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Matthews

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[54] **ELECTRONIC PILOT IGNITION AND FLAME DETECTION CIRCUIT**

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[73] Assignee: **Johnson Service Company**, Milwaukee, Wis.

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[52] **U.S. Cl.** **431/46**; 431/51; 431/59; 431/25

[51] **Int. Cl.** **F23q 9/08**

[58] **Field of Search** 431/25, 46, 51, 59

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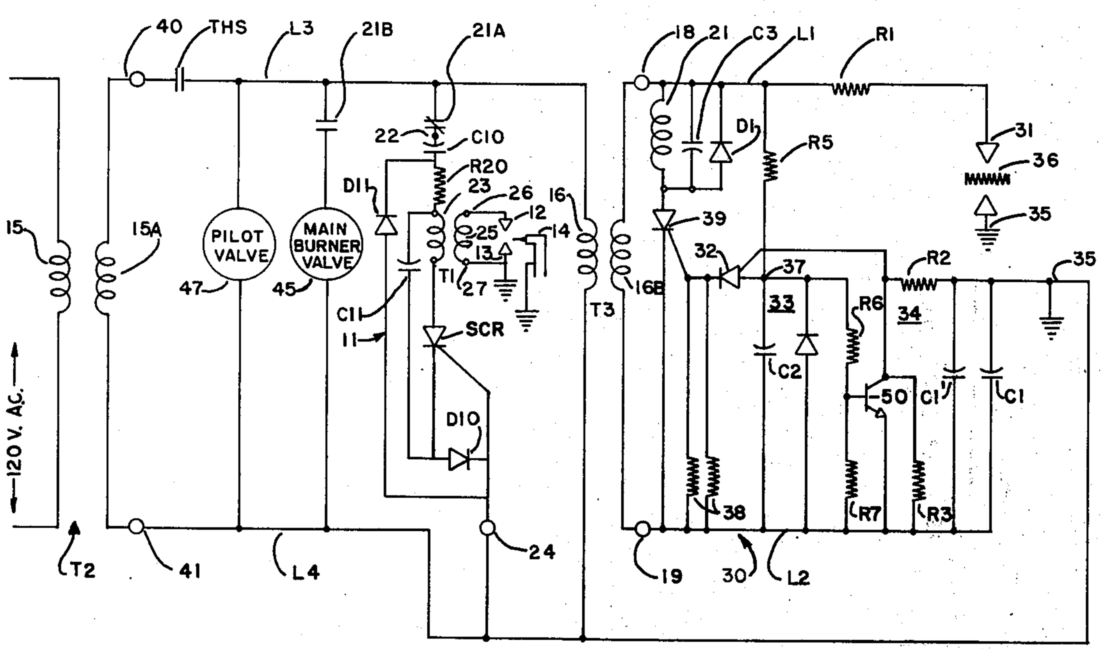
Primary Examiner—Carroll B. Dority, Jr.
Attorney, Agent, or Firm—Johnson, Dienner, Emrich & Wagner

[57] **ABSTRACT**

An electronic pilot ignition and flame detection circuit for use in a fuel ignition system including a spark ignition circuit operable when energized to generate sparks for igniting gas emanating from a pilot source, a switching circuit including a normally de-energized relay and a normally non-conducting silicon controlled rectifier which controls the relay, and a pilot flame sensing circuit operable as a pulse generating circuit for sensing the pilot flame and providing pulses of a first amplitude for enabling the silicon controlled rectifier to effect energization of the relay whenever the pilot gas is ignited to cause the spark ignition circuit to be de-energized and to prepare an energizing path for a main burner gas valve solenoid. The flame sensing circuit provides pulses of a lower amplitude whenever the pilot flame is extinguished to preclude enabling of the silicon controlled rectifier, such that the relay is disabled causing the energizing path for the gas valve solenoid to be interrupted and the spark ignition circuit to be re-energized. Alternatively, the gas valve solenoid may be substituted in the circuit for the relay coil to be controlled directly by the silicon controlled rectifier. In such a case a separate self extinguishing pilot relight circuit controls the pilot ignition.

23 Claims, 4 Drawing Figures



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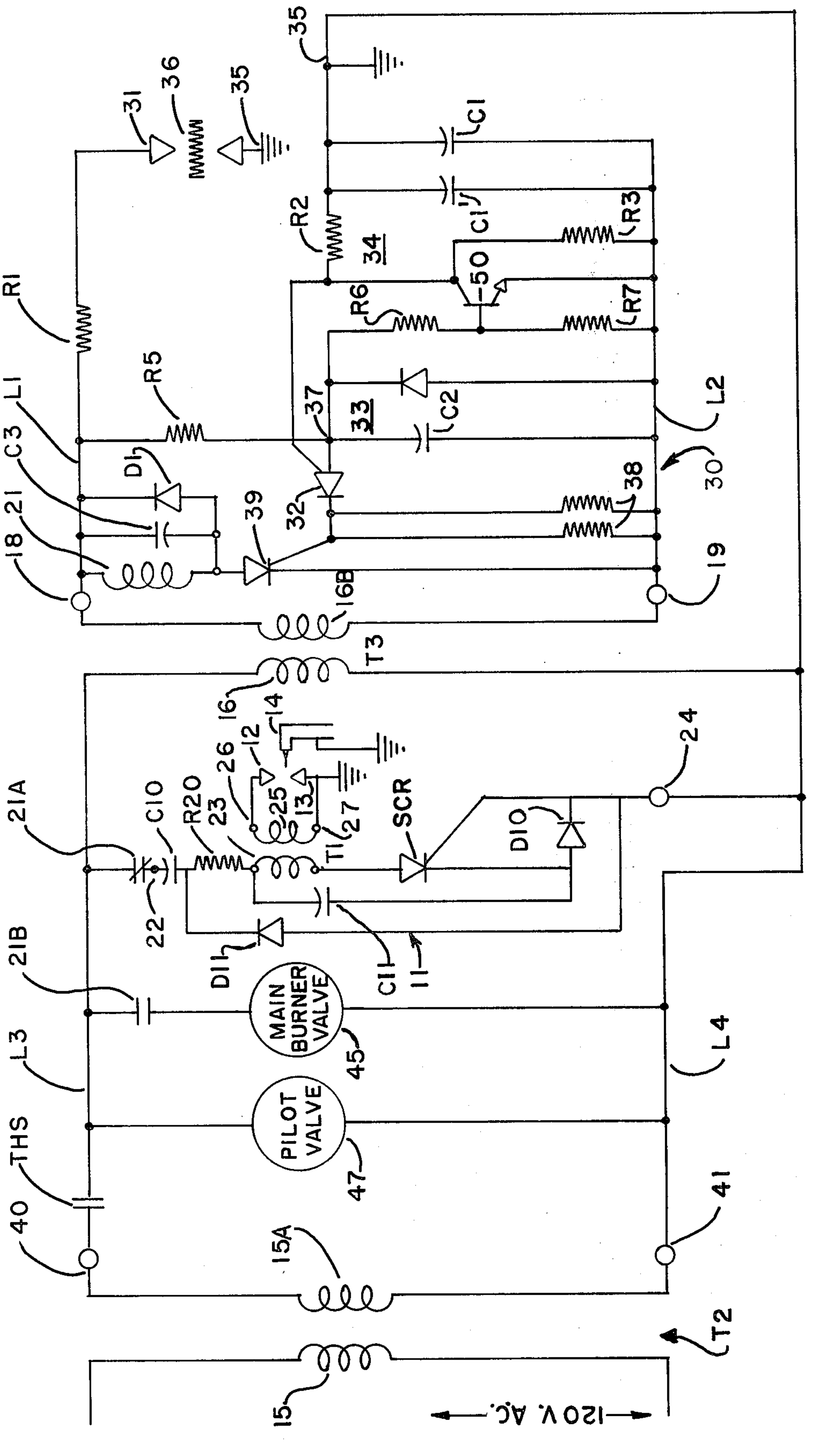
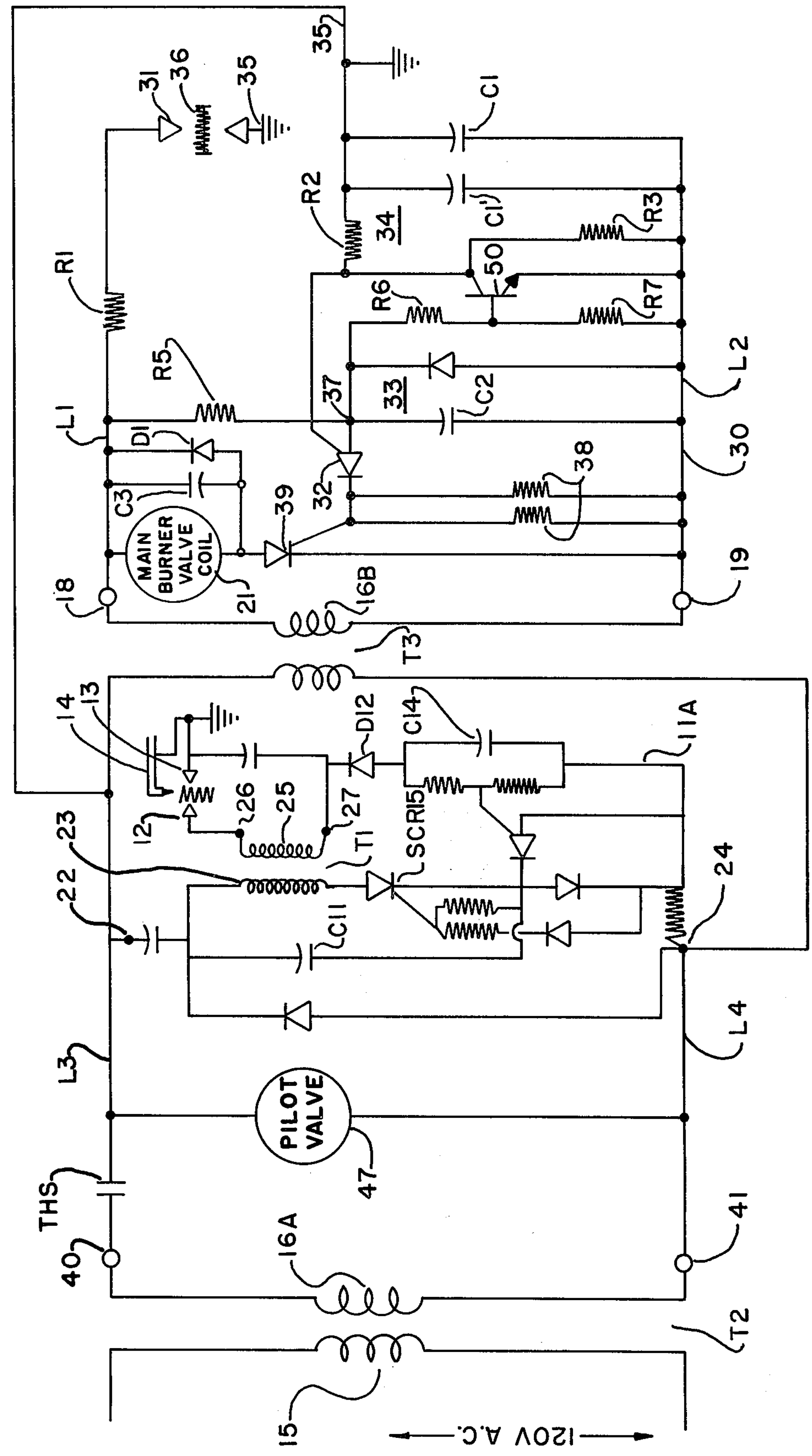


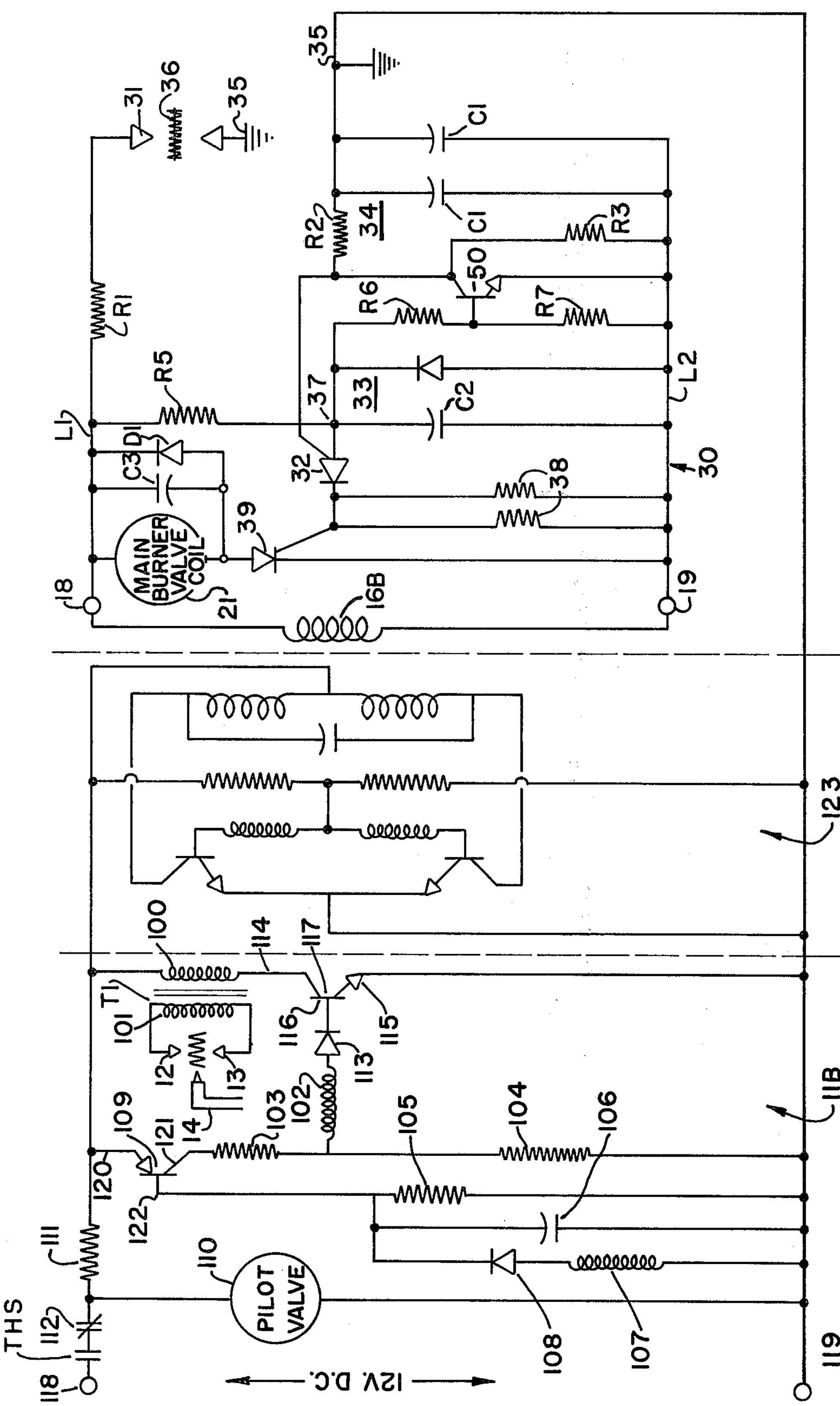
10

FIG-1

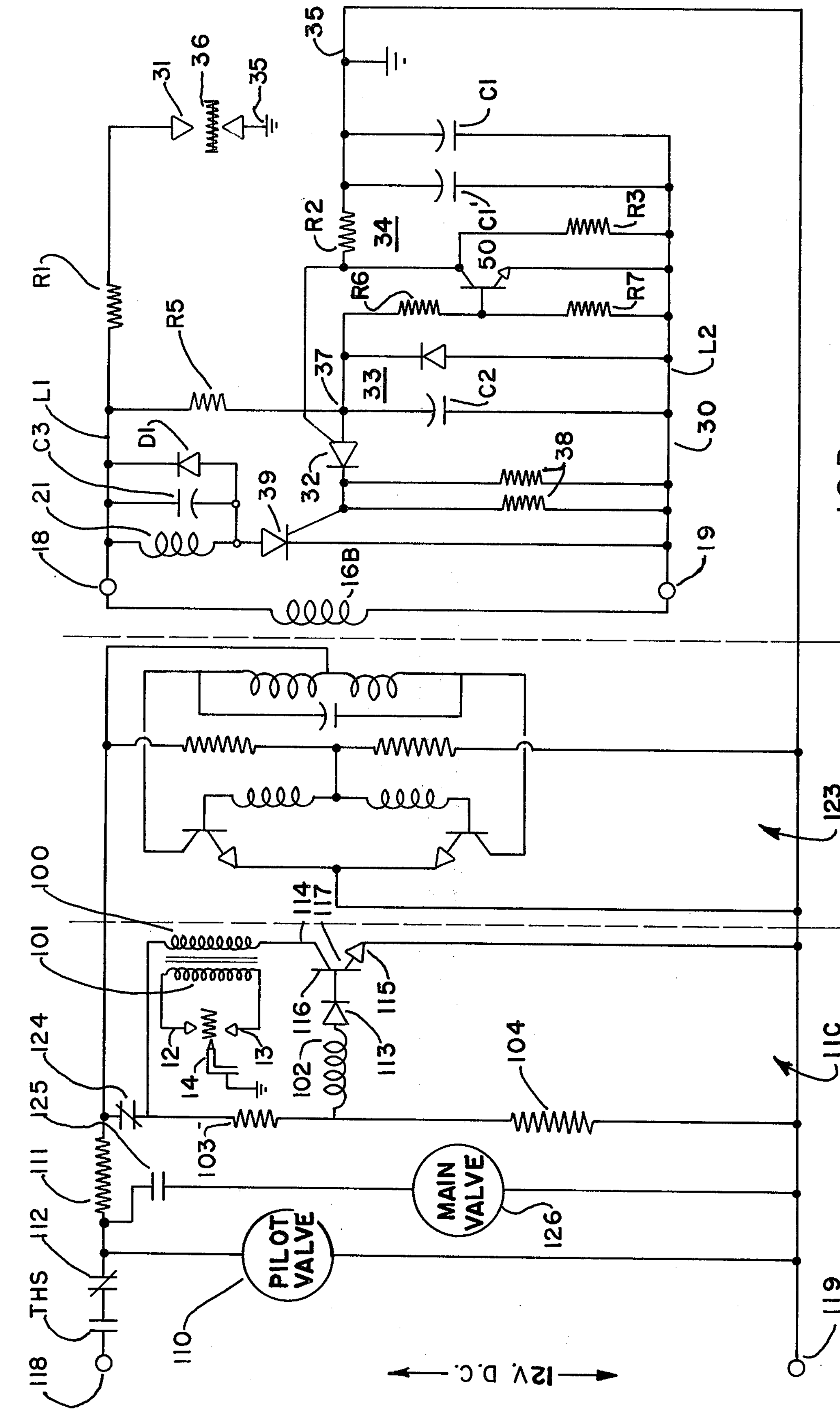

MAIN BURNER VALVE COIL
PILOT VALVE
120V A.C.
R1
R2
R3
R5
R6
R7
C1
C1'
C2
C3
C11
C14
D1
D12
SCR15
L1
L2
L3
L4
T1
T2
T3
THS
11A
12
13
14
15
16A
16B
18
19
21
22
23
24
25
26
27
30
31
32
33
34
35
36
37
38
39
40
41
47
50

10B

FIG.-2


35
36
31
C1
R2
34
R3
50
R6
R7
R1
R5
L1
C3
D1
37
33
C2
L2
32
30
38
39
MAIN BURNER VALVE COIL
18
21
16B
19
123
100
114
117
T1
101
116
115
12
13
113
14
103
102
105
104
106
109
121
11B
120
122
111
110
PILOT VALVE
THS
112
118
12V. D.C.
108
107
119

10C
FIG. 3


PILOT VALVE
MAIN VALVE
12V. D.C.
THS
118
119
110
111
112
124
125
103
104
126
100
101
102
113
114
115
116
117
12
13
14
11C
123
18
19
16B
21
C3
D1
L1
R1
R5
31
36
35
39
32
37
38
30
33
34
L2
C2
R6
R7
R3
50
C1'
C1
R2

10D

FIG. 4

ELECTRONIC PILOT IGNITION AND FLAME DETECTION CIRCUIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to fuel ignition systems, and more particularly to an electronic pilot ignition and flame detection circuit for use in such systems to monitor a pilot flame and effect the de-energization of a gas valve in response to failure of the pilot flame or a component failure in the pilot ignition and flame detection circuit.

2. Description of the Prior Art

Many known fuel ignition systems employ a thermocouple device to monitor a standing pilot flame and a relay controlled by the thermocouple device to effect de-energization of a gas valve, for example, to shut down the system in the event of a pilot flame failure. The thermocouple used to sense the pilot flame in such systems has a response time of approximately 20–45 seconds before the control relay will be de-energized to effect closing of the main gas valve. It is desirable to eliminate a standing pilot flame to conserve gas and at the same time provide a fast response time of the control arrangement therefor.

A fast response time makes possible the elimination of standing pilots, a very desirable function considering the impending gas shortage and the vast amount of gas consumed by standing pilots.

In order to accomplish this and still retain the inherent safety of a pilot ignition of a main burner, it becomes necessary to turn the pilot off when the thermostat is not calling for heat. This means that any time the thermostat calls for heat the pilot burner must be ignited first, second the presence of the pilot flame verified and then the main burner turned on.

The response of this system is so fast that less than 1 second is required for the complete sequence. This means that the circuit can replace a standing pilot system without any detectable difference in performance to the heating system.

SUMMARY OF THE INVENTION

The present invention has provided an electronic pilot ignition and flame detection circuit including an electronic flame sensing circuit which has a much faster response time than prior art systems employing a thermocouple-relay combination. The response time of the electronic flame sensing circuit may, for example, be one second or less thereby eliminating the need for a gas-wasting standing pilot flame without otherwise effecting the heating system.

Moreover, the flame detection circuit of the present invention may include an electronic pilot ignitor controlled by the electronic flame sensing circuit such that the generation of ignition sparks for igniting the pilot is provided automatically whenever loss of pilot flame is detected. Also, the electronic flame detection circuit of the present invention is extremely fail-safe in that any given component failure for an open-circuit condition to a short-circuit condition will not result in an unsafe condition in which the main gas valve may be energized when the pilot flame is not present.

In accordance with an exemplary embodiment of the invention, the electronic pilot ignition and flame sensing circuit includes pilot ignition means operable when energized to generate ignition sparks for igniting pilot gas emanating from a pilot source to establish a pilot flame.

A switching means is normally de-energized when the pilot flame is extinguished to extend a cyclical AC signal supplied to the circuit over input means and a pair of input conductors to the ignition means for energizing the ignition means. The switching means is operable to effect the de-energization of the ignition means and to prepare an energizing path for gas valve means which supplies gas to gas burner apparatus whenever the pilot flame is lit.

A flame sensing means operable as a pulse generating circuit provides pulses at first and second levels for controlling the de-energization and the energization of the switching means as a function of the presence or absence of the pilot flame. The flame sensing means includes a controlled switching device having a pair of control electrodes, a first circuit means including first capacitor means connected between a first one of the control electrodes and one of the input conductors, and second circuit means including second capacitor means connected between the second control electrode and the one input conductor.

The flame sensing means further includes means connected between the input conductors for providing a charging path for the first capacitor means to permit the first capacitor means to charge to a predetermined value during each first half cycle of the AC signal to provide a first potential at said first control electrode, and means for providing a second capacitor means to charge to a predetermined value at the first rate whenever the pilot flame is extinguished and to charge to said predetermined voltage at a faster rate whenever the pilot flame is established to provide a second potential at said second control electrode.

The controlled switching device is rendered conductive at a time during each first half cycle of the AC signal when the potential difference between the first and second control electrodes exceeds a predetermined value, permitting the first capacitor means to discharge over the controlled switching device to effect generation of pulses at the first level for energizing the switching means whenever a pilot flame is established and to effect the generation of pulses at the second level causing de-energization of the switching means whenever the pilot flame is extinguished.

In addition, in the event of a component failure in the pilot ignition and flame detection circuit, such as in the flame sensing means, for example, the controlled switching device will be maintained non-conductive so as to disable switching means and interrupt the energizing path for the main gas valve solenoid.

Thus, the electronic pilot ignition and flame detection circuit of the present invention has three levels of operation. For the condition of a pilot flame failure, the system is operable at a first voltage level in which the pulses provided by the flame sensing circuit are ineffective to enable the switching means and accordingly the energizing path for the main gas valve solenoid is interrupted. Moreover, the pilot ignition means will be energized to effect re-ignition of the pilot flame.

The presence of a pilot flame places the system at a second operating level in which the flame sensing circuit is operable to provide pulses for maintaining the switching means enabled permitting the main gas valve solenoid to be energized. In the case of a component failure, the system is operable at a third level in which the flame sensing circuit is disabled such that the switching means will remain de-energized whether or not the pilot flame is present.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic circuit diagram of a preferred embodiment of the invention operable from an alternating current source and using a relay energized by a silicon controlled rectifier for controlling main burner valve operation;

FIG. **2** is a schematic circuit diagram of another embodiment of the invention, but substituting a solenoid of the main valve for the relay coil of FIG. **1**, thereby controlling the main burner valve directly by the silicon controlled rectifier and utilizing an ignitor circuit which is self-extinguishing;

FIG. **3** is a schematic circuit diagram of still another embodiment of the invention similar to FIG. **2** in that the main valve solenoid is controlled directly by the silicon controlled rectifier but operable from a D.C. source and using an ignitor which is controlled by means of a second coil wound on the solenoid of the main valve; and

FIG. **4** is a schematic circuit diagram of yet another embodiment of the invention, similar to FIG. **1** in that a relay is responsive to a silicon controlled rectifier to control the main valve, but is energized from a D.C. source.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. **1**, there is shown an exemplary embodiment for an electronic pilot ignition and flame detection circuit **10** provided by the present invention. The electronic flame detection circuit **10**, which may be employed in a fuel ignition system, includes an electronic pilot ignition circuit **11** which supplies voltage pulses derived from an AC source to a pair of ignition electrodes **12** and **13** to ignite a gaseous fuel emanating from a pilot source **14** of a gas burner apparatus (not shown).

Energizing power for the flame detection circuit **10**, including the pilot ignition circuit portion **11**, is supplied over an input transformer T2 which has a primary winding **15** connectible to an AC voltage source which, for example, may be a standard 60 Hertz, 120 volt A.C. line voltage source, and a secondary winding **15A**. The input transformer T2 is a step-down transformer which provides approximately 24 volts A.C. between terminals **40** and **41** of winding **15A** when the primary winding **15** of the transformer T2 is connected to a 120 volt A.C. source.

Terminal **40** of the secondary winding **15A** of the input transformer T2 is connected through normally open THS thermostatic contacts over a conductor L3 and normally closed contacts **21A** of a relay **21** to a first terminal **22** of the ignition circuit **11**. Terminal **41** of the secondary winding **15** of the input transformer T2 is connected over a conductor L4 to a second terminal **24** of the ignition circuit **11**.

The ignition circuit **11** is more fully described in United States patent application Ser. No. 307,077 filed Nov. 16, 1972, now U.S. Pat. No. 3,806,305 and has an output winding **25** having a first terminal **26** connected to one of the ignition electrodes **12** and a second terminal **27** connected to the other ignition electrode **13**.

Accordingly, when the thermostat calls for heat THS contacts close and power is applied to the flame detecting circuit **10** over the input transformer T2, AC current flows through the ignition circuit **11** producing voltage pulses across the output winding **25** of the ignition transformer **T1**, which pulses are applied to the electrodes **12** and **13**, producing sparks between the ignition electrodes **12** and **13** for igniting gas emanating from the pilot source **14**. When power is applied to the ignitor circuit **11** from transformer T2 on the first half wave of applied voltage and with terminal **40** assumed positive with respect to **41**, current flows through thermostat contacts THS over line L3 through normally closed relay contacts **21A** through capacitor **C10**, resistor **R20**, capacitor **C11**, diode **D10** to terminal **24**, charging capacitors **C10** and **C11**. On the next half cycle or reverse polarity, current flows from terminal **41**, terminal **24**, diode **D11**, capacitor **C10**, normally closed contacts **21A** and thermostat contacts THS. This circuit acts as a voltage doubler, substantially doubling the charge of capacitor **C11**, which charge is applied across the anode-cathode circuit SCR **T1**. As this voltage doubling effect occurs, the bias across diode **D10** of SCR **T1** is sufficient to cause SCR to fire across its anode-cathode circuit causing capacitor **C11** to discharge through the anode-cathode circuit and through the primary winding **23** of ignition transformer **T1**. This pulses the secondary **25** of the transformer causing a high voltage spark across electrodes **13 - 12** to attempt ignition of the pilot gas coming from pilot burner **14**. This occurs once every cycle of the applied voltage until the pilot gas is ignited.

The flame detection circuit **10** also includes a flame sensing circuit, indicated generally at **30**, which is supplied with approximately 80 volts A.C. through isolating step-up transformer T3. Circuit **30** is operable to provide a pulse output indicative of the presence or absence of the pilot flame. The flame sensing circuit **30** includes a flame sensing electrode **31** and a controlled switching device **32**, embodied as a programmable unijunction transistor (PUT), such as the type 2N6028 commercially available from Motorola. The flame sensing circuit **30** also includes an anode, a control network **33** and a gate control network **34** for the PUT device **32**.

The flame sensing electrode **31** is connected over a resistor R1 to conductor L1 and is positioned in a spaced-relationship with a ground reference point **35** for the electronic flame detection circuit **10**, normally providing a high resistance path between conductor L1 and the reference point **35**. The ground reference point **35** may, for example, be a metallic ground provided by a gas burner apparatus or the pilot source **14**. The flame sensing electrode **31** is located in the region in which the pilot flame is to be produced such that the pilot flame will bridge the gap **36** between the electrode **31** and the reference point **35** thereby lowering the resistance of the current path over the electrode **31** between conductor L1 and the reference point **35** whenever the pilot flame is present.

The gate control network **34** determines the gate potential for the normally non-conducting PUT device **32**. The gate control network includes a capacitor **C1** which is connected between the reference point **35** and conductor L2. Capacitor **C1** will charge at a first rate whenever the pilot flame is unlit. However, whenever the pilot flame bridges the gap **36** between the sensing electrode **31** and the reference point **35**, the resistance of the charging path for capacitor C1 will be lower and capacitor C1 will charge at a faster rate.

The gate control network 34 further includes a resistor R2 which is connected between the reference point 35 and the gate electrode of the PUT device 32, and a resistor R3 which is connected between the gate electrode of the PUT device and conductor L2. Resistors R2 and R3 form a bleeder path for capacitor C1. A second capacitor C1' is connected redundantly in parallel with the capacitor C1 for safety purposes.

In addition, a resistor R3 and a transistor 50 are connected between conductor L2 and the gate electrode of the PUT device 32 forming a clamping circuit to limit the voltage swing at the gate to a predetermined amount.

The potential at the anode electrode of the PUT device 32 is determined by the anode control network 33. The anode control network 33 includes a capacitor C2 connected between the anode electrode of the PUT device 32 and conductor L2. The anode control network 33 further includes a voltage divider network comprised of resistors R5, R6 and R7 which are serially connected between the conductors L1 and L2 with the junction of the resistors R5 and R6 at point 37 being connected to the anode electrode of the PUT device 32 and thus to one side of capacitor C2. Accordingly, a charging path is provided for capacitor C2 from conductor L1 over resistor R5 and capacitor C2 to conductor L2.

The PUT device 32 is normally non-conducting and is rendered conductive whenever the potential at the anode electrode exceeds the potential at the gate electrode by approximately 0.6 volts as determined by the action of the anode control network 33 and the gate control network 34.

Whenever the PUT device 32 is rendered conductive, a discharge path is provided for capacitor C2 over the anode-cathode circuit of the PUT device 32 which supplies pulses provided by the flame sensing circuit 30 to a control electrode of a second controlled switching device 39, embodied as a silicon controlled rectifier, which may be the type C106A manufactured by General Electric Co.

The normally non-conducting silicon controlled rectifier (SCR) 39 has an anode-cathode circuit connected in series with a coil of relay 21 between conductors L1 and L2. The control electrode or gate of the SCR 39 is connected over the resistor 38 to the conductor L2, a redundant resistor 38' being connected in parallel with the resistor 38 for safety purposes.

Relay 21 may comprise a DC relay having a coil resistance of approximately 2.5K ohms so that in the case of a short circuit condition for the SCR 39, AC current flowing through the coil 21 will generate a high impedance and thereby precluding energization of the relay.

Alternatively, relay coil 21 may have a low resistance of approximately 450 ohms and a fuse (not shown) may be connected in the branch of the circuit including the relay. In such case a short circuit condition for the SCR device 39 will cause the current flowing over such branch to change from half wave to full wave, thereby blowing the fuse and preventing operation of the relay 21.

Relay 21, which is normally de-energized, has normally closed contacts 21A which are connected in series with the normally-open THS contacts and conductor L3 between terminal 22 of the ignition circuit 11 and terminal 40 of the secondary winding 15A of the input transformer T2. Relay 21 has a pair of normally open contacts 21B which are also connected in series with normally open thermostat switch contacts THS and a gas valve solenoid 45 which controls the flow of gas to a main gas burner (not shown). A pilot valve 47 is connected in parallel with the contacts 21B and the valve 45 to cause gas to flow from the pilot source 14 when the contacts THS close.

Thus, whenever the flame detection circuit 10 is energized, relay 21 will be de-energized in the absence of a pilot flame, permitting current flow over the normally closed contacts 21A from the input transformer T2 to the ignition circuit 11 to effect the generation of ignition sparks between the ignition electrodes 12 and 13. When the pilot gas is lit, the SCR 39 will be rendered conductive by the pulse output of the flame sensing circuit 30 effecting energization of relay 21. As relay 21 operates, contacts 21A will be opened thereby terminating the generation of ignition sparks at the pilot ignitor 11, and contacts 21B will be closed energizing the main burner gas valve solenoid.

OPERATION OF THE FLAME DETECTION CIRCUIT

For purposes of illustration of operation of the pilot ignition and flame detection circuit 10, it is assumed that the circuit 10 is initially unenergized and that the SCR 39 and the PUT device 32 are cut-off and relay 21 is de-energized. When power is applied to the primary winding 15 of the input transformer T2, 24 volts AC will be produced across conductors L3 and L4, if the THS contacts are closed causing AC current to flow through the ignition circuit 11 and the pilot valve 47 to cause gas to flow from the pilot source 14. Accordingly, voltage pulses will be induced in the output winding 25 of the ignition circuit 11, as was previously described, and applied to the ignition electrodes 12 and 13, generating sparks for igniting the gas emanating from the pilot source 14. When the pilot gas has been ignited, a pilot flame will bridge the gap 36 between the sensing electrode 31 and the reference point 35.

The proper phase relationship between the pilot ignition circuit 11 and flame sensing circuit 30 is obtained by connecting transformer T3 windings such that terminals 19 and 24 are both positive at the same time. This phases the circuit 10 so that the spark is at the ignition electrodes 12 and 13 when the potential at conductor 22 and conductor L1 are both negative and therefore the flame sensing circuit 30 is not sensing.

Accordingly, during a first half cycle of the AC line voltage applied between conductors L1 and L2 when conductor L1 swings positive relative to conductor L2, current will flow from conductor L1 through resistor R1 sensing electrode 31 and the pilot flame to the reference point 35, and over capacitor C1 to conductor L2, permitting capacitor C1 to charge. The voltage across capacitor C1, which is connected over resistor R2 to the gate electrode of the PUT device 32, establishes a gate potential for the PUT device 32.

During the same half cycle, capacitor C2 is charged over a path extending from conductor L1 over resistor R5 and capacitor C2 to conductor L2, establishing a potential at the anode of the PUT device 32.

The values of capacitors C1 and C2 are selected such that some time before the peak of the AC line voltage during the first half cycle of the AC line signal the anode to gate potential of the PUT device **32** will exceed +0.6 volts so that the PUT device will conduct, permitting capacitor C2 to discharge. Also capacitor C2 will have charged to a voltage sufficient to effect the generation of a voltage pulse across the redundant resistors **38** capable of rendering the SCR **39** conductive. The speed of response of the flame sensing circuit **30** is a function of the value of capacitor C1 and resistors R2 and R3 which form the bleeder path for capacitor C1.

When the SCR **39** is rendered conductive, an energizing path is completed from conductors L1 and L2 for relay **21** which then operates opening contacts **21**a to inhibit further sparking between the ignition electrodes **12** and **13** of the ignition circuit **11**, and closing contacts **21**b to energize the main gas valve solenoid **45**.

Accordingly, once the pilot flame has been established and bridges the gap **36** between the sensing electrode **31** and the reference point **35**, the action of the flame sensing circuit **30** will be effective to provide enabling pulses to the gate of the SCR **39** during alternate half cycles of the applied AC line signal. During the next half cycle of the AC line signal, when conductor L2 swings positive relative to conductor L1, the SCR device **39** will be cut off. However, relay **21**, once energized, will be maintained energized by capacitor C3 during the portion of the half cycle of the line voltage in which the SCR **39** is non-conductive. The above conditions will occur every cycle when a pilot flame is present at the sensing electrode **31**.

It should be understood that the only time pulses will be passed to the PUT device **32** and the gate of the SCR **39** is when the voltage at the anode of the PUT device **32** exceeds that of the gate by plus 0.6 volts and the SCR **39** will be enabled only when the capacitor C2 has charged sufficiently to provide the pulse energy required to render the SCR **39** conductive.

For the condition when the pilot flame is extinguished, a high impedance path will be provided over the sensing electrode **31** to reference point **35** such that capacitor C1 will have a longer charging time. Accordingly, as capacitors C1 and C2 are charged, the voltage at the gate of the PUT device **32** will be lower relative to the voltage at the anode since capacitor C2 will be charged at a faster rate over the voltage divider path provided by resistors R5, R6 and R7. Consequently, the anode voltage will exceed the gate voltage early in the half cycle of the AC line signal before capacitor C2 is fully charged. Charge on capacitor C2 is limited by voltage on capacitor C1 which is very low when pilot flame is extinguished and less than that required to trigger the SCR **39** into conduction. Accordingly, whenever the pilot flame is not present, pulses provided by the flame sensing circuit **30** will be ineffective to enable SCR **39** to cause relay **21** to be energized.

When the pilot gas is ignited and relay **21** is operated, the gas valve solenoid **45** will be energized permitting gas to flow to the main gas burner for ignition by the pilot flame. When the main burner flame is lit, a current path is provided through the pilot flame and the main burner flame to the ground reference point **35**. Consequently, the resistance between sensing electrode **31** and reference point **35** will decrease effecting a further increase in the charging current for capacitor C1.

When the main gas burner is lit, the clamping circuit, including the transistor **50** and resistor R3 limits the amplitude of the voltage provided at the gate electrode of the PUT device **32** to a desired operating range which may, for example, be 1 to 4 volts. Accordingly, with the gate electrode being clamped at a predetermined voltage level, the potential at the anode electrode as provided by the charging of capacitor C2 will be capable of exceeding the gate potential by an amount sufficient to trigger the PUT device **32** into conduction and provide pulses for maintaining the relay **21** energized. If desired, the clamping circuit may comprise alternatively a Zener diode in series with a resistance.

The electronic pilot ignition and flame detection circuit **10** is also characterized by a fail safe feature by maintaining the proper magnitude and phase relationship between the voltages that are applied to the gate and the anode of the PUT device **32** in the normal operating mode. The normal operating voltage range is 1 to 4 volts for voltage levels at the anode or gate electrodes of the PUT device **32**. For values above this, as may be caused by a component failure, for example, the anode voltage will not exceed the gate voltage and accordingly the PUT device **32** will not conduct. On the other hand, for voltage values below the operating range, the anode voltage will exceed the gate voltage before the charge on capacitor C2 is sufficient to pulse the gate of the SCR **39**.

Thus the electronic pilot ignitor and flame sensing circuit **10** may be considered as a pulsing system wherein the flame sensing circuit **30** is a pulse generator that stops generating pulses for any component failure or flame-out condition.

The pilot flame which bridges the gap **36** between the sensing electrode **31** and the reference point **35** serves as both a resistance and a rectifier, and the flame sensing circuit **30** utilizes the rectification properties of the flame to maintain the charge on capacitor C1 within a desired operating range. Therefore, any value of resistance between the sensing electrode **31** to the reference point **35** will not result in a condition where the main gas valve is energized when pilot flame is not present. Also, the rectification property of the flame enables the flame sensing circuit to detect the difference between a flame and leakage resistance between the sensing electrode **31** and the reference point **35**.

In one exemplary embodiment, the components of the electronic flame sensing circuit **30** may have the values listed in Table I.

Resistors 38 and 38'	2–220Δohms in parallel
Resistor R1	470K ohms
Resistor R2	2.2 Megohms
Resistor R3	4.7 Megohms
Resistor R7	5.6K ohms
Resistor R5	270K ohms
Resistor R6	18K ohms
Capacitors C1 and C1'	2–0.047 Microfarad in parallel
Capacitor C2	0.47 microfarad
Capacitor C3	22 microfarads
Transistor 50	2N3394

It is to be understood that the operating voltage range which establishes the relationship between the gate and anode voltages, both phase and magnitude, for the PUT device **32** is a matter of choice and that there are a large number of combinations of values for the resistors

R5 and R6, capacitors C1 and C2, resistor R3 and the transistor **50** that can be adjusted to provide satisfactory operation of the circuit.

With reference to FIG. **2,** the electronic pilot ignition and flame detection circuit **10B** is similar in structure and operation to that of the circuit of FIG. **1** with the exception that the solenoid coil **21** of the main burner valve **45** is substituted in the anode circuit of SCR **39** in place of the relay **21** of FIG. **1.** In addition, a different pilot relighter circuit is utilized which is self-extinguishing and which is designated as **11A.** This pilot relighter circuit is more fully described and claimed in copending application of the same assignee and of which Matthews is co-inventor, filed Nov. 16, **1972,** as Ser. No. 307,077, now U.S. Pat. No. 3,806,305.

When thermostat contacts THS are closed to energize the pilot valve to provide gas for ignition, igniter **11A** provides a spark across electrodes **12** and **13** to ignite the pilot gas. As is described in the previously aforementioned, U.S. Pat. No. 3,806,305 a spark is produced once every cycle of applied voltage when the SCR **15** conducts discharging capacitor C11 through the primary **25** of ignition transformer **T1.** The ignitor circuit is self-extinguishing. When its flame sensing portion detects flame, current flows across electrode **13** to pilot **14** and thence to ground, as is described in the copending application. This shorts the gate to cathode electrodes of SCR **15** of the ignitor circuit causing pulsing of the ignition transformer T1 to cease. Should the pilot flame be extinguished, the ignitor circuit automatically reapplies a pulse across electrodes **12, 13.**

When SCR **39** conducts through its anode-cathode circuit as was previously described for FIG. **1,** main valve **45** is energized directly through its solenoid coil **21** in the anode circuit of SCR **39.**

With reference to FIG. **3,** the electronic pilot ignition flame detection circuit **10C** shown is energized from a 12-volt D.C. source (not shown) instead of the 120-volt A.C. source (not shown) of the previous FIGS. **1** and **2.** The circuit **10C,** however, operates substantially the same as that described for FIG. **2** where the solenoid of the main valve **45** is actuated directly by SCR **39.** The circuit operation differs in the following respects: the pilot valve **110** instead of being operated directly through thermostat contacts THS as described for FIG. **2,** operates through normally closed contacts **112** of a warp switch connected in series with the ignitor circuit **11B.** As the ignitor circuit attempts to ignite the pilot gas as was previously described for FIG. **2,** current flows through warp switch heater **111** heating the warp switch, which is of a conventional type. Should the ignitor circuit continue to draw current for more than a predetermined selected time, the warp switch heater **111** is heated sufficiently to energize and open its normally closed contacts **112,** terminating energization of pilot valve **110** and the ignitor **11B.** Pilot valve **110** then closes, stopping the flow of gas to the pilot burner. In this case, the ignitor and pilot valve are in "lockout" position and must be manually reset. This is done by manual actuation of the warp switch into its normal position in which contacts **112** are reclosed, placing ignitor **11B** and pilot valve **110** subject again to energization through thermostat contacts THS.

The circuit shown in FIG. **3** is powered from a 12 volt D.C. source and utilizes a conventional inverter **123** to change the 12 volt D.C. to 110 volt A.C. at secondary **16B** to supply power to the flame detection circuit **30** previously described.

Considering now the operation of the circuit shown in FIG. **3,** a 12 volt D.C. signal applied to terminals **118** and **119** causes current to flow through warp switch contacts **112,** warp switch heater **111** to spark generator **11B** and pilot valve **110** to ignite the pilot burner. Current also flows to inverter circuit **123** to generate 110 volt A.C. at secondary **16B** to supply power to flame detector circuit **30.**

The presence of pilot flame on electrode **31** causes SCR **39** to conduct as previously described, thereby causing the energization of the valve coil **21** on main gas solenoid and causing main burner gas to flow and to become ignited by the pilot. Coil **107,** also located on the main gas valve solenoid, acts like the secondary winding of a transformer, coil **21** being the primary, and supplies a voltage to disable the spark generator **11B** whenever the main gas valve is energized.

Considering the operation of the 12 volt D.C. spark generator, the high voltage transformer T1 has three windings, high voltage secondary **101,** primary winding **100** and feedback winding **102.**

Current flows into emitter of transistor **109** to collector **121** and a voltage divider consisting of resistors **103** and **104.** The voltage at the junction of resistors **103** and **104** is sufficient to cause current to flow through feedback winding **102,** diode **113,** base **116** to emitter **115** of transistor **117** to **12** volt terminal **119.** As a result, transistor **117** conducts and allows current to flow from 12 volt terminal **118** through contacts **112** and heater **111** through high voltage primary winding **100** to induce a high voltage in the secondary winding **101** to produce sparks for ignition at the electrodes.

As the current in the primary winding increases, feedback winding **102,** located on the same magnetic core as primary winding **100,** causes transistor **117** to conduct further until it becomes saturated. At that time, the voltage induced into the feedback winding begins to decrease, thereby decreasing the conductivity of transistor **117** and the current in primary winding **100** decreasing to induce a negative voltage in the feedback winding **102** to cut off the conduction of transistor **117** to complete one cycle of oscillation. The frequency of oscillation utilized is approximately 1000 cycles per second.

After the spark ignites the pilot, sensing probe **31** causes SCR **39** to conduct to energize main gas valve solenoid coil **21** to turn on the main gas.

Energizing coil **21** induces a voltage in secondary winding **107** to increase the voltage on base **122** of transistor **109** sufficiently to cut it off. This removes the bias on SCR **117** and disables the spark generator. If the pilot becomes extinguished for any reason, coil **21** becomes de-energized removing the voltage generated by coil **107** causing transistor **109** to conduct to cause the spark generator to produce sparks for re-ignition.

If for any reason the pilot gas did not ignite, warp switch heater actuates manual resettable contacts **112** to the open condition in approximately two minutes to de-energize the system. Warp switch heater **111** normally does not actuate because one amp of current drawn by the spark circuit is eliminated during a normal operation. So, at start-up, warp switch heater current is approximately 1.3 amps and warp switch heater current during a normal cycle is approximately 0.3 amp.

With reference to FIG. 4, the operation of the circuit shown is the same as for the circuit of FIG. 3 except main valve coil 21 has been replaced by a relay coil 21 with contacts 125 and 124 for controlling main valve operation and ignitor circuit 11C.

Contacts 124 energize the spark generating ignitor circuit 11C which generates sparks in a manner previously described with respect to FIG. 3, except that when pilot gas is ignited, probe 31 causes SCR 39 to conduct to energize relay 21 to open contacts 124 to disable the ignitor circuit 11C and closes contacts 125 to energize the main gas valve 126.

If the pilot flame is extinguished for any reason, probe 31 causes relay coil 21 to de-energize to drop out the gas valve to shut off the main burner gas and to activate the spark generator 11C. If after approximately two minutes the spark generator has not turned off, the warp switch 111 opens its contacts 112 to de-energize the system, as previously described for FIG. 3.

I claim:

1. In an automatic fuel ignition system including a pilot source for establishing a pilot flame and valve means operable when energized to supply a gaseous fuel to burner apparatus, an electronic control circuit for monitoring the pilot flame and controlling the energization of said valve means, said control circuit comprising pilot flame sensing means including sensing electrode means located in the proximity of the pilot source for sensing said pilot flame, and pulse generating means controlled by said pilot flame sensing means to provide pulse outputs of a first amplitude whenever the pilot flame is established and to provide pulse outputs of a second amplitude whenever the pilot flame is extinguished, and switching means responsive to pulses at said first amplitude to effect energization of said valve means, said switching means being disabled whenever pulses at said second amplitude are provided by said pulse generating means to cause deenergization of said valve means to prevent the flow of said gaseous fuel to the burner apparatus whenever the pilot flame is extinguished.

2. An electronic control circuit as set forth in claim 1 wherein said pulse generating means includes a normally non-conducting controlled switching device, first circuit means including capacitor means connected to an input electrode of said controlled switching device and means connected to a source of potential to provide a charging path for said capacitor means, discharge circuit means including said controlled switching device for discharging said capacitor means whenever said controlled switching device is rendered conductive, said pilot flame sensing means including second circuit means connected to a control electrode of said controlled switching device and operable to periodically render said controlled switching device conductive permitting said capacitor means to discharge over said discharge path to provide said pulse outputs.

3. An electronic control circuit as set forth in claim 2 wherein said second circuit means includes further capacitor means chargeable at a first rate whenever the pilot flame is established to provide a potential at said control electrode to render said controlled switching device conductive at a time when said capacitor means of said pulse generating means has charged to a first voltage and chargeable at a second rate whenever the pilot flame is extinguished to provide a potential at said control electrode to render said controlled switching device conductive at a time when said capacitor means of said pulse generating means has charged to a second voltage.

4. An electronic control circuit as set forth in claim 2, wherein said pilot source includes a pilot valve means operable when energized to supply pilot gas to an outlet, and pilot ignition means operable when energized to generate ignition sparks for igniting pilot gas emanating from said outlet to establish a pilot flame, said normally non-conducting controlled switching device being responsive to pulses at said first amplitude to effect the deenergization of said pilot ignition means.

5. An electronic control circuit as set forth in claim 4, wherein said switching means includes a further controlled switching device which is normally disabled and enabled by pulses at said first amplitude to effect energization of said valve means.

6. An electronic control circuit as set forth in claim 11, wherein said valve means includes a solenoid operated valve having a main gas valve coil and a secondary coil, said secondary coil being energized to cause the pilot ignition means to be disabled whenever said main gas valve coil is energized.

7. An electronic control circuit as set forth in claim 5, wherein said switching means further includes normally deenergized relay means, said relay means being energized by said further controlled switching device to control the energization of said gas valve means whenever pulses of said first amplitude are provided by said pulse generating means.

8. An electronic control circuit as set forth in claim 7, wherein said relay means is operable when energized to effect deenergization of said pilot ignition means.

9. An electronic control circuit as set forth in claim 1, further including power means adapted to be coupled to a direct current source of power for supplying a DC power signal to said control circuit, and inverter means responsive to said DC power signal to provide alternating current signals for said control circuit.

10. In an automatic fuel ignition system, pilot ignition means operable when energized to generate ignition sparks for igniting pilot gas emanating from a pilot source to establish a pilot flame, pilot flame monitoring means including flame sensing means having sensing electrode means located adjacent said pilot source for sensing said pilot flame and pulse generating means including a controlled switching device having first and second control electrodes, first capacitor means connected to said first control electrode, second capacitor means connected to said second control electrode, means for permitting said first capacitor means to charge to a predetermined value to provide a first potential at said first control electrode, means permitting said second capacitor means to charge to a predetermined value at a first rate whenever said pilot flame is extinguished and at a second rate whenever said pilot flame is established to provide a second potential at said second control electrode, said controlled switching device being enabled whenever the potential difference between said first and second control electrodes exceeds a predetermined value to permit said first capacitor means to discharge over said controlled switching device to effect the generation of pulse outputs of a first amplitude whenever the pilot flame is established and pulse outputs of a second amplitude whenever the pilot flame is extinguished, switching means responsive to pulses of said first amplitude to de-energize said pilot

ignition means and to prepare an energizing path for gas valve means which supplies gas to gas burner apparatus, said switching means being disabled whenever pulses of said second amplitude are provided by said pulse generating means to interrupt said energizing path for said gas valve means and effect energization of said pilot ignition means whenever said pilot flame is extinguished.

11. An electronic control circuit as set forth in claim **10** wherein said switching means includes normally de-energized relay means having contact means connected in an energizing path for said valve means and a normally disabled controlled switching device connected in series with a coil of said relay means across a source of potential, said controlled switching device of said switching means being enabled responsive to pulses at said first amplitude to effect energization of said relay means to operate said contact means to permit energization of said gas valve means.

12. An electronic circuit as set forth in claim **11** wherein said relay means includes further contact means connected in an energizing circuit for said pilot ignition means and operated whenever said relay means is de-energized to permit energization of said pilot ignition means.

13. In an automatic fuel ignition system including pilot source means for establishing a pilot flame and valve means operable when energized to supply a gaseous fuel to burner apparatus, an electronic control circuit for monitoring the pilot flame and controlling the energization of said valve means said control circuit comprising pilot flame monitoring means having a controlled switching device, first circuit means including capacitor means connected to a source of cyclical AC voltage and to a first control electrode of said controlled switching device to permit said capacitor means to charge during each first half cycle of the AC voltage thereby providing a potential at said first control electrode, second circuit means connected to said AC voltage source and to a second control electrode of said controlled switching device including sensing electrode means located in the proximity of the pilot source means for sensing the pilot flame such that said second circuit means provides a potential at said second control electrode effective to render said controlled switching device conductive at a first time during each first half cycle of the AC voltage whenever the pilot flame is extinguished and to render said controlled switching device conductive at a later time during each first half cycle of the AC voltage whenever the pilot flame is established, output means for providing a discharge path over said controlled switching device for said capacitor means whenever said controlled switching device is rendered conductive to provide a pulse output, and switching means responsive to the pulse output provided by said flame monitoring means whenever the pilot flame is established to prepare an energizing path for said valve means, said switching means being disabled to interrupt said energizing path for said valve means whenever the pilot flame is extinguished, and said controlled switching device being maintained non-conductive in the event of a component failure in said pilot flame monitoring circuit means.

14. An electronic control circuit in a fuel ignition system as set forth in claim **13** wherein said pilot source means includes a pilot source and pilot ignition means operable when energized to generate ignition sparks for igniting pilot gas emanating from said pilot source to establish a pilot flame, said switching means including normally de-energized relay means having contact means for normally connecting said pilot ignition means to said AC voltage source to energize said pilot ignition means whenever the pilot flame is extinguished, said relay means being energized to operate said contact means to thereby disconnect said pilot ignition means from said AC voltage source whenever the pilot flame is established.

15. An electronic control circuit in a fuel ignition system as set forth in claim **14** wherein said switching means further includes a further controlled switching device connected in series with a coil of said relay means to said AC voltage source, said further controlled switching device being normally non-conducting and being rendered conductive responsive to the pulse output of said flame monitoring means to effect energization of said relay means during each first half cycle of said AC voltage whenever the pilot flame is established, said relay means having further contact means connected in an energizing circuit for said valve means and operated whenever said relay means is energized to permit energization of said valve means.

16. An electronic control circuit is a fuel ignition system as set forth in claim **15** wherein said switching means includes means for maintaining said relay means energized during each second half cycle of the AC voltage.

17. An electronic control circuit in a fuel ignition system as set forth in claim **16** wherein said output means of said pilot flame monitoring means includes a pair of resistors connected in parallel between an output electrode of said controlled switching device and a point of reference potential for said AC voltage source.

18. In an automatic fuel ignition system including a pilot source for establishing a pilot flame and valve means operable when energized to supply a gaseous fuel to burner apparatus, an electronic control circuit for monitoring the pilot flame and controlling the energization of said valve means comprising input means, said control circuit including first and second conductor means for supplying a cyclical AC voltage to said control circuit, a normally non-conducting controlled switching device, first circuit means connected between said first and second conductor means, said first circuit means including first capacitor means connected to a first control electrode of said controlled switching device and chargeable during each first half cycle of said AC voltage to provide a potential at said first control electrode, second circuit means including second capacitor means connected between a point of reference potential and said second conductor means, means for connecting a second control electrode of said controlled switching device to said point of reference potential, sensing electrode means, and means for connecting said sensing electrode means to said first conductor means, said sensing electrode means being located in the proximity of the pilot source and positioned in a spaced relationship with said point of reference potential to provide a gap therebetween which is bridged by the pilot flame whenever the pilot flame is established such that a charging path for said second capacitor means is provided between said first and second conductor means over said gap to permit said second capacitor means to charge at a first rate whenever the pilot flame is extinguished to thereby provide a potential at said second control electrode and to permit said second capacitor means to charge at a faster rate whenever the pilot flame is established and bridges said gap to thereby provide a potential at said second control electrode, said controlled switching device being rendered conductive whenever the potential difference between said first and second control electrodes exceeds a predetermined amount such that said controlled switching device is rendered conductive at a first time during each first half cycle of the AC voltage whenever the pilot flame is extinguished and at a later time during each first half cycle of the AC voltage whenever the pilot flame is established, output means for permitting said first capacitor means to discharge over said controlled switching device whenever said controlled switching device is rendered conductive to effect the generation of a pulse output, and switching means responsive to the pulse output provided over said output means whenever the pilot flame is established to prepare an energizing path for said valve means, said switching means being disabled to interrupt said energizing path for said valve means whenever the pilot flame is extinguished.

19. An electronic control circuit as set forth in claim **18** wherein said first circuit means includes means for limiting the potential at said first control electrode of said controlled switching device to a predetermined value.

20. An electronic control circuit as set forth in claim **18** wherein said second circuit means includes means connected between said second controlled switching device and said second conductor means for limiting the potential at said second control electrode.

21. An electronic control circuit as set forth in claim **18** wherein said switching means comprises normally de-energized relay means having an energizing coil and contact means connected in the energizing path for said valve means and a further normally non-conductive controlled switching device connected in series with said coil between said first and second conductor means, said further controlled switching device being rendered conductive by the pulse output provided over said output means during each first half cycle of the AC voltage whenever the pilot flame is established to effect energization of said relay means to operate said contact means.

22. An electronic control circuit as set forth in claim **19** wherein said further controlled switching device is rendered non-conductive during each second half cycle of the AC voltage and said switching means further includes means for maintaining said relay means energized during the second half cycle of the AC voltage.

23. An electronic control circuit as set forth in claim **3** wherein said controlled switching device is maintained non-conductive in the event of a component failure in said pilot flame monitoring means.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,902,839
DATED : September 2, 1975
INVENTOR(S) : Russell B. Matthews

It is certified that error appears in the above–identified patent and that said Letters Patent are hereby corrected as shown below:

Column 14, line 41, after "valve means" insert

-- , said control circuit --;

line 42, cancel "said control circuit".

Signed and Sealed this

seventeenth Day of *February 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks