are open. Let us also assume that there is no flame.

In the absence of a flame, there is only a small potential difference between the cathode 89 and the control grid 85 of the triode 87, which potential difference is due to the grid resistor bias. Thus, triode 87 conducts on the portion of the cycle when the alternating current supply is positive at terminal 75 with respect to the center tap 73. When this is the case, the triode 99 cannot conduct because its anode 103 is negative with respect to its cathode 101. While the triode 87 is conductive, the flow of plate current through its load resistor 93 charges the capacitor 94 so that it biases the control grid 98 negatively with respect to the cathode 101 of triode 99. This negative charge on the capacitor 94 prevents the triode 99 from conducting on that portion of the cycle when the terminal 105 of the secondary winding is positive with respect to terminal 75.

Let us now assume that a flame is present and is detected either by the flame electrode 77 or by the photocell 71.

Since a flame has the property of conducting an electrical current readily in the direction from junction 81 to ground, a difference of potential is developed across resistor 69 which makes the control grid 85 of triode 87 negative with respect to its cathode 89. Exactly the same effect is obtained when light from the flame impinges upon the photocell 71. A charge derived from the voltage across resistor 69 is acquired by the capacitor 79 and serves to bias triode 87 to cut-off. When triode 87 stops conducting, there is no current flow through the load resistor 93. The charge on capacitor 94 dissipates through the resistor 93 and, since there is no longer a high negative bias on its control grid 98, the triode 99 conducts sufficiently to actuate the relay 107 which is in its anode circuit.

Should the main flame suddenly go out, the voltage drop across resistor 69 due to conduction through the flame electrode 77 or the photocell 71 is no longer present. The charge stored on capacitor 79 dissipates through resistor 69 and triode 87 becomes conductive, thus cutting off conduction through triode 99 as previously described. This causes the de-energization of the relay-actuating coil 107 and the dropping out of the relay armature. Time constants are such that the drop-out of the relay armature is delayed for about three seconds.

A checking signal is developed in the following manner: let us assume that transformer 11 is energized, that triodes 87 and 99 are at operating temperature, that the control relay switch 111 and the timer switch 115 are closed, and that no flame is present. As described above, triode 87 is conducting, and the conduction through triode 87 suppresses conduction through the triode 99. Let us now assume that the timer switch 119 closes so that the voltage of that part of the secondary winding 15 of transformer 11 which is between the center tap 73 and the terminal 105 is impressed across the series combination comprising the neon lamp 96 and the resistor 97. The junction 121 and the control grid 85 are virtually at the same potential, and when junction 121 is positive with respect to the center tap 73, the control grid 85 is positive with respect to the cathode 89. Under this condition, the control grid 85 acts as the plate of a diode and the resulting conduction between the cathode 89 and the control grid 85 results in that the cathode 89 and the control grid 85 are at about the same potential, i.e. negative with respect to junction 121 by the voltage across that part of the secondary winding of transformer 15 between the center tap 73 and the terminal 105. The capacitor 95 is thus charged with junction 121 positive with respect to the control grid 85. On the inverse half-cycle, the voltage across that part of the secondary winding of transformer 15 between the center tap 73 and the terminal 105 is polarized so that the center tap 73 and the cathode 89 are positive with respect to the junction 121. Under these conditions there is, of course, no conduction between the cathode 89 and the control grid 85 of the triode 87 and the difference of potential between the center tap 73 and the terminal 105 add to the charge already present on the capacitor 95. During this inverse half-cycle, the negative bias between the cathode 89 and the control grid 85 is about twice the voltage across that part of the winding of the transformer 11 comprised between the center tap 73 and the terminal 105. Thus, while the timer switch remains closed, the capacitor 95 acquires a charge which biases the triode 87 to cut-off. The effect of the checking signal in cutting off conduction in triode 87 is similar to the effect which would result from the detection of a flame. The biasing charge on the capacitor 95 is such that when the timer switch 119 is opened, thus removing the checking signal, it takes about six seconds for capacitor 95 to discharge to the point where triode 87 will conduct sufficiently to stop conduction in triode 99 and de-energize the relay coil 107. The delay following the removal of the checking signal is thus about twice the delay which follows loss of flame signal.

Operation of programming and control circuit

The operation of the programming and control circuit will be discussed with reference to Figure 2 which is a chart showing the opening and closing of the timer switches. The timer makes one complete revolution in sixty seconds of operation and the abscissa is divided into these sixty seconds while the various timer switches are listed along the ordinate. The blanks in the chart show when the switches are opened and the heavy lines when the switches are closed.

Burner starting program

Let us assume that the limit switches 31 are closed, that the thermostat 51 is open, and that triodes 87 and

99 are at operating temperature. When the thermostat 51 closes the normal starting cycle is as follows: The control relay 49 is energized through the limit switches 31, the contact 33 of the switch 35, and the timer switch 45. The control relay switches 47 and 111 close. Checking signal is applied through the control relay switch 111, the timer switch 115 and the timer switch 119. As seen previously, the application of the checking signal stops conduction in triode 87 and triode 99 starts conducting, energizing relay coil 107. When relay coil 107 is energized, the flame relay switch 27 shifts from contact 25 to contact 41 and the flame relay contacts 53 and 109 close. This immediately energizes the timer motor 29 through the timer switch 39 and the contact 41.

The timer motor is now operating. After three seconds of operation, the timer switch 23 closes. After five seconds of timer operation, the timer switch 119 opens, removing the checking signal and the timer switch 45 opens removing starting interlock. After eight seconds of timer operation, the timer switch 39 opens and the timer stops. When the relay coil 107 is de-energized (which takes place about six seconds after the checking signal is removed), the flame relay switch 27 moves from contact 41 to contact 25 and the flame relay contacts 53 and 109 open. The timer motor starts again through the timer switch 23 and the contact 25. After fourteen seconds of timer operation, the timer switch 39 closes again. After fifteen seconds of timer operation, the timer switch 68 closes, energizing the blower motor. After sixteen seconds of timer operation, the timer switch 119 closes, the checking signal is re-applied, and the relay coil 107 is actuated, as explained previously. The flame relay contacts 53 and 109 close, and the flame relay switch 27 transfers from contact 25 to contact 41. The supply to the timer motor 29 shifts from timer switch 23 and relay contact 25 to timer switch 39 and relay contact 41. After eighteen seconds of timer operation, the timer switch 57 closes. After twenty seconds of timer operation, the timer switch 119 opens thus removing the checking signal. After twenty-one seconds of timer operation, the timer switch 55 closes. The ignition transformer and pilot valve 59 are energized through the relay contacts 53 and the timer switches 55 and 57. Assuming that a flame is established and detected, the relay coil 107 remains energized for as long as there is a call for heat. After twenty-six seconds of timer operation, the timer switch 115 opens, but the circuit to the relay coil 107 is maintained through the relay contacts 109. After twenty-eight seconds of timer operation, the timer switch 61 closes, and the fuel valve 63 is energized. After forty-three seconds of timer operation, the timer switch 57 opens de-energizing the ignition transformer and pilot valve 59. After forty-five seconds of timer operation, the timer switch 39 opens and stops the timer motor 29. All the switches are now in the position they maintain for the duration of the burner firing.

Burner stopping program

When the demand for heat is satisfied, the thermostat 51 opens and the the control relay switches 47 and 111 open. The opening of the control relay switch 47 de-energizes the fuel valve 63 and the primary 123 of the control relay 49. The opening of the control relay switch 111 de-energizes the relay coil 107. The de-energization of the relay coil 107 causes the flame relay switch 27 to shift from contact 41 to contact 25 and the timer motor 29 is, therefore, started through the timer switch 23. After fifty seconds of timer operation, the timer switch 68 opens de-energizing the burner motor 69. Also, the timer switches 55 and 61 open. After fifty-six seconds of timer operation, the timer switches 39 and 45 close. After fifty-eight seconds of timer operation, the timer switches 115 and 119 close. After sixty seconds of timer operation, the timer switch 23 opens, and the timer stops. The control is now in position for the next starting program when the thermostat 51 closes in response to the next call for heat.

Program with ignition failure

Let us now see what happens to the burner starting program when the ignition fails. The programming is the same as that described under the paragraph entitled "Burner starting program" up to twenty-one seconds of timer operation at which time the timer switch 55 closes. The ignition transformer and the pilot valve are energized by the closing of the timer switch 55. However, since no flame is established due to ignition failure, the flame relay coil 107 will be de-energized six seconds after the removal of the checking signal, which removal occurs after twenty seconds of timer operation. After twenty-six seconds of timer operation, the timer switch 115 opens. Since this is the time that the drop-out delay of relay coil 107 occurs, there is now no circuit to the relay coil 107 either through the timer switch 115 or through the flame relay contact 109. The circuit to the flame relay coil 107 can only be restored when the control relay switch 111 and the timer switch 115 are both closed. Since the relay contacts 53 are open, there is no power going to the ignition transformer and pilot valve 59 and to the fuel valve 63. After twenty-eight seconds of timer operation, the timer switch 61 closes, but the fuel valve 63 is not energized since the flame relay contacts 53 are open. After forty-three seconds of timer operation, the timer switch 57 opens. After forty-five seconds of timer operation, the timer switch 39 opens. The timer motor 29 continues to operate because it is still supplied through timer switch 23 and through contact 25 of the flame relay switch 27. After fifty seconds of timer operation, the timer switch 68 opens, thus de-energizing the blower motor 69.

Reference will now be made to Figures 3, 4 and 5 which illustrate the lock-out switch assembly. The cam assembly comprises a first cam 125 which is fixedly mounted on to the timer shaft 127 and a cam 129 which is spring biased with respect to the shaft 127 and which may move about one hundred and ten degrees. Cams 125 and 129 are provided with notches 131 and 133 respectively. The single-pole double-throw switch 35 rides on both cams 125 and 129. The switch 35 is electrically connected to contact 33 until it engages into notches 131 and 133 which happens when these notches coincide in the position shown in Figure 5. A cam arm 135 is mounted on the cam 129.

After fifty-five seconds of timer operation, the cam arm 135 is already engaged with the control relay 49 which is still energized, and the notches 131 and 133 come into alignment. The switch 35 shifts from contact 33 to contact 65. The closing of contact 65 actuates the alarm 66. Since the control relay 49 is closed, it is locked in that position (as shown in Figure 5) by the cam arm 135. The control relay switches 47 and 111 will remain closed even though the control relay 49 is de-energized. After fifty-eight seconds of timer operation, timer switches 115 and 119 close, making an electrical circuit to the relay coil 107 and applying the checking signal. The relay coil 107 responds and the flame relay switch 27 moves from contact 25 to contact 41, thus stopping the timer.

The operation of the control and of the burner can be restored only by pressing on the reset button 137 which pushes the control relay 49 open, unlatches the cam 129 and allows its bias spring to throw the notches 131 and 133 out of alignment, thus causing the switch 35 to move from contact 65 back to contact 33.

Program with flame failure

Let us now assume that the flame goes out at the end of the burner starting program. With flame detection lost, the program is as follows: the relay 107 is de-

energized, the flame relay switch **53** opens and de-energizes the fuel valve **63**, and the flame relay switch **27** moves from contact **41** to contact **25**, thus starting the timer motor **29**. It will be remembered that at the end of the burner starting program, the timer had operated for forty-five seconds. After fifty seconds of timer operation (i.e. five seconds later), timer switch **68** opens de-energizing the burner motor **67**. After fifty-five seconds of timer operation, the notches on the cams **125** and **129** come into alignment. Now the same thing happens that was described in connection with the program with ignition failure. The operation of the control and of the burner can only be restored by pressing the reset button **137**.

Safety features

The fuel burner safety control apparatus described above has a number of important safety features. No part of the cycle may be skipped. Momentary power interruption prior to five seconds of timer operation allows the program to proceed when power is restored with no function omitted. If power is lost after five seconds of timer operation and then restored, the timer continues through a complete revolution without energizing either the ignition or the fuel valve and then starts a complete new program. If a false signal is present, the program cannot advance past eight seconds of timer operation and no external loads are energized. If the timer stalls at any point, no unsafe condition is created nor is there a prolongation of an unmonitored ignition trial.

If the control relay sticks or is blocked in the closed position, the thermostat no longer governs, but the control will lock-out following flame failure or opening of the limit switch which is then the governing element. If the relay comprising coil **107** sticks or is blocked in the closed position prior to fourteen seconds of timer operation, the program halts, and there will be no burner operation until the condition is corrected. If the relay comprising coil **107** sticks or is blocked in the closed position after fourteen seconds of timer operation, there is no protection during that particular firing cycle, but with the opening of the thermostat, the control relay drops out de-energizing the fuel valve. The timer cannot advance beyond forty-five seconds of timer operation (contact **25** is open) and the control relay cannot pull in again (timer switch **45** is open). If the armature of the relay comprising coil **107** drops out after twenty-six seconds of timer operation, it cannot pull in again since timer switch **115** and relay contacts **109** are open. The control will lock out after fifty-five seconds of timer operation. The lock-out cannot be circumvented by blocking the reset button in, since this forces the control relay **49** to its de-energized position.

We claim:

A programming apparatus for a fuel burner having electrically actuated ignition means comprising: a timer having a motor and a plurality of switches controlled thereby, control means for initiating the operation of said programming apparatus, flame sensing means, a flame relay having an actuating element connected to and actuated in response to the output of said flame sensing means, means to generate a checking signal capable of operating said flame relay, means including a timer switch to apply said checking signal to said flame relay in response to the operation of said control means, means responsive to the actuation of said flame relay by said checking signal to start said timer motor, means responsive to the operation of said timer motor to actuate said timer switch so as to remove said checking signal, means responsive to the further operation of said timer motor to stop said timer motor, means responsive to the de-actuation of said flame relay in response to the removal of said checking signal to start again said timer motor, means responsive to the operation of said timer motor to actuate said timer switch to apply again said checking signal to said flame relay, and means responsive to the actuatiton of said flame relay by this last application of said checking signal and to the further operation of said timer motor to actuate said ignition means.

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