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FUEL FEED CONTROL SYSTEM RESPONSIVE TO FLAME COLOR

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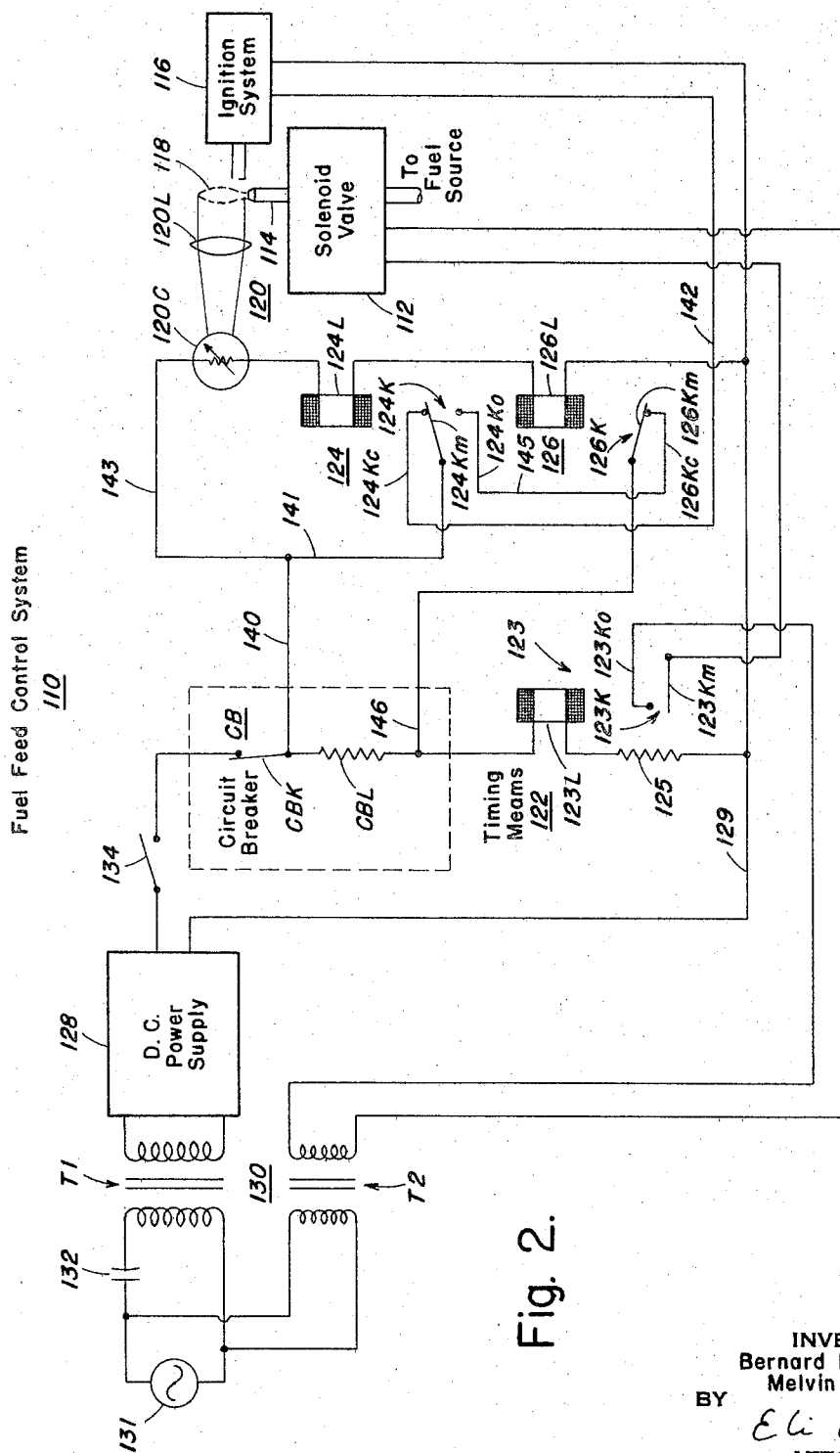


Fig. 2.

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**FUEL FEED CONTROL SYSTEM RESPONSIVE  
TO FLAME COLOR**

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1 Claim. (Cl. 158—125)

This invention pertains to systems for controlling the feeding of fuel to a fuel burner and more particularly to such systems which control the feeding of fuel to a burner in accordance with the presence of fuel combustion in the burner.

In many remote control fuel burning systems, fuel is supplied to a burner in response to a remotely generated signal. At the same time, or shortly thereafter, the fuel as it leaves the burner is ignited. Generally, there is no human supervision of the operation. Accordingly, if ignition does not take place then at best fuel is wasted. However, if the fuel is a volatile gas then there is the very serious hazard of accumulation of the gas and the danger of explosion. Systems have been proposed which shut off the flow of fuel if combustion is not attained. Nevertheless, with such proposed systems there is the possibility that sometime after combustion has been attained the flame goes out. Accordingly, every reliable system must include means for continuously monitoring the flame.

Heretofore, the flame was indirectly monitored. More specifically, the heretofore available gas flame sensors employed heat sensors such as thermocouples or ionized gas detectors. In general, a thermocouple is placed near or in the flame. The thermocouple generates an electromotive force which is functionally related to the temperature of the thermocouple junction. The electromotive force so generated is used to control the flow of fuel to the burner. It should be noted, however, that the thermocouples do not instantaneously respond to the presence or absence of a flame since there is a thermal lag due both to the thermocouple and the ability of its mechanical supporting structure to dissipate heat. Ionized gas detectors on the other hand depend on the conductivity of a hot ionized gas to provide an electrical current path to a device which controls the flow of fuel to a burner. Such detectors are delicate and have critical operating characteristics.

It is, accordingly, a general object of the invention to provide an improved system for controlling the flow of fuel to a fuel burner.

It is another object of the invention to provide an improved fuel feed system whose sensing element can be placed outside the high heat region of the fuel burner and, accordingly, has a longer lifetime.

It is a further object of the invention to provide an improved fuel feed system which is, on the one hand, rugged and reliable and, on the other hand, relatively inexpensive.

Broadly, the invention contemplates a fuel feed system to be used in combination with apparatus that feeds fuel to a burner via a valve means to a fuel burner. The system includes means for actuating the valve means for a given period of time during which only a given quantity of fuel is fed to the burner. During this time, the flame should be struck. Photoelectric means are provided for sensing illumination from the flame of burning fuel. If the photoelectric means senses such illumination, third means are activated which insure continued actuation of the valve means as long as the photoelectric means senses illumination from the flame.

In a gas burning system the optimum utilization of fuel is obtained when the flame is blue, that is, when the

proper proportion of gas and oxygen are consumed in the burner. If the flame is over rich in fuel then the flame is more luminous since it is more yellow than blue. Accordingly, even though the flame is generating heat the system is operating inefficiently. It should be apparent that the above mentioned thermocouples and hot ionized gas detectors cannot detect such an inefficiently operating fuel burner.

It is, accordingly, another object of the invention to provide a fuel control system which by employing a single flame sensor not only controls the flow of fuel to a burner in accordance with the presence or absence of a flame but also in accordance with the operating efficiency of the fuel burner.

This aspect of the invention contemplates that the photoelectric means generate a current as long as the flame is present and that this current activates means for insuring the continued actuation of the valve means. However, the photoelectric means generates a current related to the intensity of the sensed illumination. Therefore, if the flame becomes more luminous due to a yellow component, the current increases. Further means are provided which are activated when the current exceeds a predetermined magnitude to deactuate the valve means.

According to a feature of the invention, means are also provided so that if the means which first actuates the valve means to supply the initial quantity of fuel operates beyond a given period of time the valve means is deactivated whether or not a flame is sensed.

Finally, it should be noted that in many remote control heating systems thermostats or similar switching means are employed which create the demand for fuel burning. When such a switching means is incorporated in the heretofore described fuel feed control system it is possible that each time the valve means is deactivated for any malfunctioning of the control system, the switching means may attempt to restart the cycle of operation. In such a case there could be an incremental accumulation of uncombusted fuel which is as hazardous as a continuous accumulation.

Therefore, according to another feature of the invention there is provided means for de-energizing the photoelectric means and the means which initially actuates the valve means whenever the valve means is deactivated while the switching means demands the burning of fuel.

Other objects, features and advantages of the invention will be apparent from the following detailed description when read with the accompanying drawings which show, by way of example, and not limitation, apparatus for practicing the invention.

In the drawings:

FIG. 1 is a schematic diagram of a first embodiment of the invention; and

FIG. 2 is a schematic diagram of another embodiment of the invention.

Referring to FIG. 1 there is shown a fuel feed control system 10 wherein a fuel such as a gaseous hydrocarbon is fed from a fuel source (not shown) via a solenoid-operated valve 12 to burner 14 where it is ignited by a conventional ignition system 16 to produce a flame 18.

The remainder of FIG. 1 is concerned with a control system for actuating solenoid-operated valve 12 and centers around the photoelectric means 20, the timing relay 22, the blue flame relay 24, the yellow flame relay 26, the time-delay relay 28, the latching relay 30, the rectifier 32, and the demand means 34.

It should be noted that the system 10 as presently shown depicts all relays in their normal or deactivated state and with the solenoid-operated valve 12 deactivated.

Accordingly, at this time flame 18 should not be present. However, it is shown in dotted lines merely to indicate its functional relationship with photoelectric means 20.

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Before describing the operation of system 10, various components and reference character conventions will be explained.

Photoelectric means 20 includes the cadmium sulfide cell 20C and the optical system 20L which enhances the sensitivity of cell 20C. The cadmium sulfide cell 20C is a photoconductive solid state element whose electrical resistance decreases with increasing illumination falling on its active surface. Accordingly, the cell 20C is shown as a variable resistor. The response curve of the cadmium sulfide cell 20C peaks very sharply in the blue-green region of the visible spectrum and falls off very sharply in the infra-red region. Therefore, cell 20C is insensitive to the heated walls which usually surround the burner.

Timing relay 22, the means for actuating solenoid-operated valve 12 for only a given period of time, includes: a coil 22L, a timing capacitor 22C connected to one end of coil 22L, and three contact sets 22K1, 22K2, and 22K3. Contact set 22K1 includes: the normally-open fixed contact 22K1o and the moving contact 22K1m. Contact set 22K2 includes: the normally-open fixed contact 22K2o, the normally-closed fixed contact 22K2c, and the moving contact 22K2m. Contact set 22K3 includes: the normally-open fixed contact 22K3o and the moving contact 22K3m.

Blue flame relay 24, the means for continuing the actuation of solenoid-operated valve 12 as long as illumination from the flame is sensed, includes the coil 24L and the contact set 24K with the normally-open fixed contact 24Ko, the normally-closed fixed contact 24Kc and the moving contact 24Km. It should be noted that the coil 24L of relay 24 is connected to cell 20C so that when cell 20C conducts and passes current, this current passes through coil 24L as will hereafter become apparent. Yellow flame relay 26, a means for deactuating solenoid-operated valve 12 when the current passed by cell 20C exceeds a given magnitude includes a coil 26L having a sensitivity less than the sensitivity of coil 24L and a contact set 26K with a normally-open fixed contact 26Ko, a normally-closed fixed contact 26Kc and a moving contact 26Km. It should be noted that coil 26L is in series with coil 24L so that current passed by cell 20C also passed through coil 26L. It should also be noted that the sensitivities of coils 24L and 26L can be so chosen to be sensitive to different ranges of currents generated by cell 20C in response to different color flames or different ranges of colors.

Time-delay relay 28, a means for deactuating solenoid-operated valve 12 if timing relay 22 is energized beyond a given period of time, is a conventional time-delay relay which operates only after its coil 28L receives current continuously for a given period of time and includes the contact set 28K with the normally-open fixed contact 28Ko and the moving contact 28Km.

Latching relay 30, a means for latching interrupting energization of cell 20C and timing relay 22, is a conventional latching relay that is alternately energized and deenergized as its coil 30L receives sequential pulses of current. Relay 30 includes the contact set 30K with a normally-closed fixed contact 30Kc and moving contact 30Km. One end of coil 30L is connected to contact sets of relays 24 and 26 in parallel. Also, connected, in parallel with said contact sets, to said end of coil 30L is manually-operable normally-open switch 30s. Connected to the other end of coil 30L is current limiting resistor 30R. Relay 30 operates slower than relay 24.

Relays 22, 24 and 26 are D.C. operated and relays 28 and 30 are A.C. operated.

It should be noted that all the relays are shown in their normal or de-energized states. When any relay is energized its moving contact moves toward its coil, breaking contact with the normally-closed fixed contacts of the sets and making contact with the associated normally-open contacts of the sets.

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Rectifier 32 includes diode 32D whose anode is connected to contact set 30K of latching relay 30 and whose cathode is connected to the filter network of resistor 32R and 32C in parallel. Demand means 34 includes A.C. source 34A and switch 34S. Although switch 34S is shown as a manually operable switch it could also be a thermostat switch.

The normal operation of the system will now be described.

Whenever there is a demand for the burning of fuel, switch 34S is closed and remains closed until the demand no longer exists. Alternating current passes via switch 34S, contact 30K and line 35 and is rectified to a direct current by rectifier 32. The direct current is fed via line 36 to energize cell 20C by applying a D.C. voltage to its upper terminal. Charging current flows through capacitor 22C and coil 22L to return line 38 until capacitor 22C is charged to the D.C. voltage on line 36. While the charging current flows, relay 22 is energized. The period of time charging current flows is determined primarily by the capacitance of capacitor 22C and the resistance in coil 22L. While relay 22 is energized the alternating current on line 40 passes via contacts 22K2m and 22K2o of set 22K2 and line 42 to solenoid-operated valve 12. Solenoid-operated valve 12 is actuated and fuel flows to burner 14. At the same time, contact set 22K3 closes, energizing ignition system 16 which ignites the fuel flowing from burner 14 causing the striking of flame 18, which will be assumed as blue for the time being. Cell 20C starts conducting and direct current flows from line 36 via cell 20C and coils 24L and 26L to return line 38. Because of the amount of illumination from the blue flame the magnitude of the direct current flow is only sufficient to activate relay 24.

When capacitor 22C is fully charged after a given period of time, relay 22 automatically deactivates. The alternating current on line 40 now flows via contacts 22K2m and 22K2c, line 44, contacts 24Km and 24Ko, line 46, and contacts 26Km and 26Kc to line 42 to continue the actuation of solenoid-operated valve 12. Fuel will, accordingly, be fed to burner 14 as long as a blue flame is present and until switch 34S is opened. The opening of switch 34S interrupts the flow of alternating current on line 48 and, consequently, on lines 40 and 42 deactuating solenoid-operated valve 12 and terminating fuel flow to burner 14. At the same time, direct current ceases on line 36. Current no longer flows through cell 20C and relay 24 is deactivated. Capacitor 22C also discharges.

The abnormal operations will now be described. These abnormal operations are: (1) no flame is struck or the flame goes out; (2) the flame that is struck is yellow or changes from blue to yellow; (3) relay 22 operates for longer than the predetermined period of time; (4) cell 20C is open circuited; (5) cell 20C is short circuited; (6) direct current fails; and (7) alternating current fails.

Consider case 1. It will be recalled that when relay 22, after being activated and then automatically deactivated after the given period of time, fed alternating current on line 44 to contact 24Km. Any time relay 24 is not activated contact 24Km is connected to contact 24Kc and the current passes via line 50 to latching relay 30 which is activated causing contact set 30K to open. The opening of contact set 30K is equivalent to opening switch 34S and the system turns itself off. It should be noted that relay 24 will be deactivated when no current flows through coil 24. This can occur if no flame appears or the flame goes out (case 1); cell 20C is open circuited (case 4); direct current fails after the flame is struck (case 6).

Consider Case 2. Whenever the flame 18 is yellow, cell 20C conducts heavily as hereinabove described. Accordingly, sufficient current flows to activate relay 26 in addition to relay 24. Contact 26Km transfers from contact 26Kc to contact 26Ko of relay 26 and the alternating current on line 46 is transferred from line 42 to line 50.

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Solenoid-operated valve 12 is deactuated and relay 30 is activated. System 10 shuts itself down as previously described for case 1. It should be noted that heavy current flow through coil 26 can also occur if cell 20C is short circuited (case 5).

Consider now case 3. When relay 22 is initially activated, in addition to the previously described phenomena, contact set 22K1 closes and alternating current flows via line 40, contact set 22K1 and line 52 through the coil 28L of time delay relay 28 to return line 38. If, for example, the period of time of activation of relay 22 is three seconds and time delay relay 28 is chosen so that it is activated only if coil 28L receives current for five seconds, then if relay 22 remains activated for any reason more than five seconds, relay 28 is activated. Contact set 28K closes. The alternating current on line 52 passes via contact set 28K and line 54 to coil 30L. Relay 30 is activated and contact set 30K opens. Then the system shuts itself down.

Consider now the situation in case 6 when direct current is never available on line 36. Accordingly, when switch 34S is closed relay 22 is not activated and cell 20C not energized. Accordingly, the alternating current from switch 34S flows via contact set 30K, line 40, contact set 22K2, line 44, contact set 24K and line 50 to coil 30L. Contact set 30K opens and the system shuts itself down in the usual manner.

In case 7, the failure of alternating-current is equivalent to the normal opening of switch 34S.

It should be noted that except for the failure of alternating current each abnormal operation entailed the activation of latching relay 30. Relay 30 is purposely chosen to be a latching relay requiring a manual resetting to draw a user's attention to the abnormal operation of the system. Resetting is accomplished merely by momentarily closing spring-return push button switch 30S causing a pulse of alternating current to flow via line 48, switch 30S and line 50 to coil 30L. This pulse, following a pulse which activated relay 30, deactivates relay 30 causing contact set 30K to close and returns the system to its normal state.

Referring now to FIG. 2, there is shown a fuel feed control system 110 wherein a fuel such as a gaseous hydrocarbon is fed from a fuel source (not shown) via a solenoid-operated valve 112 to burner 114 where it is ignited by a conventional ignition system 116 to produce a flame 118.

The remainder of FIG. 2 is concerned with a control system for actuating solenoid-operated valve 112 and centers around the photoelectric means 120, the timing means 122, the blue flame relay 124, the yellow flame relay 126, the power supply 130 and the demand means 134.

It should be noted that the control system 110, as presently shown, depicts all relays in their normal or deactivated state and with the solenoid-operated valve 112 deactuated. Accordingly, at this time, flame 118 should not be present. However, it is shown, in dotted lines, merely to indicate its functional relationship with photoelectric means 120.

Before describing the operation of control system 110, various components and reference character conventions will be explained.

Photoelectric means 120 includes the cadmium sulfide cell 120C and the optional system 120L which enhances the sensitivity of cell 120C. The cadmium sulfide cell 120C is a photoconductive solid state element whose electrical resistance decreases with increasing illumination falling on its active surface. Accordingly, the cell 120C is shown as a variable resistor. The response curve of the cadmium sulfide cell 120C peaks very sharply in the blue-green region of the visible spectrum and falls off very sharply in the infra-red region. Therefore, cell 120C is insensitive to the heated walls which usually surround the burner.

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Timing means 122, the means for actuating solenoid-operated valve 112 is the circuit breaker CB. The relay 123 and the current limiting resistor 125 are serially connected in that order to circuit breaker CB. The circuit breaker CB includes a contact set CBK and a bimetal element CBL. Current flowing through circuit breaker CB heats the element CBL and is adjusted so that the circuit breaker CB operates in approximately four seconds. Relay 123 includes a coil 123L and a contact set 123K having a normally-open fixed contact 123K<sub>o</sub> and a moving contact 123K<sub>m</sub>.

Blue flame relay 124, the means for continuing the actuation of solenoid-operated valve 112 as long as illumination from the flame is sensed, includes the coil 124L and the contact set 125K with the normally-open fixed contact 124K<sub>o</sub>, the normally-closed fixed contact 124K<sub>c</sub> and the moving contact 124K<sub>m</sub>. It should be noted that the coil 124L of relay 124 is connected to cell 120C so that when cell 120C conducts and passes current, this current passes through coil 124L as will hereafter become apparent. Yellow flame relay 126, a means for deactuating solenoid-operated valve 112 when the current passed by cell 120C exceeds a given magnitude includes a coil 126L having a sensitivity less than the sensitivity of coil 124L and a contact set 126K with a normally-closed fixed contact 126K<sub>c</sub> and a moving contact 126K<sub>m</sub>. It should be noted that coil 126L is in series with coil 124L so that current passed by cell 120C also passed through coil 126L. It should also be noted that the sensitivities of coils 124L and 126L can be so chosen to be sensitive to different ranges of currents generated by cell 120C in response to different color flames or different ranges of colors.

The power supply 130 includes an alternating current source 131 which can vary from 80 to 130 volts A.C. The alternating current source 131 is connected to D.C. power supply 128 via transformer T1. Transformer T1 is preferably a saturable transformer which provides a near constant voltage output. Capacitor 132 limits the current fed to transformer T1. D.C. power supply 128 preferably includes a full wave rectifier including a choke-capacitor filter, and a bleeder resistor. Source 131 also feeds transformer T2 to supply current for valve 112 under control of relay 123, as will hereinafter become apparent.

The demand means 134 is a switch which for simplicity is shown as manually operable but can be a thermostat switch.

Relays 123, 124 and 126 are D.C. operated and are shown in their normal or deenergized states. When any relay is energized its moving contact moves toward its coil, breaking contact with the normally-closed fixed contacts of the sets and making contact with the associated normally-open contacts of the sets.

The normal operation of the system will now be described.

When there is a need for more heat switch 134 closes. Current flows therethrough and simultaneously through three circuits: (1) via contact set CBK, element CBL, coil 123L and resistor 125 to return bus 129; (2) via contact set CBK, bus 140, bus 141, contacts 124K<sub>m</sub> and 124K<sub>c</sub>, bus 142 and ignition system 116 to return bus 129; and (3) via contact set CBK, bus 140, bus 143, cell 120C, coil 124L, and coil 126L to return bus 129.

The current through coil 123L energizes relay 123 causing the closing of contact set 123K which results in the feeding of alternating current from transformer T2 to solenoid-operated valve 112. Fuel starts flowing from the source (not shown) to burner 114.

Since there is no flame 118, the resistance of cell 120C limits the current through coil 124L below the value required to energize relay 124. Accordingly, the ignition system 116 is actuated to ignite the fuel flowing from burner 114. As will hereinafter become apparent, a four second time period is allowed initially as a trial for igni-

tion. Under normal circumstances, the fuel will ignite well before the end of the time period. When the cell 124C senses a blue flame, relay 124 is energized and moving contact 124K<sub>m</sub> transfers from contact 124K<sub>c</sub> to contact 124K<sub>o</sub>. Ignition system 116 is deactuated and a shunting path around element CBL is established. In particular, current now flows from contact set CBK via busses 140 and 141, contacts 124K<sub>m</sub> and 124K<sub>o</sub>, bus 145, contacts 126K<sub>c</sub> and 126K<sub>m</sub> to bus 146. Therefore, little or no current flows through element CBL which stops heating.

Fuel is now fed to burner 114 until either switch 134 is opened, or the flame 118 goes out; or the color of flame 118 changes from blue to yellow. Each situation will be discussed.

When switch 134 is opened, no more current is fed to relay 123 and relay 124, and both de-energize. The de-energization of relay 123 interrupts the flow of current to solenoid-operated valve 112 stopping the flow of fuel. The de-energization of relay 124 returns it to its rest state and the system 110 is ready for reactivation.

If the blue flame 118 goes out, the current through relay 124 markedly decreases causing relay 124 to de-energize. The connection between contacts 124K<sub>o</sub> and 124K<sub>m</sub> opens breaking the shunt path around element CBL. Element CBL starts heating and in four seconds contact set CBK opens. The opening of contact set CBK has the same effect as the opening of switch 134.

When the flame 118 changes from blue to yellow, cell 120C conducts more current and relay 126 is energized. Contact set 126K opens and the shunt path around element CBL opens. Element CBL starts heating and after four seconds contact set CBK opens.

If a flame were never struck, then relay 124 would not energize and no shunt path would be established around element CBL. Accordingly, after four seconds contact set CBK would open.

Thus it is seen in every case of abnormal operation a timing element is allowed to operate so that after a predetermined period of time the means which control the flow of fuel to the burner are deactuated.

There has, accordingly, been shown and described a reliable fuel feed system which includes a photoelectric means to monitor the presence of a flame. The photoelectric means also permits the control of the flow of fuel in accordance with the color of the flame. Furthermore, by the incorporation of a latching means for interrupting current flow there is no chance of the system recycling after malfunctioning without the intervention of a human being.

While only two embodiments of the invention have been shown and described in detail there will now be obvious to those skilled in the art many modifications and variations thereof which satisfy the objects of the invention without departing from the spirit thereof as defined in the appended claim.

What is claimed is:

A fuel feed control system for use with apparatus for burning fuel fed to a fuel burner via a valve means, and including ignition means for igniting fuel at said fuel

burner, said control system further comprising: a source of electric current including first and second terminals; circuit breaker means including a contact set having a first terminal connected to the first terminal of said source of electric current and a second terminal, the terminals of said contact set being normally connected to each other, and a heating element means including a first terminal connected to said contact set and a second terminal, said heating element means causing the terminals of said contact set to disconnect when electric current has passed through said heating element means for a given period of time; a first relay including a winding connected between the second terminals of said heating element means and said source of electric current and a contact set means for controlling the actuation of said valve means; a photo conductive means for sensing the color of the flame of burning fuel and having a conductivity which increases as the color of the flame changes from blue to yellow, said photoconductive means including a first terminal connected to the second terminal of the contact set of said circuit breaker means and a second terminal; a second relay including a winding having a first terminal connected to the second terminal of said photoconductive means and a second terminal, a contact set including a normally-closed contact, a normally-open contact and a transfer contact, said transfer contact being positioned against said normally-closed contact when an electric current less than a first given value passes through the winding of said second relay and being positioned against said normally-open contact when an electric current greater than said first given value passes through said winding; means for connecting the normally-closed contact of said relay to the second terminal of said circuit breaker means, means for connecting the normally-closed contact of said second relay to said ignition means; and a third relay including a winding connected between the second terminal of the winding of said second relay and the second terminal of said source of electric current and a contact set including a first terminal connected to said normally-open contact of the contact set of said second relay and a second terminal connected to the second terminal of said heating element means, said terminals of said contact set being connected to each other as long as a current less than a second given value greater than said first given value passes through said winding.

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60 FREDERICK KETTERER, *Primary Examiner.*

UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,304,989

February 21, 1967

Bernard D. Alexander et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 2, for "fist" read -- first --; line 16, after "sensing" insert -- for --; column 8, line 33, beginning with "relay to" strike out all to and including "of said" in line 34, same column 8.

Signed and sealed this 28th day of November 1967.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents