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UNBURNED FUEL DETECTION AND BURNER CONTROL

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Fig. 1

Fig. 2

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UNBURNED FUEL DETECTION AND BURNER CONTROL


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This invention relates to ignition control for furnaces and, more particularly, to a means for preventing accumulation of unburned fuel particles in furnaces by reason of faulty operation of the ignition system.

An object of the invention is to initiate burner operation in furnaces while preventing dangerous accumulation of fuel particles.

Another object of the invention is to initiate operation of a furnace burner in such a manner that dangerous conditions may not develop.

Still another object of the invention is to provide an automatic control means which is responsive to the flame in a furnace to maintain flow of fuel to the burner of the furnace and which will also prevent dangerous accumulations of unburned fuels during the period when the furnace is being started.

A still further object of the invention is to provide a means whereby a photoelectric cell is utilized to initiate combustion in a furnace and, upon failure of the combustion, to terminate the flow of fuel to the furnace.

In industrial and other furnaces, very dangerous conditions often develop by reason of the flame in the burner going out while the flow of fuel to the burner is maintained. Such a condition may develop if, in an ignition or reignition period, the ignition system fails to work. The fuel particles continually accumulate in the fire chamber of the furnace and may reach such a substantial accumulation that a spark may cause a violent explosion. The present invention is concerned with the provision of an ignition control system in which it is inherently impossible for such conditions to develop.

Broadly stated, the present invention aims to provide a safe way of firing a furnace and attains that aim by carrying out the following steps in the following sequence:

(a) determining that no finely-divided, unignited fuel is present in a furnace,

(b) maintaining all the fuel lines to the furnace closed until any finely-divided, unignited fuel in the furnace has been removed from the furnace,

(c) putting the ignition system for the pilot burner into operation (said ignition system being maintained inoperative if any finely-divided, unignited fuel is in the furnace),

(d) starting the flow of combustible mixture to the pilot burner, or if there is no pilot burner as in Figs. 1 and 4, activating any conventional ignition means to light the main burner, and,

(e) starting the flow of combustible mixture to the main burner.

Various means are disclosed hereinafter for carrying out the foregoing steps.

In one form of apparatus for carrying out the present invention, there is provided a photoelectric system for controlling the supply of fuel to the burner of the furnace. A photoelectric cell which is positioned adjacent the burner is subjected to light from a source which is disposed across the fire chamber of the furnace so that the path of the light from the source to the cell is transversely through the path of the fuel from the burner.

The photoelectric cell is utilized to control suitable electric circuits which, in turn, operate a solenoid actuated fuel valve. The electric circuit connections are such that when the furnace is started the photoelectric cell receives light from the source and the fuel valve is held open to allow fuel to flow to the burner. However, the presence of unburned fuel particles in the fire chamber will cause the excitation of the photoelectric cell to be reduced to a point such that the solenoid valve is de-actuated and the supply of fuel to the burner is interrupted. After the furnace is started, the light from the separate source is extinguished and, so long as the flame is maintained in the fire chamber of the furnace, the intensity of light falling upon the photoelectric cell will be sufficient to maintain the valve in an open position. If the flame goes out, the photoelectric cell closes the valve.

The intensity of the light is enough to energize the photoelectric cell before the burner is lighted if there is no accumulation of unburned fuel particles intervening. But the light is dispersed when an accumulation of unburned fuel particles are present and such accumulation of particles reduces the light reaching the photoelectric cell to below the amount of light required to energize the cell sufficiently to energize the valve.

It is a feature of the embodiment of the invention herein disclosed and described that the electric circuits which control the solenoid valve in response to the excitation of the photoelectric cell is particularly adapted for the successive performance of the necessary control functions necessary to the starting of the furnace.

Other objects, features and advantages of the invention will be apparent from a consideration of the following detailed specification taken in connection with the accompanying drawings, in which:

Fig. 1 is a sectional view of a furnace showing the relative disposition of a burner and the photoelectric apparatus of the invention;

Fig. 2 is a schematic diagram of an electric circuit which forms a part of the present embodiment of the invention;

Fig. 3 is a wiring diagram of a modified form of apparatus embodying this invention;

Fig. 4 is a sectional view of a furnace showing an alternate means for conducting a beam of light through the fuel path in the furnace and to a photoelectric cell;

Fig. 5 is another sectional view of a furnace showing still another arrangement for directing a light beam toward a photoelectric cell;

Fig. 6 is a diagrammatic view of an embodiment of this invention similar to that shown in Fig. 5, but including two light sources and two photoelectric cells; and

Fig. 7 is a wiring diagram of a system incorporating the present invention.

Referring now to Fig. 1, the furnace 10, with which the apparatus of the invention is adapted to be utilized, is of known form. The furnace 10 is mounted upon a base, such as a floor 11, and comprises a front wall 12, a back wall 13 and a base 14. A burner 15 is mounted upon the front wall and is supplied with fuel, such as oil, through a pipe 16. A suitable draft opening 17 provides a sufficient flow of air to support combustion in the fire chamber 18. The fuel is, of course, under pressure, and the burner 15 serves to project the fuel into the fire chamber 18 in a finely-divided form.

A light detector including a photoelectric cell 19 is mounted at the front wall 12 of the furnace 10 and is adapted to receive light from the interior of the furnace through an opening 20 in the wall of the furnace. The photoelectric cell 19 may be one of any of a number
of well-known forms of cells which generate an electric current in response to incident electromagnetic radiation. The particular form of cell utilized is not deemed to form a part of the invention.

The photoelectric cell 19 is subjected to light from a source, such as a lamp 11 which is mounted in the rear wall 13 of the furnace 10 and is adapted to project light through an opening 22 in the rear wall of the furnace. The source 21 is disposed with relation to the position of the photoelectric cell 19 that light travels from the lamp 21 to the opening 22 transversely through the path of the fuel particles which issues from the burner 15. The path of the light will thus be through either the path of the atomized fuel before the fuel is ignited, or into and through the flame when the burner is in a normal operative condition.

The output of the photoelectric cell 19 is utilized to control a solenoid operated valve 23 in the fuel supply line 16 by means of suitable electric circuits 24. As shown particularly in Fig. 2, the electric circuits include suitable means for amplifying the currents generated by the photoelectric cell and appropriate relays for actuating the valve 23. In particular, the operation of the photoelectric cell 19 is integrated with and forms a part of the starting operation for the furnace.

The electric circuit 24 comprises a primary circuit 25 including conductors 26 and 27 which are connected to a source of power (not shown) through an on-off switch 28. The primary circuit 25 energizes the light source 21 and flame detector relay 29 and a suitable amplifier 30 for operating the relay 29 in accordance with the illumination of the photoelectric cell 19.

The flame detector relay 29 includes a set of normally open contacts 31 which are connected in series with a coil 32 of the solenoid valve 23 and the primary circuit 25. The connections between the photoelectric cell 19, the amplifier 30 and the relay 29 are such that when the intensity of light upon the photoelectric cell 19 exceeds a predetermined intensity, the contacts 31 are closed to energize the coil 32 and thus open the valve 23 to allow fuel to pass to the burner 15. When the intensity of light upon the photoelectric cell 19 falls below this critical level, the contacts 31 open and the valve 23 closes.

The set of contacts 31 also comprises a set of normally open contacts 33 which are connected in series with the coil 32 of the solenoid valve 23 and the primary circuit 25. The connections between the photoelectric cell 19, the amplifier 30 and the relay 29 are such that when the intensity of light upon the photoelectric cell 19 exceeds a predetermined intensity, the contacts 31 are closed to energize the coil 32 and thus open the valve 23 to allow fuel to pass to the burner 15. When the intensity of light upon the photoelectric cell 19 falls below this critical level, the contacts 31 open and the valve 23 closes.

The actuation of the coil 32 in response to the operation of the relay 29 is determined by a relay 33 which is, in turn, controlled by a starting switch 34. The relay 33 includes a set of Normally closed contacts 35 which are connected in series with the coil 32 of the solenoid valve 23 and the normally open contacts 31 of the relay 29, so that when the contacts 31 are closed the solenoid will be actuated.

The starting switch 34 includes a set of normally open contacts 36 which are connected in series across the primary circuit 25 with the lamp 21, the time delay type coil 37 of a thermal relay 38 and a low-fire interlock switch 39. The starting switch 34 also includes a set of normally closed contacts 40 which are connected in series with the coil of the relay 33 through a set of normally open contacts 41 of that relay.

It is not an essential to this invention that light 21 and coil 37 may be series connected as shown in Figure 2. Light 21 and coil 37 may be parallel connected to provide power source through starter switch 36.

The delay relay 38 includes a set of normally open contacts 42 which are connected between the coil of the relay 33 and the conductor 26 in order to provide an ancillary control means for that relay. When the contacts 42 are closed by the time delay relay 38, the relay 33 is energized, thus opening the relay contact 35 and closing fuel valve 23. The contacts 40 of the switch 34 also operate relay 33 through normally closed contacts 44 and 45. Contact 41 closes before contact 43 opens. Thereafter, contact 41 controls the operation of the relay 33 until contact 40 of start switch 34 is opened for another attempt to start the burner.

The low-fire interlock switch 39 which is connected in series with the normally open contacts 36 of the switch 34 and with the thermal relay coil 37 is a mechanically interlocking switch having a pair of normally open contacts which close only when the burner 15 is adjusted for low fire. The switch 39 is operated solely by adjustment of the burner 15 and is provided so that initiation of the ignition process may be made only upon a proper setting of the burner 15.

The coil of the relay 33 is connected to the conductor 26 of the primary circuit 25 through the normally closed contacts 40 of the starting switch 34 through parallel circuits including the normally open contacts 41 of the relay 33 as one circuit, and a set of normally closed contacts 42 of the relay 33 and a set of normally closed contacts 44 of the relay 39 as a parallel circuit. The relay 33 is actuated to open the contacts 35 whenever the starting switch 34 is in a burn position and the relay 29 has not been actuated to open the contacts 44. The contacts 41 of the relay 33 serve to hold the relay in an actuated position.

In operation, the on-off switch 28 is closed to energize the photoelectric cell 19, and the amplifier 30. The burner 15 is then positioned to low-fire to close the interlock switch 39. The ignition means is then operated and the start switch 34 is actuated. Upon actuation of the start switch 34, the relay 33 is energized by the opening of contacts 40, the normally open contacts 36 are closed and the lamp 21 is lighted. If the path between the lamp 21 and the photoelectric cell 19 is substantially clear, the light will be received upon the cathode of the photoelectric cell and cause relay 33 to close to actuate to close the contacts 31. The valve is then opened by a circuit including contacts 31 and 35, and the fuel may be ignited. Upon ignition of the fuel, the light from the flame will activate the photoelectric cell to cause the valve to be maintained in an operative condition and the start switch may be released.

If the flame is not established within a reasonable time after the start switch 34 is actuated, the time delay relay 38 will cause the contact 42 to close, thus actuating the relay 33 and opening contacts 35 to terminate the flow of fuel to the burner 15. During normal operation, light 21 is off and, if the flame fails, the light from the furnace will be reduced to such an intensity that the relay 29 will be deactuated thus opening contacts 31 and deenergizing coil 32 of the valve 23.

In Fig. 3, the circuit of which the described circuit of my invention is shown as consisting of a light source such as an incandescent bulb 50, a photoelectric cell 51, a vapor and fuel detector relay 53 and a coil 55 operatively connected to a metering pump (not shown), supplying fuel to the burner (also not shown) of the system. The circuit also includes an off-on switch 57 and a start switch 58.

This circuit may advantageously be employed in the furnace of Fig. 4 wherein 60 designates the burner mounted on furnace 62 similar to that shown in Fig. 1 and described above. Cell 51 which is mounted adjacent to burner 60 and receives light from bulb 50 as a beam reflected by reflector 64 mounted on the opposite side of the furnace from the burner so that the light beam traverses the furnace chamber twice. Pump 66 supplies fuel to burner 60 and is controlled by electrical means including cell 51 and cell amplifier 67 which shuts off the pump in response to a signal from the cell following failure of the light beams to reach the cell.

The installation shown in Fig. 5 utilizes the light reflector concept, i.e., the "long path" light ray, but in this case there is substantial vertical space between the two positions of the reflector traversing the combustion chamber. Also, the delivery of fuel to the burner is controlled through a spring actuated valve instead of the solenoid valve or the pump of the systems described above.

In Fig. 5 a conventional furnace is designated at 70, an oil burner at 71, and a spring-actuated valve of suit-
able conventional design at 72. A photoelectric cell 73 is mounted in register with an opening in the furnace wall just above burner 71, and at a point well above the burner an incandescent bulb 75 is mounted outside the furnace so that light from the bulb can enter the combustion chamber through another opening in the furnace wall at 78. In this way, the bulb 75 is mounted on the outside of the furnace opposite cell 73 and bulb 75 to intercept a light beam emerging from the furnace through an opening in register with bulb 75, and to direct this beam downwardly to the level of cell 73 and back into the furnace through an opening in the furnace wall register with cell 73.

Vapor and fuel detector relay 80, which is electrically connected to cell 73 and to a power source, operates the latch of valve 72, releasing a spring which closes the valve when the light beam between the bulb and the cell is broken at any point. This relay may be of the same construction as relay 67 and that of Figs. 1 and 2 and those skilled in the art will understand that the mode of operation of the circuit of Fig. 5 will be essentially the same as that of the circuits described above.

The Fig. 6 system constitutes an alternative to that just described whereby the pincone is eliminated and an additional bulb and photoelectric cell are substituted for it. Thus the advantage of having two vertically-spaced detection zones is retained without the addition of a second detection system by merely duplicating two basic elements in the basic circuit of this invention. As the drawing indicates, bulbs 82 and 83, suitably connected in parallel, are paired with cells 84 and 85, respectively, which are electrically connected in series to vapor and fuel detector relay 86 for operation of a burner fuel flow control means (not shown) previously set forth. Again, interruption of either light beam will trigger said fuel control means through the electric circuit serving cells to stop flow of fuel to the burner and into the combustion chamber of the furnace.

If cells 84 and 85 were connected in parallel to the relay, it would be necessary to interrupt both light beams at one time to cause the relay to stop the flow of fuel to the burner. This arrangement and operation may be desirable in certain installations and is within the scope of the appended claims, although not representing my preferred practice of this invention.

The installation shown in Fig. 7 has features of structure and function in common with the other systems of my invention herein illustrated and it affords the special advantages of those other systems. Thus not only will the gas supply to the burner be automatically stopped when a dangerous condition arises in the combustion chamber, but also ignition of the main burner will be prevented as long as such condition persists. A furnace equipped with a gas pilot and with this Fig. 7 system cannot be charged with fuel oil through its main burner so long as the gas flame of the pilot is not adequately to insure ignition of fuel entering through the main burner.

Furnace 90 of Fig. 7 is provided with an oil burner 91 and a gas pilot burner 92 to ignite oil sprayed into the combustion chamber by burner 91. Oil is delivered to the main burner by an electrically powered pump 94 and line 95, while gas reaches the pilot through line 96 under control of weight-loaded valve 97. On opposite sides of the furnace an incandescent light bulb 98 and a photoelectric cell 100 are mounted so that a light beam traveling from the bulb into the furnace and through the combustion chamber will strike the cell, hatched openings being provided in the furnace walls for this purpose. Another pair of openings are provided between the pilot and main burners to receive flame rods 102 and 103, which together with bulb 98 and cell 100 comprise the testing or sensing elements of the control system of this installation.

These sensing elements are operatively associated with pump 94 and valve 97 through electric circuits including an amplifier and relay 105, spark ignition transformer 106, automatic switch 107, and manual pilot and main burner starting switches 109 and 110.

Rod 102 is a grounding rod and rod 103 is an insulated rod and in normal use these two devices make contact with a gas flame of the pilot burner. Cell 100 and rod 103 then are electrically series connected through the gas flame which acts as a conductor or rectifier to ground. Consequently, either the failure of the gas flame or of sufficient light from the light source to reach cell 100 results in a signal or impulse and closing of valve 97 and opening of pump 94. The electronic relay here impresses voltage on the cell to energize a lamp, and if the current passes through the circuit unless the cell is sensitized by the light ray from bulb 98 and a flame exists between flame rod 103 and ground rod 102.

In operating the Fig. 7 installation switches 109 and 110 are pushed to closed position to light the pilot burner. The pilot will be ignited by a spark through the operation of transformer 106 only in the event that a light beam from bulb 98 falls upon cell 100. The manual switches are then pulled to open the shunt and ignite the main burner. This last result cannot be obtained until the flame is opened through the flame contact rods in series circuit with cell 100 which simultaneously checks for accumulations of fuel fog in the furnace combustion chamber and for continuance of an adequate pilot flame. Before the pilot is shut off after establishing the oil flame, the normally ungrounded flame rod may be grounded, thus allowing cell 100 to supervise the continuing operation of the main burner.

From the foregoing description it will be understood that this Fig. 7 system prevents ignition of the gas pilot flame if the combustion chamber is filled with smoke or fuel mist. It also operates to stop oil and gas flow to the main and pilot burners in case of accumulation of dangerous amounts of fuel mist in the combustion chamber. In case of failure of the gas ignition flame during the oil ignition period, both oil and gas flow to the burners is automatically stopped immediately. Consequently, the compromise between safety and practicability always involved in prior art systems of this general type is no longer necessary.

This Fig. 7 system may be modified to provide visual or audible alarm means where it is desirable that the furnace not be immediately shut down. The operator on receiving the warning can take appropriate action and operations depending upon uninterrupted operation of the furnace may be continued while the alarm-causing condition is being relieved.

Timers may advantageously be incorporated in this Fig. 7 system to provide time for heating or recirculating of fuel and preheating of the furnace, flues, chimney, and fuel lines. Such timers also may aid in fixing the timing for the pre-firing sequential check of the system components and the photoheating of the furnace for fuel mist prior to and during the establishment of ignition and the flow of fuel to the main burner.

This application is a continuation-in-part of my application Serial No. 365,653 filed July 2, 1953, and abandoned in view of the filing of this application.

Having thus described this invention in sufficient full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains to make and use the same, and having set forth the best mode contemplated of carrying out this invention, I state that the subject matter which I regard as being my invention is particularly pointed out and distinctly claimed in the appended claims, and that equivalents or modifications of, or substitutions for, parts of the above specifically described embodiments of the invention may be made without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:
1. In an ignition and combustion control system in-
including a furnace having a combustion chamber and a burner adapted to deliver dispersed fuel particles, a fuel supply line for the burner, an electrically operable valve means in said fuel line, an electrically operated source of light and a photoelectric cell mounted outside and on opposite sides of said fuel combustion chamber, means for directing light from said source toward said photoelectric cell through the path of fuel issuing from said burner into said chamber, a system energizing switch, a first relay including a coil having a plurality of normally closed switches and a normally open switch, a second relay having a normally open switch and a normally closed switch, a circuit means including the photoelectric cell for energizing said second relay, a switching means having a normally closed set of contacts and a normally open set of contacts, circuit means including said normally closed set of contacts connecting the coil of said first relay to said system energizing switch through said normally closed switch of said second relay to energize said first relay upon closing said system energizing switch whereby said normally open switch of said first relay is closed, a circuit for said relay energizing cell having a holding circuit for said first relay and including said normally open switch, a circuit including said normally open set of contacts and said switching means and a thermal means and said electrically operated source of light connected in series, operation of said switching means to close said set of normally open contacts serving to energize said source of light and said thermal means, the simultaneous opening of said normally closed set of contacts de-energizing said first relay, said photoelectric cell being effectively energized by said light to energize said second relay to close said normally open switch of said second relay, a circuit including the normally open switch of said second relay and said electrically operable valve means, whereby said electrically operable valve means in said fuel line is open when said normally open switch of said second relay is closed, said second relay adapted to be de-energized by an accumulation of unburned fuel particles in said combustion chamber blocking the path of light to de-energize said photoelectric cell whereby said normally open switch of said second relay is opened to cause said electrically operable valve means to close.

3. The combination of claim 1 wherein said thermal means is operatively connected to a switch in series with a coil of the first said relay, said switch being closed by the thermal heating of the thermal means to energize said first relay to open one of said normally closed switches of said second relay, first relay to close said normally open switch of said second relay to close said second relay and to de-energize said photoelectric cell whereby said normally open switch of said second relay is opened to cause said electrically operable valve means to close.

4. In an ignition and combustion control system including a furnace having a combustion chamber and a burner adapted to deliver dispersed fuel particles thereto, a fuel supply line for the burner, an electrically operable valve means in said fuel line, an electrically operated source of light and a photoelectric cell mounted outside and on opposite sides of said combustion chamber, means for directing light from said source toward said photoelectric cell through the path of fuel issuing from said burner into said chamber, electrical means comprising a relay having an actuating coil connected to said photoelectric cell and having normally open contacts connected to said valve means, starting means to energize said source of light, said photoelectric cell normally receiving light from said source of light for effective energization of said photocell when there is an absence of an accumulation of unburned fuel particles in said combustion chamber thereby actuating said relay to open said valve means, said photoelectric cell remaining effectively energized by said source of light when an accumulation of unburned fuel particles is present in said combustion chamber and said valve means for said fuel then remaining closed.

5. Fuel burning and safety apparatus for preventing explosions due to the presence of unburned dispersed particles of fuel in the combustion chamber of a furnace comprising a furnace having a combustion chamber, a burner positioned to deliver dispersed particles of fuel to such a combustion chamber, a photoelectric cell outside of the combustion chamber and arranged to direct light across said chamber, a photoelectric cell outside of the combustion chamber and positioned to receive light from said source after passing through said combustion chamber, said flame flow control means being actuated by the said cell only when there is insufficient unburned fuel in the space between the light source and the cell to block a predetermined amount of light in its travel toward the photoelectric cell.

6. Fuel burning and safety apparatus for preventing explosions due to the presence of unburned dispersed particles of fuel in the combustion chamber of a furnace comprising a furnace having a combustion chamber, a main burner positioned to deliver dispersed particles of fuel to the combustion chamber, a pilot burner in the combustion chamber to ignite fuel, a source of light outside the said chamber and arranged to direct light across said chamber, a photoelectric cell outside of said chamber and positioned to receive light from said source after passing through said chamber, a pipe line leading to the main burner, a pipe line leading to the pilot burner, means controlled by said cell for controlling the flame flow through said lines to said combustion chamber, said flame flow control means being actuated by the said cell only when there is insufficient unburned fuel in the space between the light source and the cell to block a predetermined amount of light in its travel toward the photoelectric cell.

7. Fuel burning and safety apparatus for preventing explosions due to the presence of unburned dispersed particles of fuel in the combustion chamber of a furnace comprising a furnace having a combustion chamber, a burner positioned to deliver dispersed particles of fuel into said chamber, a source of light outside of said chamber, a photoelectric cell outside of said chamber, means for directing light from said source through said combustion chamber and to said cell, a pipe line leading to the burner, means for control of flow of fuel through said pipe line, means actuated by said cell for igniting fuel discharged from said burner, and means controlled by said cell for controlling the actuation of said fuel control means, said flame flow control means being actuated by the said cell only when there is insufficient unburned fuel in the space between the light source and the cell to block a predetermined amount of light in its travel toward the photoelectric cell.

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