Jan. 21, 1969 N. A. FORBES 3,423,158

COMBUSTION CONTROL CIRCUIT

Filed May 12, 1966

FIG. 1

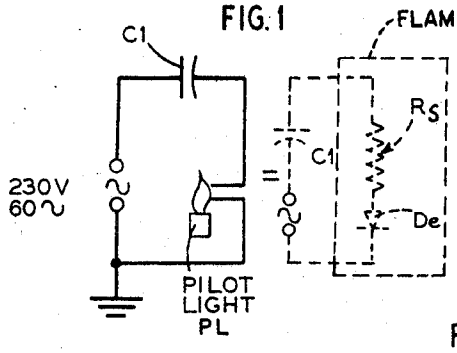


FIG. 3

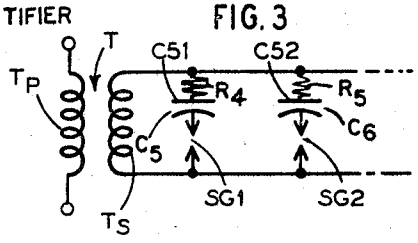
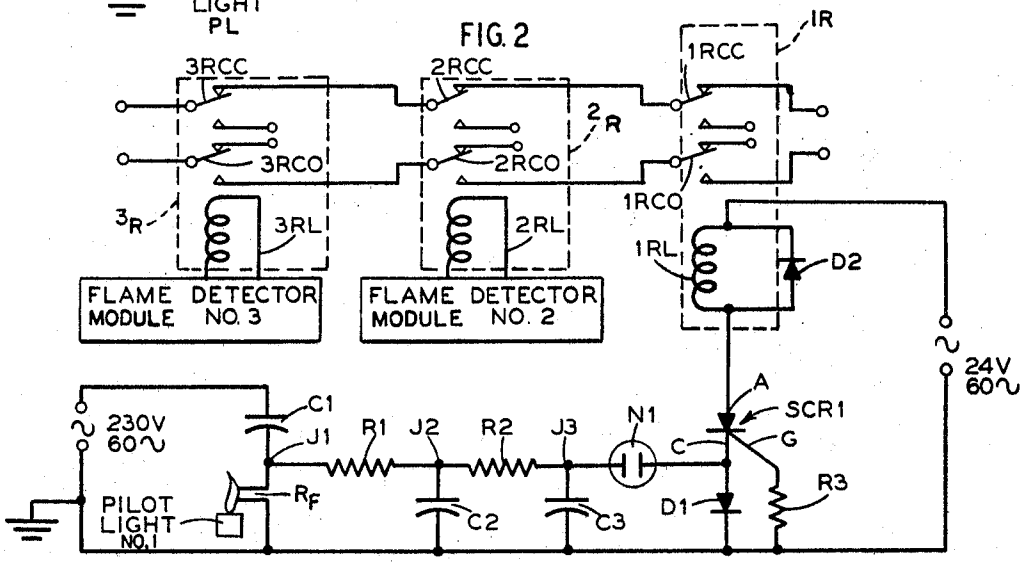


FIG. 2



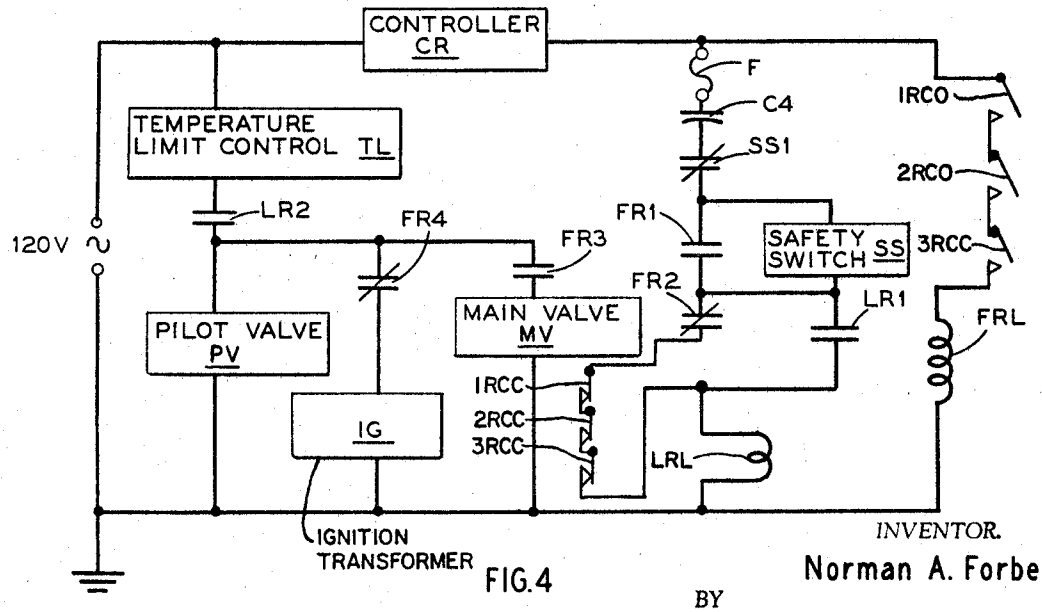


FIG. 4

INVENTOR.
Norman A. Forbes
BY
Eli Weiss
ATTORNEY

United States Patent Office 3,423,158 Patented Jan. 21, 1969

3,423,158

COMBUSTION CONTROL CIRCUIT

Norman A. Forbes, Louisville, Ky., assignor to American Radiator & Standard Sanitary Corporation, New York, N.Y., a corporation of Delaware

Filed May 12, 1966, Ser. No. 549,725
U.S. Cl. 431—46 8 Claims
Int. Cl. F23n 5/24, 5/12; G01k 7/40

ABSTRACT OF THE DISCLOSURE

This invention involves a gas burner control system for a boiler having a plurality of pilot burners. The control system employs a relay switch for each pilot burner. The relay switch will be moved between two positions, one in response to the operation of the associated pilot burner and the other in response to the non-operation of that pilot burner. The control system also includes flame-detecting means which responds to the condition of the pilot burner to operate the associated relay switch. All relay switches must be in the non-operation position at the beginning of a startup, for ignition to be successful, and all pilots must light before the main valve can be opened.

The invention relates to a boiler control system for supervising the operation of large boilers, and more particularly large atmospheric boilers using multiple flame-sensing points and pilots.

Large boiler installations often employ several burners. To insure smooth ignition multiple pilots are used to light the main burner. In order to provide safe and reliable operation of a gas-fuel boiler, it is necessary to insure proper operation of all pilots, that is, all pilots are supervised.

Therefore, it is an object of the invention that such a system have the following features, namely:

(a) Spark ignited pilot;

(b) All pilots must be proven before the main gas valve delivers gas to the main burners;

(c) Interrupted ignition (the spark ignition is turned off when all pilots have lit and turns on again if any one pilot goes out);

(d) The main gas valve closes quickly (in two to four seconds) if any one pilot goes out;

(e) Fail-safe operation in the sense that a component failure must cause the boiler to shut down;

(f) Increased reliability by elimination of certain components found in prior art control systems; and

(g) Greater economy.

Briefly, the invention contemplates a gas burner control system for a boiler having a plurality of pilot burners, with each pilot burner provided with a supervisory means. The control system comprises in association with each pilot a relay switch operable to a first position to control a control circuit to prove the related pilot is burning, and operable to a second position to prove that the related pilot is not burning, and flame-detecting means responsive to the condition of the pilot for operating the relay switch.

Other objects, features and advantages of the invention will be apparent from the following detailed description when read in connection with the diagrammatic circuits in the accompanying drawings, wherein:

FIG. 1 is a simple schematic diagram to indicate the circuit equivalence of a flame in a pilot light to a simple diode rectifier with a series resistance;

FIG. 2 is a schematic diagram of the flame sensing circuitry contained in each flame detector module for supervising one related flame, and shows also the circuit relation of the pilot flame detector relay to the corresponding flame detector relays of two other flame detector modules;

FIG. 3 is a schematic circuit diagram of two of the several pilot sparking gaps; and

FIG. 4 is a schematic circuit diagram of the main control system.

The flame control circuit

Each flame at a pilot is supervised through the use of the rectifying properties of a gas flame.

The recognition of flame at a supervised pilot causes a double-pole double-throw relay inside the flame control module to pull in. The normally-closed contacts of one pole of all such relays are connected in one series string and the normally-open contacts of the other pole of all such relays are connected in another series string. These two series connections are used by the main control circuit, described below, to check that all flame detector relays are dropped out at the beginning of a trial for ignition, and that all flame detector relays are pulled in, indicating that all pilots are lit, before the main gas valve is opened.

Referring to FIGURES 1 and 2, a 230-volt, 60-cycle AC voltage is coupled through capacitor C1 to the flame rectifier R_F which is shown schematically as embodying a diode D_e and a resistor R_s and sometimes referred to as the "flame rectifier." When no flame is present, the flame rectifier R_F is essentially an open circuit with an AC voltage across it. When a flame is present, the flame rectifier R_F behaves like a diode D_e with a very high series resistance R_s, approximately 10 megohms, and with appreciable leakage. The cathode of the flame rectifier R_F is necessarily grounded, because the rectifying properties of a flame and the polarity of the flame rectifier R_F depend on the relative area of the ground electrode and the probe. In spite of the imperfect rectification by the flame, enough rectification occurs to cause the junction J1 (see FIG. 2) of the flame rectifier R_F and capacitor C1 to be charged negatively by approximately 100 volts. The voltage at this junction is therefore the algebraic sum of a 230-volt sine wave and a DC voltage of —100 volts.

A resistor R1 and a capacitor C2 in series bridge the flame rectifier R_F. The junction J2 of the resistor R1 and capacitor C2 is connected to subsequent series circuit including resistor R2 and capacitor C3. The junction J3 of resistor R2 and capacitor C3 is connected via a neon lamp N1 to a relay control circuit containing silicon controlled rectifier SCR1 having an anode A, a cathode C, a gate G and it is controlled by a diode D1 and a resistor R3, to operate the flame relay coil IRL from a 24-volt, 60-cycle supply source.

Resistor R1 and capacitor C2 of FIG. 2 form a filter which removes all but 25 volts of the 230 volt AC component from the flame rectifier voltage, while leaving the DC component relatively unattenuated. The voltage at the junction J2 of resistor R1 and capacitor C2 is therefore the algebraic sum of a 25 volt sine wave and a DC voltage of approximately —100 volts. The 25 volt AC component in this waveform, when correctly phased with anode-to-cathode voltage across silicon controlled rectifier SCR1 ensures that there is no relay chatter at flame signals just large enough to fire neon lamp N1.

Resistor R2, capacitor C3, and neon lamp N1 form a discharge path across capacitor C2. When capacitor C2 is charged, neon lamp N1 discharges in a series of short pulses several hundred times a second. In this process resistor R2 serves two purposes: (1) it ensures that neon lamp N1 discharges in many closely spaced pulses at a rate determined by the time constant of resistor R2 and capacitor C3, instead of a few widely spaced pulses, (2) together with capacitor C2 it provides a delayed release circuit so that loss of flame recognition does not occur

more rapidly than in two to four seconds. Capacitor C3 determines both the firing rate (about 350 pulses per second) and the peak current per discharge pulse (about two milliamperes). The discharge itself takes about seven microseconds.

Current through neon lamp N1 is used to turn on silicon controlled rectifier SCR1. However, instead of driving the gate G of switch SCR1 directly in the usual manner, the cathode C is driven. The reason for this connection is that the gate and cathode terminals of switch SCR1 must be bridged with a low resistance (1,000 ohms), thereby preventing the leakage current through silicon controlled rectifier SCR1 from possibly turning it on. If the gate were driven directly, this resistor would reduce the system current sensitivity. Also the resistor would not be failsafe, since if it failed because it opened it would not shut down the burner. In the schematic diagram of FIG. 2, this resistor R3 is connected between the gate G of switch SCR1 and ground. In this position resistor R3 prevents leakage current from firing SCR1, yet does not have as much effect on the sensitivity of the silicon controlled rectifier SCR1 as a gate drive system would have. In practice, the cathode drive circuit shown has typically a 150 microampere sensitivity when using a silicon controlled rectifier with a basic sensitivity of 30 microamperes, the difference being due to current cancellation in the cathode drive circuit by transistor action within the silicon controlled rectifier before it fires. A gate drive system with 1000 ohms across the gate to cathode terminals would by comparison have about a 700 microampere sensitivity.

Diode D1 has two functions: (1) when discharge current from capacitor C3 flows through neon lamp N1, reverse voltage appears across diode D1, diode D1 blocks the voltage, and the discharge current flows out of cathode C and into the gate G of silicon controlled rectifier SCR1, thus turning silicon controlled rectifier SCR1 on, and (2) when silicon controlled rectifier SCR1 fires, diode D1 conducts in the forward direction and provides an easy path for cathode current.

Diode D2 is a "free-wheeling" diode across the coil 1RL. Even though the coil 1RL is driven by a half-wave voltage, the current in the coil 1RL is relatively smooth because the inductance of the coil 1RL causes current to continue flowing through the coil 1RL and through diode D2 long after the voltage across coil 1RL has fallen to zero.

Relay coil 1RL is associated with two contacts, as shown in FIG. 2, and the assembly is identified as flame relay 1R. The normally open contacts 1RCO, 2RCO, 3RCO of all such flame relays 1R, 2R, 3R, etc., are connected in series as shown, so that a connection is made in the main control circuit when flame is established at all supervised pilots. The normally-closed contacts 1RCC, 2RCC, 3RCC, etc., of all such flame relays are also all connected in series so that the main control circuit can check that all such flame relays have dropped out before the beginning of a trial for ignition. Each flame relay 1R, 2R, 3R is therefore checked against sticking in either a closed or an open position.

Fail-safe analysis

Although the manner in which the circuit is made failsafe is implied in the foregoing, the subject of safety control circuits being fail-safe is so important that a separate fail-safe analysis is presented below. The definition of "fail-safe," as the term is used here, is as follows: "an electronic component fails safe if either opening or shorting it causes the flow of fuel to cease, either immediately or at the beginning of the next ignition cycle."

If capacitor C1 of FIG. 2 opens, no voltage can be applied to the flame rectifier R_F and there is no flame recognition signal to fire neon lamp N1. If capacitor C1 shorts, the voltage across the flame rectifier R_F has no DC component (even though the current through it does), so that again there is no flame recognition signal.

If resistor R1 shorts, then capacitor C2 is connected directly across the flame rectifier R_F and the voltage divider effect of capacitors C1 and C2 causes the voltage applied to the flame rectifier R_F to be so low that the flame recognition signal is insufficient to fire neon lamp N1. If resistor R1 opens, the flame recognition signal is prevented from reaching neon lamp N1.

If capacitor C2 shorts, the flame recognition signal is shorted to ground and cannot fire neon lamp N1. If capacitor C2 opens, its filtering action ceases and the large AC component in the flame recognition signal fires neon lamp N1 continuously. Flame relay 1R now pulls in permanently. At the beginning of the next ignition cycle, the control system checks the flame relays in all the flame detector modules to make sure that they have all dropped out. If one flame relay has not dropped out, no fuel can be delivered to either the pilot gas valves or the main gas valve, and the trial for ignition stops.

If resistor R2 opens, the flame recognition signal is prevented from reaching neon lamp N1. If resistor R2 shorts, the frequency at which neon lamp N1 discharges falls so low that the gate G of silicon controlled rectifier SCR1 does not receive positive drive every cycle, and flame relay 1R does not pull in.

If neon lamp N1 opens, switch SCR1 cannot be turned on and flame relay 1R does not pull in. If neon lamp N1 shorts, then the gate G of silicon controlled rectifier SCR1 receives a small continuous current of several microamperes instead of a series of pulses of approximately 150 microamperes. Under these conditions, the gate drive is too low to fire silicon controlled rectifier SCR1, and flame relay 1R does not pull in.

If capacitor C3 shorts, there is no voltage available to fire neon lamp N1, silicon controlled rectifier SCR1 does not fire, and flame relay 1R does not pull in. If capacitor C3 opens, neon lamp N1 fires more rapidly, but with such low current that silicon controlled rectifier SCR1 does not fire, and flame relay 1R does not pull in.

If resistor R3 opens, no current can flow into the gate G of silicon controlled rectifier SCR1, so that switch SCR1 does not fire, and flame relay 1R does not pull in. If resistor R3 shorts, then the initial buildup of cathode current in silicon controlled rectifier SCR1 (transistor action) cancels the gate drive, so that silicon controlled rectifier SCR1 does not fire and flame relay 1R does not pull in.

If diode D1 shorts, the cathode of silicon controlled rectifier SCR1 is shorted to ground, silicon controlled rectifier SCR1 does not fire, and relay 1R does not pull in. If diode D1 opens, there is no path to ground for the cathode current of silicon controlled rectifier SCR1, so that flame relay 1R does not pull in.

If diode D2 shorts, the coil 1RL of flame relay 1R is shorted and the flame relay does not pull in. If diode D2 opens, the current in relay coil 1RL is made to pulsate so that flame relay 1R chatters, but does not pull in.

If silicon controlled rectifier SCR1 shorts, flame relay 1R pulls in continuously, causing a shutdown at the next trial for ignition.

The main control circuit

The main control circuit is used only once in a boiler installation regardless of the number of supervised pilots.

The main control circuit combines information from all the flame control modules, so that all flame relays must drop out before a trial for ignition can begin, and all flame relays must pull in before gas is delivered to the main burners.

A schematic diagram of the main control is shown in FIG. 4.

The main operating components are indicated as Controller CR, for appropriate initiating or control switching; PV, for pilot gas valve; IG, for ignition transformer;

MV, for main gas valve; SS, for a safety switch that is essentially a thermally-operated time delay relay switch; TL, a temperature limit control; LR, a load relay coil LRL associated with contacts LR1 and LR2; and a flame relay coil FRL associated with contacts FR1, FR2, FR3 and FR4.

When all the individual flame relays 1R, 2R, etc., in the respective flame detector modules of FIG. 2 have dropped out, a series circuit through the normally-closed back contacts 1RCC, 2RCC, 3RCC of one pole on each of all these relays make a through closed connection, as indicated in FIG. 2. This closed series connection is shown also in FIG. 4.

Similarly, when all the flame relays of the respective pilot flame detectors are energized, indicating all pilot flames are lit, a series circuit through the normally-open contacts 1RCO, 2RCO, 3RCO, of another pole on each of all the flame relays, is closed to make a closed circuit connection. These contacts are shown in FIG. 4.

Under normal conditions, therefore, when the controller CR calls for heat, the load relay LR is energized initially by current passing via capacitor C4, the closed contacts of safety switch SS, the heater winding of safety switch SS, the closed back contact FR2, the series connected contacts 1RCC, 2RCC, 3RCC and coil LRL. If any of these contacts is open relay coil 1RL will not be energized and the trial for ignition will cease.

If everything is normal, load relay coil LRL is energized contact LR1 shorts out the series connection of contacts FR2 1RCC, 2RCC and 3RCC so that these four contacts can subsequently open. Also, on the 120 volt line, contact LR2 energizes the pilot gas valve PV and the ignition transformer IG.

In a normal ignition, the pilots will all light, but not necessarily in unison. The first pilot to light opens a contact in the series contact circuit 1RCC, 2RCC, 3RCC, and the last pilot to light closes the series contact circuit 1RCO, 2RCO, 3RCO, energizing relay coil FRL, opening contact FR2, and closing its contact FR1.

Up to the instant that front contact FR1 closes, all the current for relay coil LRL has been flowing through the heater winding of the safety switch SS. If ignition of all pilots is not confirmed by the closing of front contact FR1 within (typically) 15 seconds, then safety switch SS, which is essentially a temperature-compensated thermal circuit breaker, operates, opening its back contact SS1 and terminating the trial for igntion. However, if front contact FR1 does close before 15 seconds, then the heater of safety switch SS is shorted and the trial for ignition is successfully completed.

Successful lighting of all the pilots, as indicated by the energizing of relay coil FRL, causes the main gas valve MV to be energized through closing contact FR3, and causes the ignition IG to be interrupted by opening contact FR4, since all pilots are now ignited. The boiler is now operating normally.

If any one of the pilots such as the pilot associated with relay 1R extinguishes for any reason, then relay coil 1RL becomes de-energized and the series circuit 1RCO, 2RCO, 3RCO opens, relay coil FRL is deenergized, contact FR1 opens, the heater of safety switch SS is re-energized, the ignition IG is re-energized, and the main gas valve MV is de-energized. The circuit is now back in the "trial for ignition" mode, and if all the pilots do not now light, the safety switch SS will cause a safety shutdown as before.

For successful operation of the main control circuit, the current in relay coil LRL must not change appreciably when the heater of safety switch SS is shorted. One conventional way to achieve this objective is to design relay coil LRL with an inductance that is high compared to both its own resistance and the resistance of the safety switch heater, so that shorting the safety switch heater upon flame recognition does not cause a large change in current through the relay coil LRL. However, such a design requires a large wire size, resulting in a large coil bobbin and a large core. Such a relay is wasteful of materials by normal standards, and hence is a special design. Another conventional approach to this problem is to make relay coil LRL close a third contact, and use the extra contact to connect the junction of safety switch SS and contact LR1 (FIG. 3) to a tap on a 24-volt transformer, so that relay coil LRL receives the correct voltage under normal running conditions. This approach solves the problem of current increase through relay coil LRL when the safety switch heater is shorted, but raises the problem of procuring a three-pole relay with spacings sufficient to meet UL requirements. In the present design, a constant-current source has been created by the use of capacitor C4, with the result that the current in the coil LRL changes only slightly when safety switch SS is shorted, so that a special design for relay coil LRL is not needed. Fuse F1 protects the circuit against a short in capacitor C4.

Ignition circuit

The ignition circuit developed for this control system is shown schematically in FIG. 3.

The objective of this ignition circuit is to permit multiple pilots to be ignited from a single ignition transformer T, having a primary winding T_p for receiving the AC ignition voltage and a secondary winding T_s. This objective is achieved by placing a small capacitor, C5 in FIG. 3, rated at 630 pf. and 10 kv. in series with spark gap SG1 and a similar capacitor C6 in series with spark gap SG2. To limit the current, resistor R4 is placed in series with capacitor C5 and resistor R5 is placed in series with capacitor C6. In practice, as the terminal voltage of the ignition transformer rises, the gaps fire in a random manner. When a gap such as gap SG1 fires, a pulse of current passes across the gap until the corresponding capacitor C5 in series with the gap is charged. At some later instant, another gap SG2 fires, charging its series capacitor C6 and causing the terminal voltage of the transformer to dip momentarily. This dip in voltage causes the first capacitor C5 to discharge into the second capacitor C6, intensifying the spark in the second gap SG2. As many as ten spark gaps have been operated in this manner from one ignition transformer. The analysis presented above is confirmed by the fact that as each new spark gap was added, the energy in the gaps increased. The effect of resistors R4 and R5 is to reduce spark gap erosion, and to limit the rate of rise of transient voltages across transformer T.

The capacitors C5 and C6 are fail-safe because if one capacitor such as C5 opens, then the spark gap SG1 in series with the capacitor C5 will not be energized and the associated pilot will fail to ignite, while if one capacitor shorts, then the spark gap in series with the capacitor will be the only one to be energized and all the others will fail to light. In either case, since all the pilots fail to light, the control circuit goes through a safety shutdown as shown in a previous analysis. The resistors are fail-safe only against opening; therefore they would have to be of a type that is not likely to short.

Thus, by the system circuitry shown, a simple economical and safe ignition control system is provided for a multiple-pilot furnace. It will be understood, of course, that variations or re-arrangements of the circuitry and components may be made without departing from the spirit and scope of the invention, as set forth in the claims.

What is claimed is:

1. A gas burner control system for a boiler having a plurality of gas burners, with each burner provided with a pilot light, said control system comprising, in association with each pilot light, a relay switch operable to a first position to control an indicating circuit to indicate that the related pilot light is burning, and operable to a second position to indicate that the related

pilot light is not burning; flame-detecting means responsive to the condition of the pilot flame for operating the relay switch; said relay switch including an operating coil; a silicon controlled rectifier switch for controlling the energization of said operating coil; and a pulsing circuit as part of said flame-detecting means and operable at a high pulsing rate to control the operation of said silicon controlled rectifier switch.

2. A gas burner control system, as in claim 1, in which said flame-detecting means includes a circuit including the pilot light flame and a capacitor to establish a voltage-divider circuit with a variable voltage across the pilot flame; the pulsing circuit including a capacitor-resistor circuit connected to be energized from said variable voltage and to have a relatively short time constant; a gas discharge device for discharging the capacitor of said capacitor-resistor circuit and for generating a rapid sequence of short time pulses; and means controlled by said pulses for controlling the operation of said relay switch.

3. A gas burner control system, as in claim 2, in which said means controlled by said pulses includes a circuit including the silicon controlled rectifier.

4. A gas burner control system, as in claim 3, in which said silicon controlled rectifier is provided with an anode, a cathode and a firing electrode; and said pulsing discharge device is connected to the cathode of said silicon controlled rectifier to cause rapid firing and rapid energization of said silicon controlled rectifier for establishing substantially continuous energization of said operating coil for said relay switch.

5. A gas burner control system, as in claim 1, in which ignition means are provided to ignite each pilot gas stream; and said relay switches, when all are operated to their respective first positions, complete a circuit to indicate that all pilot flames are burning effectively; and means are provided to be responsive to said circuit for

operating a main valve to said plurality of gas burners when said pilot flames are all ignited.

6. A gas burner control system, as in claim 5, including a main valve for controlling a main gas stream to the several burners; and means responsive to said circuit that indicates all pilot flames are ignited, for controlling the operation of said main valve.

7. A gas burner control system, as in claim 6, including means for de-energizing said ignition means when all the pilot flames are ignited.

8. A gas burner control system, as in claim 1, in which ignition means are provided to ignite each pilot light gas stream, said ignition means comprising an ignition transformer including a primary winding for receiving an AC ignition voltage and a secondary winding, and a plurality of ignition circuits, each connected in parallel with said secondary winding, each of said ignition circuits comprising spaced ignition electrodes and a capacitor and resistor connected in series.

References Cited

UNITED STATES PATENTS

2,127,445	8/1938	Hardgrove	158—28
2,216,534	10/1940	Kirk	158—28
2,410,524	11/1946	Richardson et al.	158—28
3,150,709	9/1964	Bolmgren	158—28
3,266,026	9/1966	Plambeck	158—28 X
3,301,307	1/1967	Nishigaki	158—28
3,318,358	5/1967	Potts	158—125 X
3,238,423	3/1966	Giuffrida	328—6 X
3,348,104	10/1967	Zielinski et al.	317—130

FREDERICK KETTERER, *Primary Examiner.*

U.S. Cl. X.R.

307—252; 317—148.5; 328—6; 340—228.1; 431—70, 15