# United States Patent [19]

**Miles**

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[54] **FLAME RESPONSIVE CONTROL CIRCUIT**


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[58] **Field of Search** .......... 431/24, 25, 68, 69, 431/70, 71, 72, 73, 74, 75, 76, 77, 78, 79



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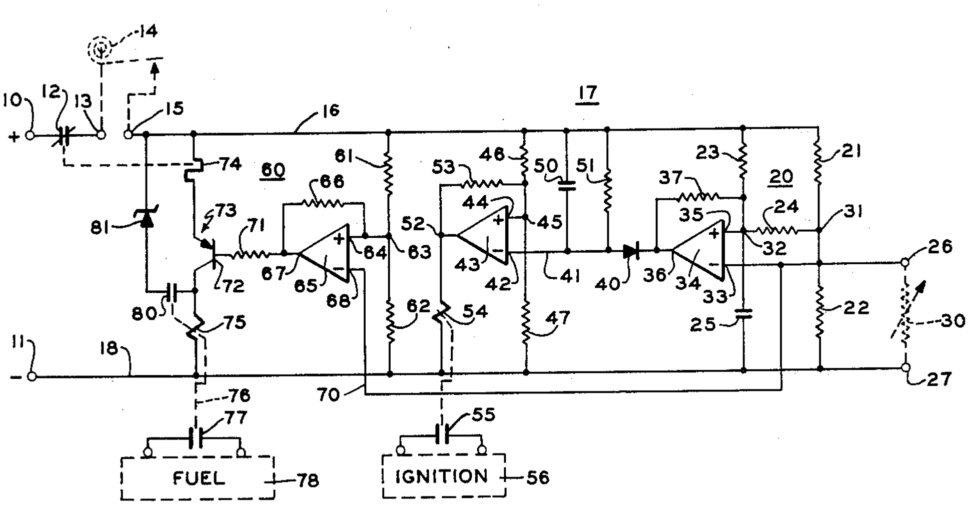
[57] **ABSTRACT**


A flame responsive control circuit means has been disclosed which responds to the flame in a burner. The response is to the sudden rate of change of the resistance or impedance of a photocell upon the loss of flame. The two embodiments disclosed both utilize a rate of change sensing means to determine that a loss of flame has occurred. If a loss occurs, ignition is reinstituted immediately and the system either operates normally or locks itself out in a safety shut down.


**14 Claims, 2 Drawing Figures**



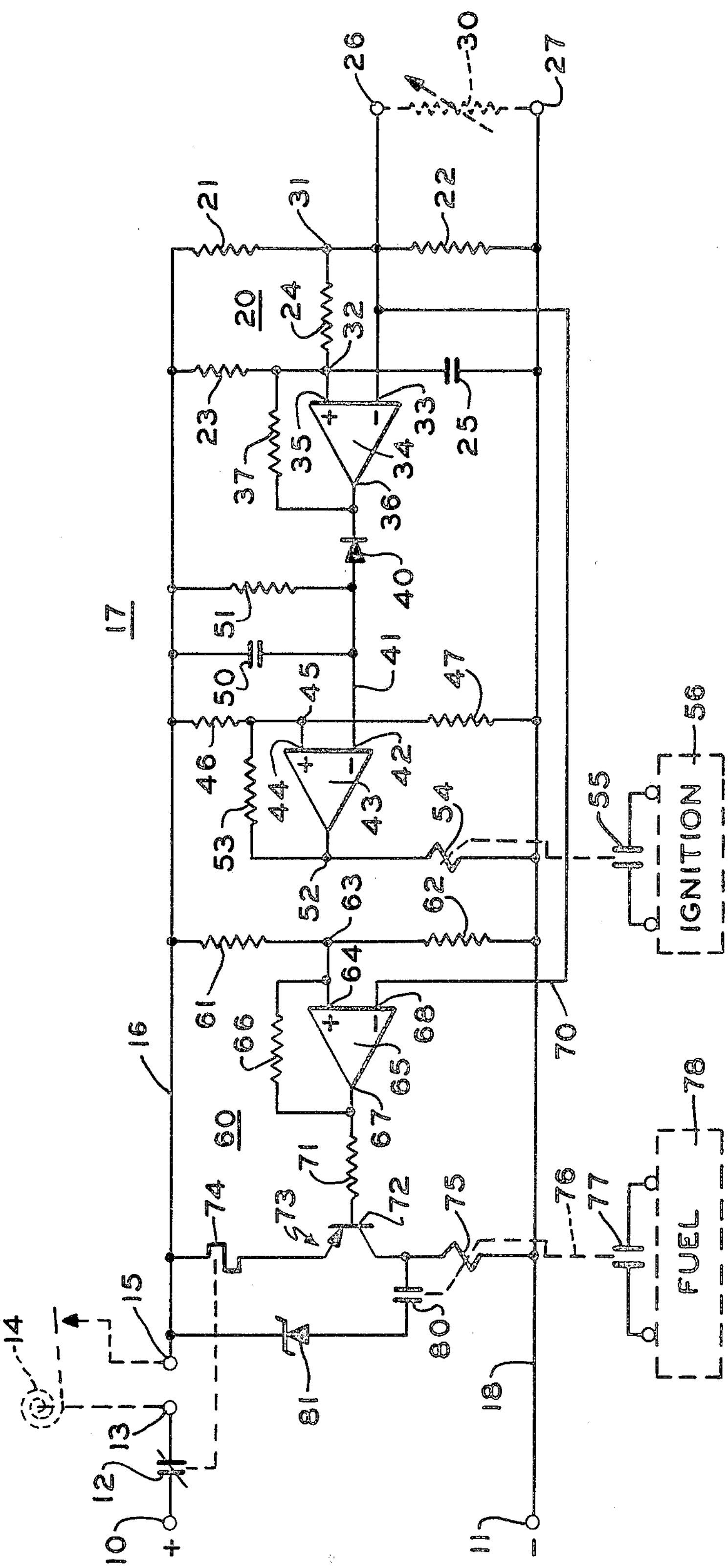



FIG. 1

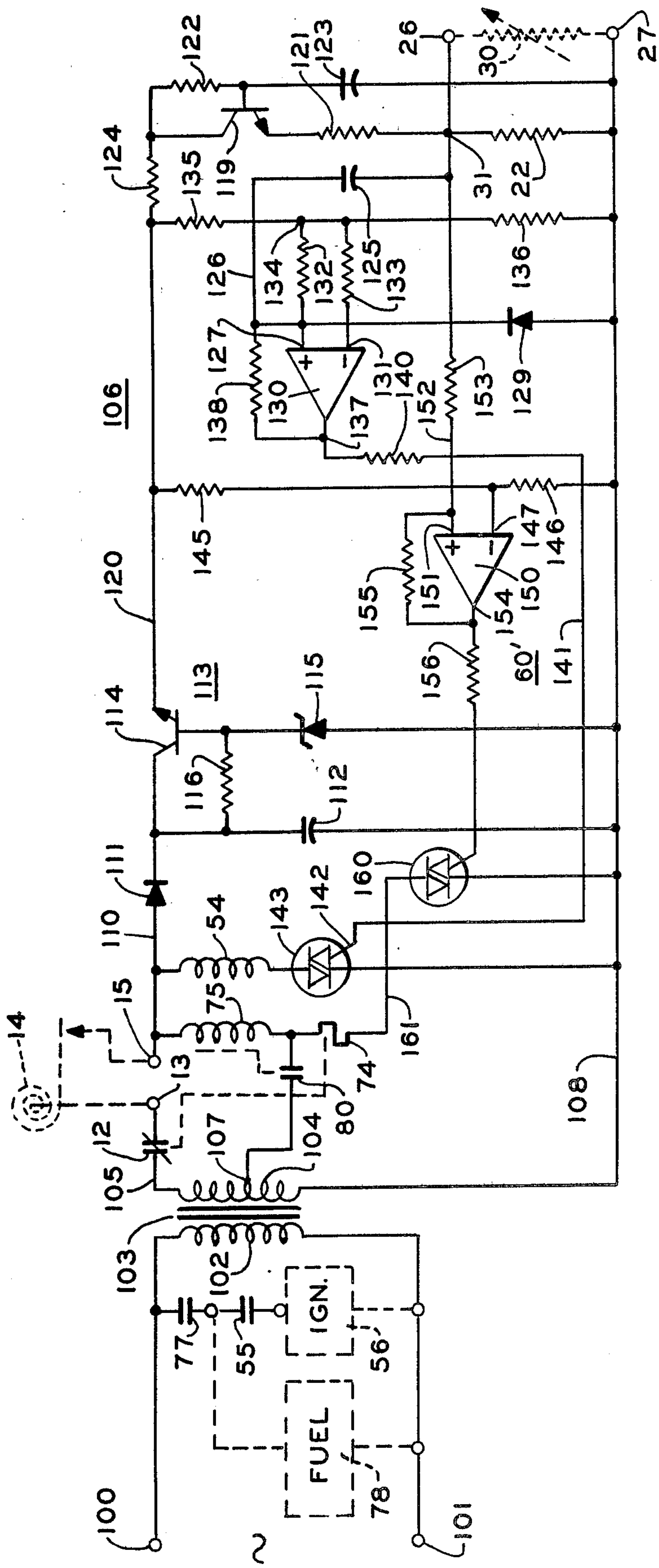



FIG. 2

# FLAME RESPONSIVE CONTROL CIRCUIT

## BACKGROUND OF THE INVENTION

In recent years the method or mode of operating fuel burners has been altered because of the escalating cost of fuel. Until recent years, fuel burners, particularly oil burners, were operated with an intermittent source of ignition, a source of combustion air, and the continuous monitoring of a flame by a sensor. The sensor normally was a cadmium sulfide type of cell. The control devices themselves generally were large and utilized electromechanical components.

In the older types of fuel burners or oil burners, the operation of the ignition source occurred whenever fuel was introduced into the combustion chamber. This type of operation was generally considered as quite safe as there was little chance of the flame going out and there being no source of ignition to reignite the fuel. Also, there was little or no problem with the photocell or sensor being fooled by a hot refractory wall of the oil burner. The overall monitoring of the operation of the system relied both on the operation of the photocell and on a safety switch which ultimately would remove the power to the source of oil and ignition in the event of the loss of a flame. The loss of a flame was normally sensed by the photocell and even though the photocell had a relatively slow response time, the source of ignition was still "on" to prevent any build up of oil.

In order to accomodate for the higher operating costs, fuel burners of the oil burner type are now more commonly operated with an interrupted source of ignition. The quality of the fuel being used now varies considerably, as opposed to a more uniform quality of fuel that was available a number of years ago. This variation in fuel quality and the interrupted operation of an ignition source provides a potential for the loss of flame which is less stable under present operating conditions than under the older operating conditions. In the event of the loss of a flame when the ignition source has been turned "off", the photocell requires a short period of response time. This response time can be extended or exaggerated by a hot refractory wall of the burner. During such a loss of flame when no ignition source is present and with a hot refractory wall present, the oil burner might introduce oil that was not properly ignited and create an unsafe condition before a safety switch caused the shut down of the burner. In order to overcome this unsafe operating mode for an oil burner, it has become necessary to improve the response time to the photocell that is used to sense the existance of flame.

## SUMMARY OF THE INVENTION

The present invention is directed to a generally solid state oil primary control with an improved response in the event of a loss of flame in the burner. The present invention is a flame responsive control circuit means that is adapted to be connected to a flame responsive cell means such as a cadmium sulfide photocell. The control circuit means is provided with an improved, rapid response to the loss of flame in a burner, such as an oil burner, by responding to the rate of change of the resistance or impedance of the photocell itself. This response to a rate of change allows the flame responsive control circuit means to respond long before the resistance of the cell would reach a level where an absolute potential or reference type of operating circuit would respond.

It has been found in studying the response curve of the flame responsive cell means that as soon as the main flame in a burner is extinguished, the impedance of the cell immediately rises sharply. In order to prevent false flame signal responses, an absolute potential level for operating the flame responsive control circuit has been provided in prior devices at some levels significantly above the immediate reaction of the impedance to a flame out. In burner installations with a high refractory visibility, the change to the absolute control level by the photocell may take a few seconds due to the radiation that the cell receives from the hot refractory prior to the refractory cooling after the loss of flame.

The present invention relies on sensing the sudden rate of change of the resistance or impedance of the photocell to indicate that a flame has been lost. This type of a device is not responsive to the refractory radiation which might otherwise delay the safe shut down of an associated oil burner. In the present invention the loss of a flame is immediately sensed by the flame responsive control circuit means by the use of a rate of change sensing means that immediately responds to the sudden change in the impedance of the photocell when the flame is extinguished. With an immediate response to the loss of flame the source of ignition, which has been operated as an interrupted ignition, can be reinitiated to either re-establish a flame or to maintain ignition until an associated safety switch circuit shuts down the entire device in a safe manner.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic circuit of part of an improved oil burner control or flame responsive control circuit means, and;

FIG. **2** is a schematic circuit of a complete oil burner control circuit using a second embodiment of the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of an improved interrupted ignition flame responsive circuit control means is disclosed in FIG. **1**. The embodiment of FIG. **1** is adapted to be connected to a fuel burner, and more particularly to an oil burner. Portions of a fuel or oil burner have been disclosed but is should be understood that not all of the components that necessarily make up a complete installation have been identified.

A souce of direct current is applied to a pair of terminals **10** and **11** for the control circuit means disclosed in FIG. **1**. The voltage between terminals **10** and **11** would be a form of regulated and filtered direct current. Terminal **10** is connected through a normally closed safety switch contact **12** to a terminal **13**. Terminal **13** is adapted to be connected to a control means such as a thermostat **14** which has its other side connected to a terminal **15**. The closing of the thermostat **14** applies the direct current potential from terminal **13** to the terminal **15** where it is in turn supplied to a common conductor **16** for the flame responsive control circuit means generally disclosed at **17**. The terminal **11** connected to the negative potential of the applied direct current is connected to a conductor **18** which forms a common for the control circuit means **17**.

Connected between the conductor **16** and **18** are a number of components that will now be enumerated. A bridge 20 is made up of a group of resistors 21, 22, 23 and 24 and a capacitor 25. The resistor 22 is connected to a pair of terminals 26 and 27 across which is connected a cell means 30. The cell means 30 is a flame responsive cell means that varies its impedance with its exposure to the light from a flame. Typically the cell means 30 would be a cadmium sulfide cell which changes resistance from a relatively high resistance in a dark ambient to a low resistance of approximately two hundred ohms when viewing a flame. The light resistance of the cell means 30 could rise as high as approximately one thousand ohms in some applications and one thousand ohms generally is considered to be the highest practical application level for a cadmium sulfide cell in a working system. The resistance 22 which parallels the cell means 30 typically would be in the order of two thousand ohms or higher, but its value is variable depending on the type of installation. The value of the resistance 22 must be higher than the resistance of cell means 30 when the cell means 30 is exposed to a flame in a fuel burner.

The resistors 21, 22, and 24 have a common connection or node 31, while the resistors 23 and 24 along with the capacitor 25 have a common connection or node 32. The connection 31 is connected to the inverting terminal 33 of an operational amplifier generally disclosed at 34. The operational amplifier 34 has a non-inverting terminal 35 which is connected to the junction 32. The operational amplifier 34 further has an output 36 and a feed back resistor 37 which is connected between the output 36 and the non-inverting terminal 35 to provide a positive feed back for causing the operational amplifier 34 to act as a switch.

The output 36 of the operational amplifier 34 is connected to a diode 40 which in turn is connected to a conductor 41 that forms an input to an inverting terminal 42 of a further operational amplifier 43. The operational amplifier 43 has a non-inverting terminal 44 that is connected to a junction 45 between a pair of resistors 46 and 47 that form a voltage divider to establish an operating point for the operational amplifier 43. Also connected between the conductor 41 and the conductor 16 is a capacitor 50 and a resistor 51 that will provide a time delay function, as will be explained in connection with the operation of the device. The operational amplifier 43 has an output 52 that is connected through a resistor 53 to the non-inverting terminal 44 of the operational amplifier 43 to again provide a positive feed back to make the operational amplifier 43 a switch.

The output 52 of the operational amplifier 43 is connected to a relay 54 that in turn is connected to the common conductor 18. The operation of the relay 54 operates at least one normally open contact 55 that is used to control an ignition means generally disclosed at 56. The ignition means 56 is, in an oil burner, normally a transformer or a solid state spark generating means. The type of ignition means 56 is not material to the invention but is shown as part of the fuel burner or oil burner means for which the present control circuit means provides an operating control. It is quite clear that whenever the relay 54 is energized by the operational amplifier 43 having a high output voltage that the relay contact 55 closes to energize the ignition means 56.

A fuel control means is generally disclosed at 60 for the present control circuit means 17, and includes a voltage divider network made up of resistor 61 and 62 which have a common junction 63 that is in turn connected to an input 64 of an operational amplifier 65. The non-inverting input 64 is also connected through a resistor 66 to an operational amplifier output 67 to provide a positive feed back so that the operational amplifier 65 is a switch. The operational amplifier 65 further has an inverting input 68 that is connected to a conductor 70 that in turn is connected back to the junction 31 which is common to the resistors 21, 22, and 24 at the terminal 26 of the cell means 30. It is thus apparent that the operational amplifier 65 receives a direct input signal from the cell means 30 and which is not related to the signal that is supplied by the bridge means 20 to the operational amplifier 34 and 43.

The operational amplifier output 67 is connected through a resistor 71 to a base 72 of a transistor generally disclosed at 73. The transistor 73 has its emitter connected through a safety switch heater element 74 to the conductor 16. Its collector is connected through a relay 75 to conductor 18, and the relay further has a linkage 76 to a normally open contact 77 that controls a source of fuel generally disclosed at 78. The source of fuel 78 typically would be an oil valve and a source of burner air driven by a motor. Whenever the contact 77 is closed fuel and air are supplied by the fuel source 78 to function with the ignition means 56 to form a conventional fuel burner or oil burner.

The relay 75 has a further normally open contact 80 that is connected from the collector of the transistor 73 through a zener diode 81 to the conductor 16. The closing of the contact 80 by the relay 75 directly connects the potential on conductor 16 through the zener diode 81 to the relay 75 to latch the relay into an operative state. The reason for this latching arrangement will be described in the subsequent description of the operation of the device.

## OPERATION OF FIG. 1

The normal operation of the flame responsive control circuit means 17 will first be described and then the novel function will be detailed. With the safety switch 12 closed, the closing of the thermostat or control switch 14 applies the direct current potential between the conductors 16 and 18 to energize the entire device. At this particular time the cell means 30 is exposed to a dark burner and has a very high resistance, normally in the many thousands of ohms. The bridge means 20 has potential applied to it immediately and the capacitor 25 is completely discharged. Since the capacitor 25 is discharged there is a very low voltage at the junction 32 and a higher voltage at the junction 31. This difference in voltage is applied to the terminals 33 and 35 and the operational amplifier 34 is switched to a low value thereby pulling the output 36 near to the potential on the conductor 18. This allows current to flow through the resistor 51 and the capacitor 50. The voltage on the conductor 41 is compared at the input to the inverting terminal 42 against and immediately appearing voltage at the junction 45 that is provided by the voltage divider 46 and 47. Since the output 36 of the operational amplifier 34 is near the voltage of the conductor 18, the voltage on the conductor 41 is substantially the negative voltage on conductor 18. The operational amplifier 43 has a relatively high differential voltage applied to it such that the operational amplifier 43 switches its output 52 to the higher voltage on conductor 16. This relatively high voltage causes the relay 54 to immediately pull in and close the contact 55 to initiate the ignition means 56.

At this same time the relatively high voltage appearing at the junction **31** is applied on the conductor **70** to the inverting terminal **68** of the operational amplifier **65**. The relatively high voltage appearing on the inverting terminal **68** causes the operational amplifier output **67** to switch low to approximately the voltage on conductor **18**. This pulls the base **72** of the transistor **73** to a relatively low potential and the transistor **73** is driven into conduction. This immediately draws current through the safety switch heater **74**, the transistor **73**, and the relay **75**. The relay **75** pulls in and closes the contact **77** to energize the fuel means **78** thereby supplying air and oil to the burner. Since the ignition has also been turned "on", the supplying of fuel to the burner should initiate operation of a normal cycle immediately. The operation is completed by the relay **75** closing the contact **80** thereby latching in the relay **75** so that it can only be dropped out by the removal of the potential from the relay **75**. During this time the safety switch heater **74** begins the heating in a normal trial for ignition of a burner.

As soon as a flame appears, the cell means **30** drops to a very low resistance and the potential at the junction **32** has risen due to the charging of the capacitor **25**. The relatively low resistance of the cell means **30** combined with the resistance **22** in parallel causes the operational amplifier **34** to now switch its output **36** to a high potential thereby back biasing the diode **40**. Back biasing of the diode **40** allows the capacitor **50** to start to discharge through the resistance **51** to provide a time delay which holds the ignition **56** in an energized state. As soon as the time delay effect of the discharge of capacitor **50** through the resistor **51** is accomplished, the voltage at the inverting terminal **42** no longer controls the operational amplifier **43**, but the voltage from the voltage divider network made up of resistors **46** and **47** cause the non-inverting terminal **44** to cause the operational amplifiers output **51** to switch high. The switching high after the time delay interval causes the contact **55** to open thereby removing the ignition and providing an interrupted ignition system for the oil burner. Operational amplifier **65** has switched high to turn "off" current through transistor **73** and heater element **74**.

The description of operation to this point has been the normal sequence in a burner where no flame out has occurred. If a flame failure occurs in the burner, the cell means **30** will start to rise in resistance value. Its rise initially will be quite sharp and it will gradually taper off in its rise as it continues to respond to the cooling of the hot refractory background of the burner. If the system were allowed to operate strictly on the absolute value of impedance or resistance of the cell means **30**, a substantial time delay could occur from a flame out to the time the ignition is reinstituted. The present invention alleviates and removes that problem. The sudden rise in the resistance of the cell means **30** is immediately coupled from the terminal **26** and junction **31** to the inverting terminal **33** of the operational amplifier **34**. The sudden rate of rise is sensed by the resistance and capacitance configuration of the bridge **20** to cause the operational amplifier **34** to immediately switch low. The inverting terminal **42** of the operational amplifier **43** to be drawn to a low potential immediately thereby causing the operational amplifier **43** to again switch high and re-energize the ignition **56** by pulling in the relay **54**. The rate of change sensing means in the input of the operational amplifier **34** keeps the relay **54** energized for a long enough period of time for either one of two things to happen. Either a flame is re-established and the cell means **30** drops to a low resistance, or the ambient refractory sensed by the cell means **30** allows the cell resistance to rise high enough so that the operational amplifier will keep the ignition **56** energized. If the flame is not re-established, the relatively high absolute value of potential on conductor **70** from the junction **31** causes the operational amplifier **65** to switch its output **67** to a low state thereby causing the transistor **73** to start conducting. If the transistor continues to conduct for any period of time the safety switch heater **74** is activated and opens the contact **12** to drop out the entire system. The safety switch mechanism is a type of mechanism which requires manual reset and advises of a fault which requires human intervention.

It is thus apparent that the present system utilizes a rate of change sensing means which controls the ignition and is combined with an absolute potential level control for the fuel control means **60**. The present system recognizes the loss of flame by the immediate sharp rate of rise of the impedance or resistance of cell means **30** and utilizes this rate of change through the rate of change sensing means to provide for safe reignition and subsequent shut down of the fuel burner.

In FIG. **2** a second embodiment of the present flame responsive control circuit means is disclosed. To the extent possible, similar items will carry the same reference numbers as used in FIG. **1**.

A pair of terminals **100** and **101** are connected to a source of alternating current such as a common line voltage. The terminals **100** and **101** are connected to a primary winding **102** of a transformer **103** which has a tap secondary **104**. Connected across the conductors from the terminals **100** and **101** to the primary winding **102** are relay contacts **77** and **55** which supply power to the ignition means **56** and the fuel and air source means **78**. The relay contacts and the fuel burner or oil burner elements are the same in the embodiment of FIG. **2** as in FIG. **1**.

The secondary tapped winding **104** is connected to a common conductor **105** that in turn is connected through a safety switch contact **12**. The safety switch **12** is connected to a terminal **13** and a control means or a thermostat **14** along with a terminal **15** to supply an energizing source for an interrupted ignition flame responsive control circuit means generally disclosed at **106**. The tapped transformer secondary **104** has a winding connection **107** and a common conductor **108**. The transformer **103** uses a step down winding **104** to provide a low voltage for safety and convenience in operating the present flame responsive control means **106** in a low voltage control mode as is common in the industry.

The flame responsive control means **106** has a pair of terminals **26** and **27** across which is connected a cell means **30**. The cell means **30** is again a variable impedance or resistance and could be a cadmium sulfide cell as in FIG. **1**. Connected across the terminals **26** and **27** is the parallel resistor **22** that again typically would be in the range of two thousand ohms. The overall potential supplied for the flame responsive control means **106** is accomplished by the terminal **15** being connected by a conductor **110** which is connected to a diode **111** and a capacitor **112** which forms a direct current supply for the circuit means **106**. The capacitor **112** is connected to the common conductor **108** in a conventional fashion. A voltage regulating means **113** is disclosed made up of the transistor **114**, a zener diode **115**, and a resistance **116** with the transistor **114** connected so that its acts as a variable impedance to supply a well regulated voltage on a conductor **120** with respect to the conductor **108** for the electronics of the actual control circuit means **106**.

The voltage on conductor **120** is supplied to a transistor **119** which is connected with its collector-emitter circuit through a resistor **121** to the resistor **22**. A further resistor **122** and a capacitor **123** are connected across the source of potential along with a dropping resistor **124** to provide input power for the flame responsive control means **106**. It is understood that when the transistor **119** is conducting that a voltage will appear at the junction **31** which is common to the cell means **30** and the resistor **22**. The junction **31** provides some of the same functions as in FIG. **1** as will be described in connection with the operation of FIG. **2**.

Junction **31** is connected to one side of a capacitor **125** that is in turn connected by a conductor **126** to a non-inverting terminal **127** of an operational amplifier **130**. The operational amplifier **130** has an inverting terminal **131**. The inputs **127** and **131** are connected directly to two resistors **132** and **133** which are of the same numerical value. Both of the resistors **132** and **133** are connected at a common point **134** between two resistors **135** and **136**. When power is supplied to the control circuit means **106** a voltage appearing at the junction **134** is directly applied to both the non-inverting terminal **127** and the inverting terminal **131** of the operational amplifier **130**. A diode **129** clamps the non-inverting terminal **127**. The operational amplifier **130** has an output at **137** which is connected by a resistor **138** back to the non-inverting terminal **127** to form a switch.

The output **137** of the operational amplifier **130** is connected through a resistor **140** to a conductor **141** and then in turn is connected to the gate **142** of a triac **143**. The triac **143** is connected in series with the relay **54**. Relay **54** is the same relay as disclosed in FIG. **1**. It is apparent that whenever the triac **143** conducts that the relay **54** is energized and that it controls the contact **55** to the ignition means **56**.

The system is completed by a fuel control means generally disclosed at **60'**. The fuel control means **60'** is made up by providing a circuit very similar to that disclosed in FIG. **1**. A voltage divider network made up of resistors **145** and **146** provide a common input to the inverting terminal **147** of an operational amplifier **150**. The operational amplifier **150** has a non-inverting terminal **151** that is connected by a conductor **152** and a resistor **153** to the junction **31** to receive the absolute potential that appears at the cell means **30**. The operational amplifier **150** has an output **154** and a feed back resistor **155** to provide for switching of the operational amplifier. The output **154** is connected through a resistor **156** to a second triac **160**. The triac **160** is connected by a conductor **161** to the safety switch heater element **74** and the relay **75** as was disclosed in connection with the burner in FIG. **1**. Again the relay **75** has a normally open contact **80** that is used to latch the relay into an operative state by connecting it to conductor **107** whenever the relay **75** operates.

## OPERATION OF FIG. 2

The operation of the present fuel burner control in many respects is the same as in FIG. **1**. As a result of that only a brief description of the similar functions will be provided. The thermostat **14** closes and supplies power to the conductor **120** of a regulated nature due to the voltage regulating means **113**. At the time that this power supplied the capacitor **123** is discharged and the junction **31** is at a very low potential. With **123** discharged, the base of the transistor **119** is low and the transistor does not conduct until the capacitor **123** takes on a charge. The operation of the circuit utilizing the transistor **119**, the resistor **122**, and capacitor **123**, the resistor **121** forms a circuit that removes the ripple, if any of the supply to the cell means **30**. This circuit is optional in the use of the present invention. The eventual conduction of transistor **119** provides a voltage drop across the resistor **121** and **122** to provide a rising voltage at the junction **31**. This rising voltage reflects the fact that the resistance of a cell means **30** is high in a dark ambient. The rising voltage at junction **31** is coupled through the capacitor **125** to the non-inverting terminal **127** of the operational amplifier **130**. When the system was initially energized, the two equal resistances **132** and **133** provided the same voltage levels at the inverting terminal **131** and the non-inverting terminal **127**. As a result of this, the operational amplifier **130** initially is caused to react to the current that is driven through the capacitor **125** and subsequently through the resistor **132** back to the ground conductor **108**. This generates a more positive potential at the non-inverting terminal **127** than at the inverting terminal **131**, and the operational amplifier **130** switches its output **137** to a high voltage level. This high voltage level is coupled by the conductor **141** to the gate **142** of the triac **143**. The triac **143** then starts to conduct and supplies a current through a relay **54** so that the relay **54** is energized pulling in the contact **55** to energize the ignition means **56**. It can thus be seen that the initial reaction of the present system in driving current through the capacitor **125** and through the resistor **132** causing a positive potential at the non-inverting terminal **27** is to energize the ignition means **56**.

At the same time that this was occurring the absolute potential or voltage at the junction **31** is directly connected by conductor **152** and the resistor **153** to the non-inverting terminal **151** of the operational amplifier **150**. This voltage is sufficient with respect to the voltage on the inverting terminal **147** to cause the output **154** of the operational amplifier **150** to switch high. This causes a potential to be coupled through the resistor **156** to the triac **160** thereby causing the triac **160** to conduct. Current is pulled through the relay coil **75**, the safety switch heater **74**, and the triac **60**. This immediately causes the relay **75** to lock itself in through the contact **80** and to start heating the safety switch heater **74**. The operation of the relay **75** also closes the contact **77** thereby energizing the fuel means **78** to supply fuel along with ignition means **56**. The normal operation would be for the burner to establish a flame and for the cell means **30** to drop sharply in resistance.

The drop in resistance of the cell means **30** causes the charge on the capacitor **125** to flow in a reverse direction from that which it provided initially. The discharge of the capacitor **125** to the lower resistance of the cell means **30** causes a current to flow through the resistor **132** such that a positive potential is generated at the right side of the resistor **132** thereby driving the non-inverting terminal **127** lower than the inverting terminal **131** and causing the operational amplifier **130** to switch its output **137** to a low value. This removes the gating potential from the triac **143** and the relay **54** is dropped out thereby removing the ignition. This is the normal run condition for the device.

Once again the present system is responsive to a rate of change of the cell means **30** in the event of a flame out. In the event that flame is lost the cell means **30** has a sharp initial rise in resistance value. This initial sharp rise is very similar to the rise that occurs at start up and the rise causes the voltage at junction **31** to rise with respect to that which existed when the system was operating with a flame in the burner. The rise in the voltage at junction **31** forces current through the capacitor **125** in an upward direction thereby causing a voltage drop across the resistor **132** so that a more positive potential is applied to the non-inverting terminal **127** than is present at the inverting terminal **131**. The operational amplifier **130** immediately switches its output **137** high and a voltage is again supplied through the resistor **140** to the triac **143** to pull in the ignition relay **54** to energize the ignition means **56**.

If the flame is re-established, the system goes back into normal operation. If the flame is not re-established, the resistance of the cell means **30** continues to rise and the absolute value of the voltage at the junction **31** is conducted directly to the non-inverting input **151** of the operational amplifier **150** which ultimately will turn the triac **160** on so that conduction occurs through the relay **75** (which has been latched in) and the safety switch heater **74**. The heating of the safety switch heater **74** eventually opens the normally closed contact **12** to remove all of the voltage from the flame responsive control circuit means **106** thereby closing the burner down in a safe manner.

Both of the circuits disclosed in FIGS. **1** and **2** rely on a rate of change sensing means to sense the sudden loss of a flame. The two circuits implement the rate of change sensing means in different ways. There are a number of possible ways of further implementing this arrangement and the inventor therefore wishes to be limited in the scope of his invention solely by the scope of the appended claims.

The embodiments of the invention in which an exclusive property or right is claimed are defined as follows:

**1.** A flame responsive control circuit means adapted to be connected to flame responsive cell means to provide an improved, rapid response to the loss of a flame in burner means and to initiate ignition means upon said flame loss, including: rate of change sensing means having input means adapted to be connected to said cell means to respond to a change in the impedance of said cell means; said rate of change sensing means including amplifier means having output means connected to ignition control switch means; said rate of change sensing means being responsive to the application of an energizing potential to said control circuit means to cause said control circuit means and said ignition control switch means to initiate the operation of said ignition means; said rate of change sensing means further responsive to a rate of change in the impedance of said flame responsive cell means to also initiate said ignition means upon said cell means being first exposed to a flame and subsequently changing impedance rapidly due to the loss of said flame; and fuel control means connected to initiate a supply of fuel to said burner means in response to an absolute potential at said cell means.

**2.** A flame responsive control circuit means as described in claim **1** wherein said fuel control means has output means including a solid state switch, a relay, and a safety switch heater element connected in a series circuit wherein current conduction of said solid state switch energizes said relay and said heater element; and a normally open relay contact operated by said relay to latch said relay into a further circuit upon operation of said relay.

**3.** A flame responsive control circuit means as described in claim **1** wherein said cell mens is paralled by a resistor whose value is higher than the resistance of said cell means when said cell means is exposed to a flame in a fuel burner.

**4.** A flame responsive control circuit means as described in claim **1** wherein said input means for said rate of change sensing means includes said cell means and a capacitor in different legs of a bridge.

**5.** A flame responsive control circuit means as described in claim **4** wherein said amplifier means includes time delay means to delay the de-energization of said ignition means upon said cell means sensing the presence of flame.

**6.** A flame responsive control circuit means as described in claim **5** wherein said ignition control switch means includes a relay having a normally open contact for control of said ignition means.

**7.** A flame responsive control circuit means as described in claim **6** wherein said fuel control means has output means including a solid state switch, a relay, and a safety switch heater element connected in a series circuit wherein current conduction of said solid state switch energizes said relay and said heater element; and a normally open relay contact operated by said relay to latch said relay into a further circuit upon operation of said relay.

**8.** A flame responsive control circuit means as described in claim **7** wherein said cell means is paralleled by a resistor whose value is higher than the resistance of said cell means when said cell means is exposed to a flame in a burner.

**9.** A flame responsive control circuit means as described in claim **8** wherein said cell means is a cadmium sulfide photocell; and said fuel burner means is an oil burner.

**10.** A flame responsive control circuit means as described in claim **1** wherein said input means for said rate of change sensing means includes a coupling capacitor between said cell means and an input for said amplifier means; and said amplifier output means change state in response to a current coupled through said capacitor upon a change in the impedance of said cell means.

**11.** A flame responsive control circuit means as described in claim **10** wherein said ignition control switch means includes a relay having a normally open contact for control of said ignition means.

**12.** A flame responsive control circuit means as described in claim **11** wherein said fuel control means has output means including a solid state switch, a relay, and a safety switch heater element connected in a series circuit wherein current conduction of said solid state switch energizes said relay and said heater element; and a normally open relay contact operated by said relay to latch said relay into a further circuit upon operation of said relay.

**13.** A flame responsive control circuit means as described in claim **12** wherein said cell means is paralled by a resistor by whose value is higher than the resistance of said cell means when said cell means is exposed to a flame in a fuel burner.

**14.** A flame responsive control circuit means as described in claim **13** wherein said cell means is a cadmium sulfide photocell; and said fuel burner means is an oil burner.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

PATENT NO. : 4,235,587

DATED : November 25, 1980

INVENTOR(S) : GREGORY M. MILES

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

Claim 3, line 2, delete "mens" and insert --means--.

Claim 10, line 5, delete "change" and insert --changes--.

**Signed and Sealed this**

*Seventeenth* **Day of** *February 1981*

[SEAL]

*Attest:*

RENE D. TEGTMEYER

*Attesting Officer* *Acting Commissioner of Patents and Trademarks*