

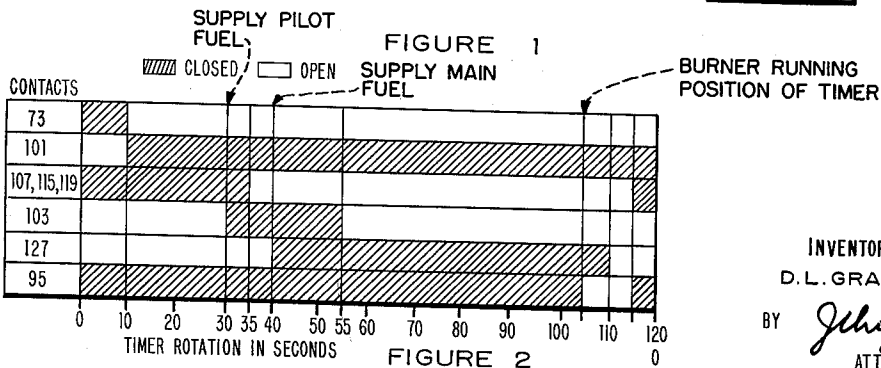
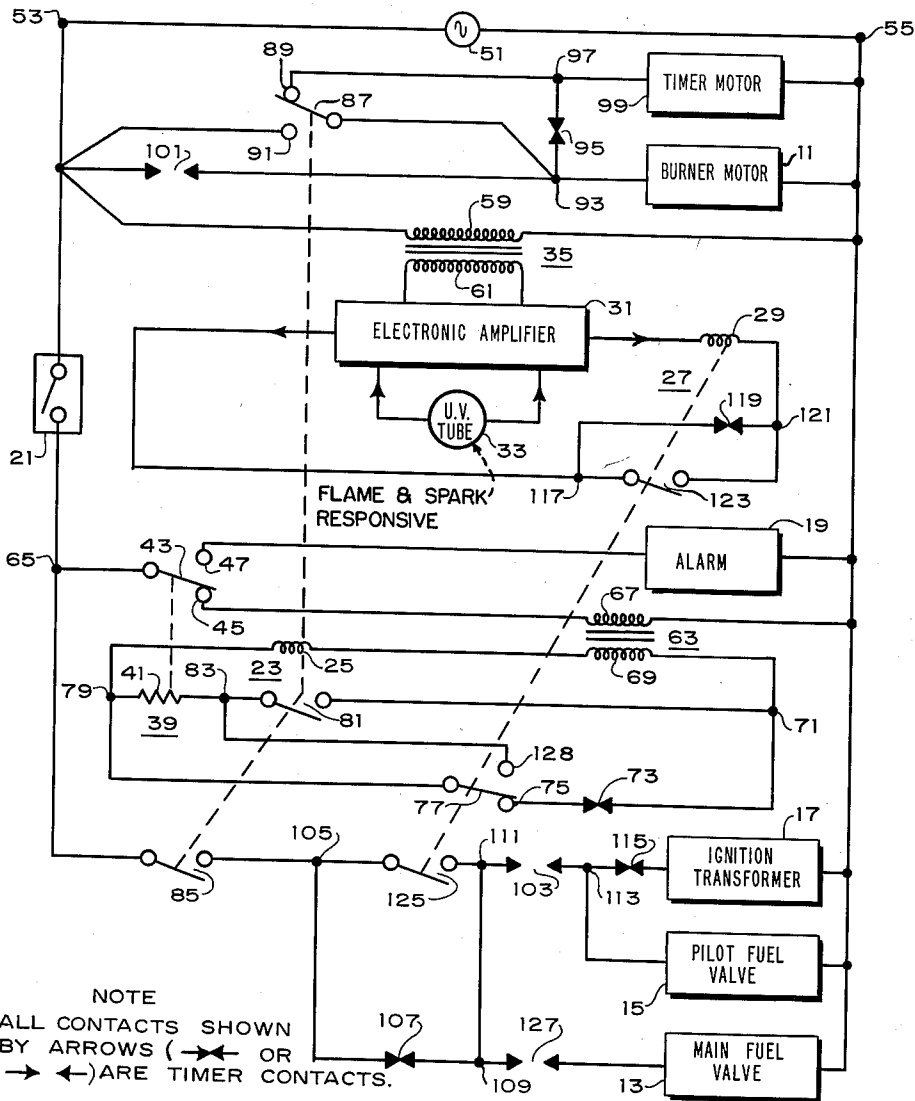
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COMBUSTION CONTROL APPARATUS

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COMBUSTION CONTROL APPARATUS

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This invention relates to combustion control apparatus for fuel burners, and more particularly to combustion control apparatus suitable for 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 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 detector 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.

Flame detectors are of various types and respond to such flame characteristics as flame conduction, visible radiation, infrared radiation and ultraviolet radiation. Each of these characteristics may be simulated by other conditions in the combustion chamber and may result in a false indication as to the presence of a flame. Ultraviolet flame radiation, in particular, may be simulated by the electric spark which is commonly used to ignite pilot burners.

It is the usual practice with pilot ignited burners to detect and prove the presence of proper pilot flame before admitting fuel to the main burner. Since an ultraviolet responsive detector reacts indiscriminately to pilot flame and electric spark and since it is difficult to avoid sighting the spark or its reflected radiation, positive proof of pilot flame establishment is problematical. The false indication of the pilot flame may result in a disastrous explosion.

It is the principal object of this invention to allow positive proving of the establishment of the pilot flame with a flame detector responsive primarily to ultraviolet radiation.

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 combustion con-

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trol programming device in accordance with this invention; and

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

Referring now to the drawings, the fuel burner control system includes a burner motor 11, a main fuel valve 13, a pilot fuel valve 15, an ignition transformer 17, and a flame failure alarm 19. These devices are controlled by an automatic control which, in turn, responds to a thermostatic switch 21 which closes upon a call for heat and opens when the demand for heat is satisfied. The automatic control includes a control relay 23 with a plurality of contacts actuated from a first position to a second position when its coil 25 changes from a de-energized condition to an energized condition and vice versa; a flame relay 27 with a plurality of contacts actuated from a "flame out" to a "flame on" position when the current through coil 29 exceeds a predetermined value, and actuated from a "flame on" to a "flame out" position when the current through coil 29 decreases below a predetermined value; an electronic amplifier 31 which amplifies and otherwise processes signals which the ultraviolet flame sensor 33 develops when sighting flame and in response to said signals causes current through flame relay coil 29 to exceed the predetermined value necessary to cause actuation of flame relay contacts; a transformer 35 which converts supply line voltage to such voltages as are required for the electronic amplifier; a transformer 63 which converts supply line voltage to a low voltage for operation of the control relay coil 25; a thermal lockout switch 39 having a resistance heater element 41 which is caused to heat bimetallic switch blade 43 in the event of ignition or flame failure so that said blade after a predetermined time disengages from contact member 45 and engages with contact member 47 where it remains until a reset actuator is manually operated; a timer with a plurality of contacts actuated by a plurality of cams having a fixed relation to each other on a common shaft which is rotated by a synchronous timer motor 99.

The ultraviolet sensor 33 may be a photomultiplier, a gas discharge counter tube of the Geiger-Muller type or any other form of detector having a response in the ultraviolet spectrum between 2200 and 3400 angstroms. The type of signal developed and its resultant amplification and processing have no significant bearing on the invention.

In describing the operation of the system shown in FIGURE 1, it will be assumed that a source of power 51, usually 115 or 230 volts single-phase A.C., is present at the supply terminals 53 and 55 of the burner safety control and that all controlled loads unless otherwise noted are energized upon completion of a circuit from one supply line to the other. Also assume, initially, that thermostatic switch 21 is open and that the timer is in starting position as shown in FIGURE 2.

Normal burner starting

Transformer 35 is energized by a circuit extending from point 53 to point 55 through primary winding 59. The voltage induced in secondary winding 61 of transformer 35 is applied to the electronic amplifier 31 where it is suitably rectified, divided, or otherwise altered as required to suit the particular requirements of the type of detector and amplifier circuit configuration chosen. With no flame established and detected at this time, flame sensor 33 develops no signal at the amplifier input and essentially no current flows in the amplifier output circuit which includes flame relay coil 29.

When the thermostatic switch 21 closes, the transformer 63 is energized by a circuit from point 53 through switch

21, point 65, contact members 43 and 45 of lockout switch 39, and primary winding 67 of transformer 63 to point 55. The voltage induced in secondary winding 69 of transformer 63 energizes coil 25 of control relay 23 by a circuit extending from one side of secondary winding 69 through point 71, timer contact 73, contact members 75 and 77 of flame relay 27, point 79, and coil 25 to the other side of secondary winding 69, and the contacts of control relay 23 are caused to move from a first position to a second position. In said second position, contact 81 closes and completes a circuit between points 71 and 79 through point 83 and heater 41 of lockout switch 39, shunting the circuit path afforded by timer contact 73 and contact members 75 and 77 of flame relay 27; contact 85 closes but completes no circuit at this time; contact member 87 disengages from contact member 89 (no effect) and engages contact member 91, completing a circuit from point 53 through point 93 to energize the burner motor 11, and through point 93, timer contact 95 and point 97 to energize the timer motor 99. The burner motor 11 drives a blower which introduces combustion air into the combustion chamber, said air serving to purge the chamber of unburned gases prior to the time fuel and ignition are introduced. Timer motor 99 rotates the cams which will actuate timer switches at predetermined times.

After ten seconds of timer rotation, timer contact 101 closes and timer contact 73 opens. Beyond this point, until contact 101 opens, the burner motor 11 remains energized from point 53 through contact 101 and point 93. Coil 25 of control relay 23 remains energized through a circuit extending from one side of secondary winding 69 of transformer 63 through point 71, contact 81 of control relay 23, point 83, heater 41 of lockout switch 39, point 79, and coil 25 to the other side of secondary winding 69.

After thirty uninterrupted seconds of timer rotation, timer contact 103 closes. Pilot fuel valve 15 is energized by a circuit extending from point 53 through switch 21, point 65, contact 85 of control relay 23, point 105, timer contact 107, points 109 and 111, timer contact 103, and point 113. Ignition transformer 17 is simultaneously energized from point 113 through timer contact 115. With pilot fuel and ignition spark present, pilot flame is established and flame sensor 33 develops a signal which is impressed at the input of amplifier 31 and causes to flow in the amplifier output a current of sufficient magnitude to actuate the flame relay 27. The energized output circuit is from one amplifier output connection through point 117, timer contact 119, point 121, and coil 29 of relay 27 to the other amplifier output connection. With flame relay 27 actuated, its contacts assume a position indicative of "flame on": contact 123 closes and shunts timer contact 119; contact 125 closes and shunts timer contact 107; contact member 77 disengages from contact member 75 (no effect) and engages with contact member 128, thus completing a shunt path around heater 41 of lockout switch 39.

After thirty-five seconds of uninterrupted timer rotation, timer contacts 119, 115, and 107 are actuated simultaneously: opening of contact 115 de-energizes the ignition transformer 17; opening of contact 119 results in the circuit to flame relay coil 29 being maintainable only through flame relay contact 123; with the opening of contact 107 the circuit to the pilot fuel valve 15 can be maintained only if contact 125 of flame relay 27 remains closed.

After forty seconds of uninterrupted timer rotation, timer contact 127 closes and main fuel valve 13 is energized by a circuit extending from point 53 through switch 21, point 65, contact 85 of control relay 23, point 105, contact 125 of flame relay 27, points 111 and 109, and timer contact 127. With the main fuel valve 13 energized, the main flame will ignite from the pilot flame.

After fifty-five seconds of uninterrupted timer rotation, the timer contact 103 opens and thereby de-energizes the pilot fuel valve 15. With the main flame established and detected, flame relay 27 remains energized.

After one hundred and five seconds of uninterrupted timer rotation, timer contact 95 opens and thereby de-energizes the timer motor 99. The timer cams remain at the one hundred and five seconds position and the burner continues to operate until heat demand is satisfied and the thermostatic switch 21 opens.

Normal shutdown

When thermostatic switch 21 opens, the main fuel valve 13 and transformer 63 are de-energized. With transformer 63 de-energized there is no energy source for coil 25 of control relay 23 and the contacts of relay 23 revert from the second position to the first position: contact 85 opens (no effect); contact 81 opens (no effect); contact member 87 disengages from contact member 91 and engages with contact member 89 thereby completing a circuit from point 53 through timer contact 101, point 93, contact members 87 and 89 of control relay 23, and point 97 to timer motor 99 which thereupon resumes rotation. Fifteen seconds after the instant the thermostatic switch 21 opened, timer contact 101 opens and thereby de-energizes both the timer motor 99 and the burner motor 11. The timer has now made one complete revolution and all timer contacts are again in starting position. The automatic burner safety control and the burner remain in ready but inoperative condition until thermostatic switch 21 closes again in response to a need for heat.

Operation following power interruption

If power is interrupted and restored prior to the point where timer contact 73 opens (ten seconds after start), a normal sequence will resume where it left off.

If power interruption occurs after the point where timer contact 73 opens (and contact 101 closes), there is no energizing circuit for coil 25 of control relay 23 and the relay will not actuate from its first position when power is restored. Burner motor 11 will be re-energized upon power restoration by a circuit extending from point 53 through timer contact 101 and point 93; timer motor 99 will also be re-energized by a circuit continuing from point 93 through contact members 87 and 89 of control relay 23 and point 97. Both motors will continue energized until timer contact 101 opens. If switch 21 is still closed, a normal cycle will immediately begin since timer contacts 101 and 73 are actuated simultaneously.

Operation if pilot does not ignite

As described for normal operation, both ignition transformer 17 and pilot fuel valve 15 are energized after thirty seconds of timer rotation. Flame sensor 33 may develop a signal at this point from ignition spark radiation even if no pilot flame is established, and flame relay 27 will then be energized as if flame was detected. At thirty-five seconds of timer rotation, ignition transformer 17 is de-energized and spark ceases. Assuming no pilot flame established, flame sensor 33 will cease to develop signal, coil 29 of flame relay 27 will be de-energized and contacts of flame relay 27 will actuate to "flame out" position: contact 123 opens and, since timer contact 119 is open at this time, coil 29 cannot be re-energized until after timer contact 119 recloses; contact 125 opens and thereby de-energizes pilot fuel valve 15 since timer contact 107 is open at this time; contact members 128 and 77 disengage, thereby removing the shunt around heater 41 of lockout switch 39, and heater 41 is energized. After heater 41 is energized for about one minute, contact member 43 of lockout switch 39 disengages from contact member 45 and thus de-energizes transformer 63 which, being the energy source for coil 25 of control relay 23, causes said coil to be de-energized and the contacts of said relay to revert to their first position.

When contact member 43 of lockout switch 39 disengages from contact member 45, it engaged contact member 47 and thus completed an energizing circuit for alarm 19 from point 53 by way of switch 21 and point 65.

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If timer contact 95 opens before the lockout switch 39 actuates, timer motor 99 stops until lockout occurs and contacts of control relay 23 have reverted to their first position. A normal shutdown then ensues except that the main fuel valve 13 is already de-energized and in fact was not energized because timer contact 107 and flame relay contact 125 were both open before timer contact 127 closed and remain open until after control relay contact 85 opens. If lockout occurs before timer contact 95 opens, said contact is shunted by contact members 87 and 89 of control relay 23 and the timer motor continues from the starting portion of the cycle into the shutdown portion of the cycle without interruption.

After the contacts of lockout switch 39 are actuated from normal to tripped position, they must be manually reset before another starting cycle can begin.

Operation if main flame does not light

Assuming that pilot flame is established and detected, the main fuel valve 13 will be energized as described above for normal operation. Also, as described earlier, the pilot fuel valve 15 will be de-energized fifteen seconds after the main fuel valve 13 was energized. If no main flame was established and with the pilot flame now extinguished, flame sensor 33 will cease to develop signal and flame relay 27 will revert to "flame out" position. In so doing, contact 125 opens and since timer contact 107 opened previously, the circuit to the main fuel valve 13 is broken and lockout ensues as described previously.

Operation following flame failure

Failure of pilot flame after timer contact 107 opens and before main flame is established, or failure of main flame after pilot fuel valve 15 is de-energized results in discontinuance of signal development by flame sensor 33 followed immediately by actuation of flame relay 27 to "flame out" position. The opening of flame relay contact 125 thus de-energizes any and all of the loads represented by ignition transformer 17, pilot fuel valve 15, and main fuel valve 13 which were energized at the time of flame failure, and lockout ensues as described earlier.

Operation if flame is simulated prior to starting

If any condition develops which maintains flame relay 27 in a "flame on" position when the switch 21 is open, no burner starting cycle will be initiated when switch 21 recloses. This is because flame relay contact members 75 and 77 are disengaged and there is no energizing circuit for coil 25 of control relay 23.

I claim:

1. In a burner ignition and control system including a spark ignition means for a pilot burner, an electrically operable pilot valve for the pilot burner, and a main fuel valve for a main burner, a programming apparatus comprising ultra-violet flame sensing means responsive to radiation from the pilot flame and from the spark of said

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ignition means, a timer, means responsive to said timer to energize said pilot valve and said ignition means so that both are on during a first time interval, means responsive to said timer to de-energize said ignition means but to leave said pilot valve on during a second time interval subsequent to said first time interval, and means to energize said main fuel valve only in response to the detection by said flame sensing means of the presence of a pilot flame during said second time interval.

2. A programming apparatus according to claim 1 further comprising a flame relay actuated by said flame sensing means, said flame relay having an energized position indicative of the presence of flame and a de-energized position indicative of the absence of flame, said flame relay comprising a first flame relay switch in series therewith which is closed when said flame relay is energized, and a first timer switch operated by said timer and connected in shunt with said first flame relay switch.

3. A programming apparatus according to claim 2 further comprising a second flame relay switch which is closed when said flame relay is energized, a second timer switch operated by said timer and connected in shunt with said second relay switch, a third timer switch operated by said timer and connected with the pilot valve in series with the shunt circuit formed by said second flame relay switch and said second timer switch, and a fourth timer switch operated by said timer and connected with said spark ignition means in series with said third timer switch and in parallel with said pilot valve.

4. A programming apparatus according to claim 3 further comprising a fifth timer switch operated by said timer and connected with said main fuel valve in series with the shunt circuit formed by said second flame relay switch and said second timer switch.

5. A programming apparatus according to claim 4 including circuit means whereby said spark ignition means and said pilot valve are turned on through the closing of said second, third and fourth timer switches during said first time interval, and that said spark ignition means are turned off and the presence of pilot flame is tested by opening said first, second and fourth timer switches during said second interval.

6. A programming apparatus according to claim 5 including circuit means whereby upon the detection of the presence of pilot flame during said second time interval said main fuel valve is energized through said second flame relay switch and said fifth timer switch.

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