Jan. 12, 1971 S. H. MALAVASI 3,554,680
BURNER CONTROL SYSTEM
Filed Dec. 3, 1968 2 Sheets-Sheet 1

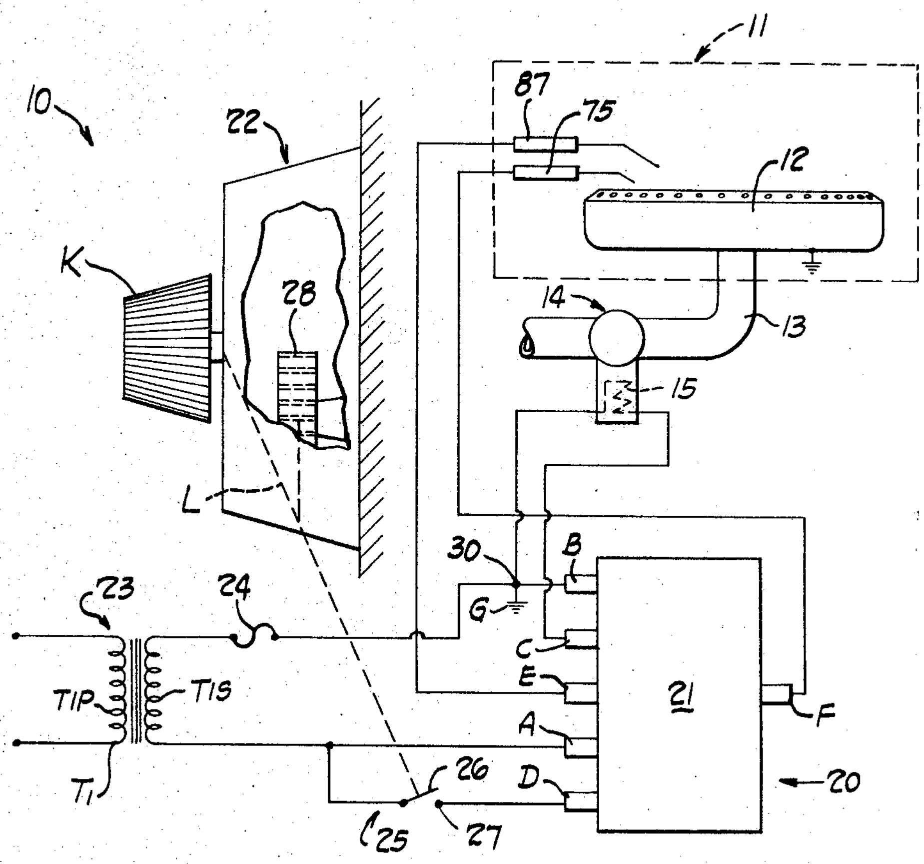

Fig. 1

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Jan. 12, 1971 **S. H. MALAVASI** **3,554,680**

BURNER CONTROL SYSTEM

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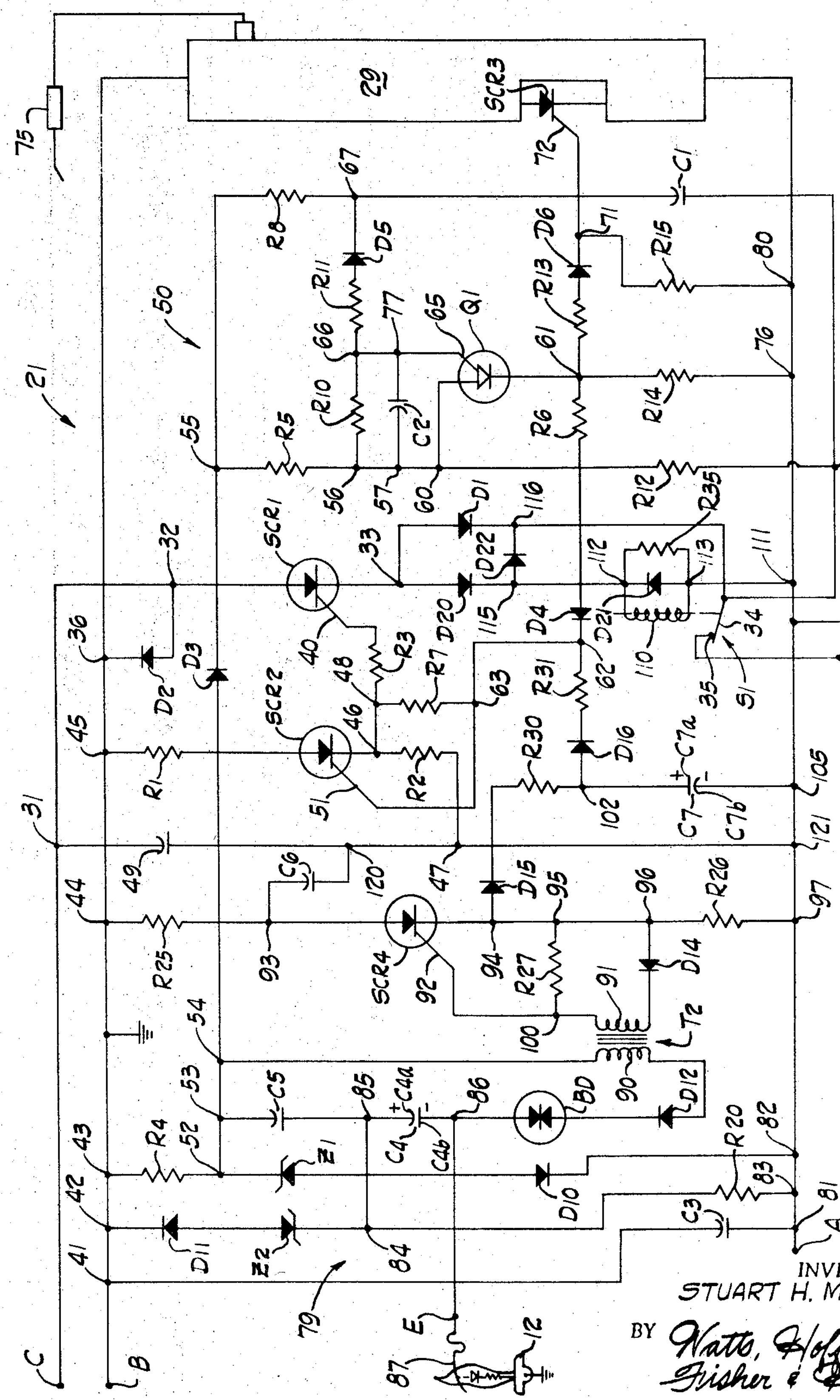

Fig. 2

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3,554,680
BURNER CONTROL SYSTEM

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ABSTRACT OF THE DISCLOSURE

The present invention provides a burner control system for use in a furnace or the like. The system includes switching circuitry controlling energization of a solenoid operated fuel valve, trial circuitry for initially opening the fuel valve and establishing ignition at the burner, and flame sensing circuitry which maintains the fuel valve open in response to the presence of flame at the burner. The system is thermostatically controlled in accordance with the temperature of the heated medium.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a burner control system and more particularly relates to an electrical control system for thermostatically governing a fuel valve for a burner in a furnace or the like, and which operates in a failsafe manner and is self checking for malfunctions.

Theromstatic control systems for mediums heated by burners such as controls for gas fired dryers, oven, furnaces, hot water heaters, and the like, are constructed so that failure of the control results in closing a fuel supply valve. Such design is referred to as "failsafe" and is a necessary feature of any system which is suitable for commercial use, particularly in household applications. Such systems must operate in a substantially failsafe manner in order to insure avoidance of explosion or fire due to accumulated unburned fuel.

With the advent of small electronic components which require relatively little power to operate, it has been possible to provide electrical thermostatic control of fuel valves by flame monitoring systems, as well as to ignite fuel at the burner by electrical ignition systems. The systems must operate in a substantially failsafe manner in order to be approved for sale. These systems must fail safely under various test conditions simulating operating conditions and wherein individual components of the system are shorted out or otherwise caused to malfunction.

The prior art

Certain prior art proposals for electrically controlled fuel valves utilizing electronic circuitry have not provided failsafe operation, the use of semiconductor devices conditons and thus are not commercially feasible. Furthermore while some portions of prior art systems have provided failsafe operation, the use of semiconductor devices to control and energization of solenoid operated fuel valves has been such that a malfunction of the semiconductor controlling the fuel valve can occur without any apparent effect on the system.

Some previously constructed systems have been constructed and arranged so that if fuel valve controlling semiconductor elements are short circuited the system can continue to function in a seemingly normal fashion so long as other failures in the system do not occur. Thus such systems have provided no warning of malfunction of the valve controlling elements and the systems can be operated indefinitely even though the malfunction exists. Continued operation of these systems can result in dangerous conditions particularly when used in connection with a thermostatic control. For example if the gas supply is for any reason terminated when the thermostat is not satisfied, the malfunctioning fuel valve controlling elements would not permit the fuel valve to close and unburned fuel will accumulate about the burner when the fuel supply is reinstated.

Additionally prior art systems utilizing electrical flame detection have not been capable of operating effectively in the presence of a flickering or high impedance flame at the burner. Such systems have terminated fuel flow in the presence of such flames when a malfunction has not occurred.

Furthermore some previously constructed systems have utilized pulsing circuitry for initiating fuel flow and causing ignition of the fuel during an ignition trial period. The trial period is controlled by an R-C circuit associated with a semiconductor element. The previously constructed ignition trial circuits have included transistors for conducting pulses during the trial period; however these devices have not been entirely satisfactory because variations in the strength of the signal pulses over the period occur and the duration of the trial period has been inconsistent.

SUMMARY OF THE INVENTION

The present invention provides a thermostatic control system for a medium heated by a burner which operates in a substantially failsafe manner; permits maintenance of a high impedance of flickering flame at the burner; provides an ignition trial period of consistant length from cycle to cycle; and is self-checking so that any malfunction in the circuit which tends to falsely indicate the presence of flame at the burner is discovered during the cycle of operation of the system during which they occur.

Accordingly, a principal object of the present invention is the provision of a new and improved burner control system utilizing electrical components organized to insure substantially failsafe operation of the system and which is self-checking so that any malfunction of the system tending to falsely indicate the presence of flame at the burner renders the system incapable of operating after the cycle of operation during which the malfuction occurs.

A preferred form of the invention provides a system having ignition trial circuitry, and flame monitoring circuitry associated with a thermostatic control device so that a medium heated by a burner can be maintained at a desired temperature by automatically cycling the burner. The flow of fuel to the burner is automatically terminated when flame is absent from the burner during a heating cycle, or after an unsuccessful trial for ignition.

The electrical control system also includes switching circuitry controlling energization of the valve. The switching circuitry includes a semiconductor switch element rendered conductive to establish an energization circuit for the valve. A thermostatically operated switch is connected into the valve energization circuit to control energization of the fuel valve when the semiconductor switching circuitry is conditioned to permit completion of the energization circuit.

The switching circuitry is coupled to the ignition trial circuit whch operates the switching circuitry to open the fuel valve for a brief interval subsequent to closing of the thermostatic switch. The ignition trial circuitry additionally operates the ignition circuitry so that fuel emitted from the burner during the ignition trial interval is ignited.

The flame monitoring or detecting circuitry renders the switching circuitry capable of maintaining the fuel valve open only in response to the presence of flame at the burner subsequent to the ignition trial. If a flame is not detected at the burner at the end of the ignition trial, or flame is not continuously detected throughout a heating cycle, the flame detecting circuitry causes the switching circuitry to close the fuel valve.

The system is self-checking so that malfunctioning of the switching circuitry disables the system during the cycle of operation when the malfunction occurs. If, because of malfunction, the switching circuitry remains conductive when the thermostatic switch is opened, safety circuitry connected to the switching circuitry causes the fuel control valve to close and prevents further energization of the fuel valve through the thermostatic switch when that switch recloses. Furthermore, any malfunction of the system which falsely indicates the presence of flame at the burner results in operation of the safety circuitry as described in the cycle of operation during which the malfunction occurs.

Other objects and advantages of the present invention will become apparent from the following detailed description thereof made with reference to the accompanying drawings which form a part of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a control system embodying the present invention; and

FIG. 2 is a schematic illustration of a portion of the system of FIG. 1.

DESCRIPTION OF A PREFERRED EMBODIMENT

For purposes of illustration, a portion **10** of a household furnace embodying the present invention is illustrated in FIG. 1. The furnace includes a combustion chamber **11** (illustrated by broken lines) which may be of any suitable construction and which includes an electrically grounded gas burner **12** connected to a fuel supplying system. The fuel supplying system includes a gas pipe **13** and a solenoid operated fuel control valve **14**. The valve **14** is constructed so that the solenoid **15** is energized to open the valve and deenergized to close the valve and preventing fuel from flowing to the burner **12**. In the preferred construction energization of the solenoid **15** fully opens the valve **14** to permit a substantially unthrottled flow of fuel to the burner.

Energization of the solenoid **15** is controlled by a burner control system, generally designated **20**, which includes flame controlling circuitry **21**, a thermostatic control apparatus **22** and a suitable electric power supply **23**. While the invention is described in reference to a household gas fired furnace, it is apparent from the following description that a burner control system embodying the present invention can be utilized in conjunction with burners of various types of combustion equipment.

The power supply **23** includes suitable step-down transformer **T1** having primary winding **T1P** adapted for connection to a 117-volt AC power supply, and a secondary winding **T1S** constructed to provide 24-volt AC power through the flame controlling circuitry **21** and the solenoid **15** through a suitable fuse **24**.

The thermostatic control apparatus **22** is in the form of a wall-type room thermostat having a control knob K which is manually operated to adjust the air temperature. The knob K is linked to a switch **25** including a moving contact arm **26** and a stationary contact **27**. A thermally responsive device **28** including for example, a temperature sensing bimetal is situated in heat exchange relationship with the air in the household. A linkage L connects the moving contact **26** of the switch to the knob K and to the thermally responsive element **28**. The thermally responsive element may be of any suitable construction and accordingly is not described in detail. When the knob K is set to provide a desired temperature, the thermally responsive element opens and closes the switch **25** at the extremes of a relatively narrow temperature range. When the knob K is turned to an "off" position, the switch **25** is positively maintained open and the thermally responsive element is ineffective to close the switch regardless of the temperature of air in the home.

The furnace is "turned on" by rotating the knob K from the off position to a desired air temperature setting. The thermally responsive element closes the contacts of the switch **25** as a result of rotation of the knob if the temperature is below that called for. Closing of the contacts of the switch **25** establishes an energizing circuit for the flame control circuitry **21** from the power supply **23** across the terminals A, B of the circuit **21** through the switch **25**. Energization of the circuitry **21** energizes the solenoid **15** to open the fuel valve **14** and, simultaneously, ignition circuitry **29** (see FIG. 2) is activated so that igniting arcs are struck through the flow of gas from the burner to establish a flame at the burner. When a flame is established at the burner the circuitry **21** detects the presense of the flame and maintains the fuel valve open until the thermostat **22** is satisfied. An ignition trial period is provided so that should the fuel at the burner **12** fail to be ignited the circuitry **21** automatically deenergizes the solenoid **15** to terminate the fuel flow.

The terminal B is connected to the ground G in the illustrated embodiment and the voltage level at the terminal A alternates between voltage levels which are positive and negative with respect to the terminal B. The circuitry may presently be described in reference to "positive" and "negative" half cycles of the power supply and according to the convention used herein a positive half cycle of the power supply is a half cycle during which the terminal B is positive with respect to the terminal A and a negative half cycle is a half cycle during which the terminal B is negative with respect to the terminal A.

SWITCHING CIRCUITRY FOR THE SOLENOID 15

The energization circuit for the solenoid **15** is completed from the power supply through the fuse **24**, a junction **30**, the windings of the solenoid, a terminal C of the circuitry **21**, junctions **31**, **32** (see FIG. 2), the anode and cathode of a silicon controlled rectifier **SCR1**, a junction **33**, a diode **D1**, normally closed contacts **34**, **35** of a switch **S1**, the terminal D the closed contacts of the thermostatic switch **25**, and to the treminal A connected to the power supply. The solenoid **15** is energized by half wave rectified AC power due to the rectifying effects of the **SCR1** and diode **D1**. A "flywheel" diode **D2** is connected in parallel with the solenoid **15** between the junction **32** and a junction **36** connected to the terminal B so that the solenoid **15** remains pulled in during alternate half cycles in which the solenoid **15** is not energized from the power supply. It should be pointed out that the terminals A, B, and C are connected to the power supply at all times and only the terminal D is disconnected from the power supply by opening of the switch **25** when the circuit is not functioning.

The **SCR1** is an element of switching circuitry which controls energization of the solenoid **15** when the thermostatic switch is closed. The **SCR1** is rendered conductive in response to a pulse to its control electrode **40** from a silicon controlled rectifier **SCR2** which is connected into the circuitry to "drive" the **SCR1**. The **SCR2** is rendered conductive to establish a circuit from the terminal B through junctions **41–45**, a resistor **R1**, anode and cathode electrodes of the **SCR2**, a junction **46**, resistor **R2**, and a junction **47** at the voltage level of the terminal A. The control electrode **40** of the **SCR1** is connected to the cathode of the **SCR2** and when the **SCR2** is conductive pulses are conducted to the control electrode **40** through junctions **46**, **48** and a resistor **R3**. Establishment of current flow from the control electrode **40** to the cathode of the **SCR1** renders the **SCR1** conductive to energize the solenoid **15**. A filter capacitor **49** is connected in parallel with the **SCR1** to prevent circuit transients from rendering the **SCR1** conductive when undesired. Terminals A, B are connected at all times to the power source **T15**.

THE IGNITION TRIAL CIRCUITRY

The circuitry **21** includes an ignition trial circuit generally designated at **50** which is effective to render the SCR1 and the SCR2 conductive when the thermostatic switch **25** is intially closed so that the fuel valve **14** is opened to permit flow of fuel to the burner **12** at least during the relatively brief ignition trial interval. The ignition trial circuitry **50** includes a programmable unijunction transistor Q1 which is rendered conductive during positive half cycles of the power supply to provide a pulse to the control electrode **51** of the SCR2 so that the SCR2 is rendered conductive to drive the SCR1 as described. The pulse conducting circuit for the control electrode **51** of the SCR2 is established from the terminal B through junctions **41–43**, a resistor R4, junctions **52–54**, a diode D3, junction **55**, resistor R5, junctions **56, 57, 60**, the anode and cathode electrodes of the transistor Q1, a junction **61**, resistor R6, diode D4, junctions **62, 63** to the control electrode **51** of the SCR2.

A resistor R7 is connected between the junctions **63, 48** across the control and cathode electrodes of the SCR2 to maintain a suitably high voltage level at the control electrode **51** to insure triggering of the SCR. The resistor R7 additionally provides a current path from the anode electrode of the SCR2 through the control electrode **51** and to the terminal A so that rapid voltage rises across the SCR do not render the SCR conductive when undesired.

The transistor Q1 is poled to conduct half wave 60-cycle pulses to the SCR2 so that when the transistor is conductive the SCR2 and the SCR1 conduct during positive half cycles of the power supply. The period during which the ignition trial circuitry produces the noted pulses is determined by an R–C network connected to the control electrode **65** of the transistor Q1 which is connected to a junction **67** in the R–C circuit. The R–C circuit is established from the terminal B through the resistor R4 and diode D3, the junction **55**, a resistor R8, the junction **67**, a capacitor C1 and to the power supply through the switch S1, terminal D and the thermostatic switch **25**. A secondary charging circuit for the capacitor C1 is established from the junction **55**, through the resistor R5, the junction **56**, a resistor R10, a junction **66**, a resistor R11, a diode D5, the junction **67**, the capacitor C1, switch S1, and to the power supply through the terminal D and the thermostatic switch **25**.

The charging circuits establish a voltage level at the junction **67** which is dependant upon the charge condition of the capacitor C1. As the voltage level at the junction **67** increases, the voltage level at the junction **66** increases. Since the junction **66** is connected to the control electrode **65** of the transistor Q1 the voltage level at the junction **66** controls conduction of the transistor during positive half cycles of the power supply. The anode of the transistor Q1, the resistor R5, and a resistor R12, are connected in series between the junction **55** and a junction **70** connected to the power supply through the switch S1, terminal D and thermostat **25**. These resistors form a voltage divider which establishes a voltage level at the junction **60** and anode of the transistor Q1 which is a fixed proportion of the voltage across the junctions **55, 70**.

As previously noted the transistor Q1 is of the type known as a programmable unijunction transistor. This transistor operates in somewhat the same manner as an SCR in that the anode-cathode current does not depend on the relative strength of the gating signal. The transistor Q1 is rendered conductive when the anode voltage level is positive with respect to the voltage level at the control electrode by a predetermined amount. As the voltage level at the control electrode **65** of the transistor Q1 approaches the anode voltage level the transistor is not rendered conductive during positive half cycles. Thus as the voltage levels at the junctions **66, 67** increase the voltage level at the control electrode of the transistor Q1 approaches the anode voltage and the transistor is rendered nonconductive at a predetermined control electrode voltage level.

When the switch **25** is initially closed the capacitor C1 begins to charge during positive half cycles and produces a voltage level at the control electrode **65** which is negative with respect to the voltage level at the anode of the transistor Q1. Accordingly, the transistor Q1 is rendered conductive during positive half cycles. As the capacitor C1 continues to charge the voltage level at the junction **66** increases gradually and when the voltage levels at the junctions **60, 66** are are substantially equal to the transistor Q1 no longer conducts.

The charging circuits are constructed of components which maintain the voltage level at the junction **66** sufficiently negative with respect to the voltage level at the junction **60** that the transistor Q1 is conductive only during a period of approximately four seconds immediately following closing of the thermostatic switch **25**. The diode D3 prevents discharging of the capacitor during negative half cycles of the power supply.

A resistor R14 is connected between the junction **61** and a junction **76** connected to the power supply through the terminal A. The resistor R14 stabilizes the voltage at the junction **60** to prevent erratic ignition trial periods which might otherwise occur as a result of line voltage changes. A filter capacitor C2 is connected between the junction **57**, and a junction **77** at the control electrode **65** to prevent changes in the voltage across the anode and control electrodes of the transistor Q1 in response to transients.

The transistor Q1 conducts to provide pulses to the SCR2 resulting in the fuel valve **14** being opened. Additionally, the transistor Q1 operates the ignition circuitry **29**. More particularly the transistor Q1 operates the ignition circuitry **29**. More particularly the transistor Q1 establishes a pulsing circuit from the junction **61** through a resistor R13, a diode D6, junction **71** and to the control electrode **72** of a silicon controlled rectifier SCR3. The SCR3 is connected into the fuel ignition circuitry and when rendered conductive causes the ignition circuitry to establish electric arcs between a spark electrode **75** and the grounded burner **12** through the fuel flowing from the burner (see FIG. 1). A resistor R15 is connected between the junction **71** and a junction **80** at the voltage of the terminal A to prevent the SCR3 from being turned on at high temperatures, when undesired, due to leakage currents.

After the ignition trial circuitry **50** has operated for approximately 4 seconds the capacitor C1 is charged sufficiently to cause the voltage at the junction **66** to approach the voltage level at the junction **60**, and the transistor Q1 is rendered nonconductive.

THE FLAME DETECTING CIRCUITRY

Assuming that a flame is established at the burner during the ignition trial period, the fuel valve **14** is maintained open by operation of a flame monitoring or detecting circuit generally indicated at **79**. The flame detecting circuitry relies on the rectifying effect of flame on electric current to produce signal pulses by way of a pulse transformer T2 to render the SCR1 and SCR2 conductive and maintain the valve **14** open so long as flame is detected at the burner.

The flame detecting circuitry **79** includes a filter capacitor C3 connected between the terminals B, A through junctions **41, 81**, and full wave voltage regulating circuits. Voltage regulation during positive half cycles of the power supply is provided by the resistor R4, a Zener diode Z1 having its cathode electrode connected to the junction **52**, and a diode D10 having its anode connected to the anode of the Zener diode Z1 and its cathode connected to a junction **82** at the terminal A. The peak voltage applied across the circuitry **21** during positive half cycles of the power supply is determined by the Zener voltage of the diode Z1.

During negative half cycles of the power supply, voltage regulation is provided by a resistor **R20**, Zener diode **Z2**, and a diode **D11** which are serially connected between the junction **42** at the treminal B and a junction **83** connected to the terminal A. The cathode electrode of the Zener diode Z2 is connected to the resistor **R20** through a junction **84** and the anode electrode of the Zener diode Z2 is connected to the anode electrode of the diode **D11**. Thus during negative half cycles of the power supply the peak voltage across the circuitry **21** corresponds to the Zener voltage of the Zener diode Z2.

During negative half cycles of the power supply and when a flame is present at the burner **12**, a charging circuit is established from the junction **83** through the resistor **R20**, the junction **84**, a junction **85**, a capacitor **C4**, a junction **86**, the terminal E, an electrode **87** positioned in the flame and through the flame to the grounded burner **12**. Thus during negative half cycles of the power supply the plate C4*a* of the capacitor C4 is charged to a positive state relative to the plate C4*b*. The capacitor C4 is maintained in its charged state during positive half cycles of the power supply due to the rectifying effect of the flame, i.e., the flame does not conduct during positive half cycles.

The capacitor C4 continues to charge through the flame during negative half cycles of the power supply until the voltage across the capacitor C4 reaches a level which is sufficient to render a breakdown diode BD conductive to establish a circuit through the primary winding **90** of the pulse transformer T2. Generally the capacitor **C4** is fully charged during each negative half cycle. The circuit through the primary **90** is established from the plate C4*a* of the capacitor C4 through a junction **85**, across the capacitor C5, through the junction **53**, **54**, the primary **90**, anode and cathode electrodes of the diode **D12**, and to the plate C4*b* through the breakdown diode BD, and junction **86**. The capacitor C5 provides a low impedance discharge path for the capacitor C4 so that the current pulse through the primary **90** is in the form of a well defined spike.

It should be apparent that the breakdown diode is selected to breakdown and conduct in response to a predetermined voltage across the capacitor C4. The time required for the capacitor C4 to charge sufficiently to render the diode BD conductive depends on the impedance of the flame. If the flame "flickers" or is blown out of contact with the electrode **87**, the flame impedance is high and the capacitor C4 charges relatively slowly requiring a number of half cycles of the power supply to breakdown the diode BD.

The pulse transformer **T1** transmits current pulses to a silicon controlled rectifier SCR4 which is coupled to the SCR2 so that when the SCR4 conducts the SCR2 and the SCR1 are rendered conductive to open the fuel valve. Current in the primary **90** of the transformer T1 induces a current pulse in the secondary winding **91** which is conducted to the control electrode **92** of the SCR4. The pulse renders that SCR conductive to establish a circuit from the junction **44** through a resistor **R25**, a junction **93**, anode and cathode electrodes of the SCR4, junctions **94**–**96**, a resistor **R26**, and to the terminal A through the junction **97**. A resistor **R27** is connected across the control and cathode electrodes of the SCR4 between a junction **100** and the junction **95** to prevent that SCR from being turned on when undesired by transient voltages across the anode and control electrodes.

A diode **D14** is connected between the junction **96** and the secondary winding **91** of the transformer T1 with its cathode electrode connected to the winding **91** to decouple the winding **91** from the SCR4 during collapse of the primary field which would otherwise result in the SCR4 turning off. A filter capacitor C6 is connected between the junction **93** at the anode electrode of the SCR4 and a junction **101** connected to the terminal A. The capacitor C6 prevents rapid voltage rises across the anode and cathode electrodes from rendering the SCR4 conductive when undesired.

The SCR4 conducts to "drive" the SCR2 when the SCR4 conducts. A signal circuit is established from the junction **94** to the control electrode **51** of the SCR2 through a diode **D15**, a resistor **R30**, a junction **102**, a diode **D16**, a resistor **R31**, and the junctions **62**, **63**. The described signal circuit renders the SCR2 conductive which in turn drives the SCR1 to open the valve **14**.

A capacitor C7 is included in the circuitry to increase the sensitivity of the flame detecting circuitry to high impedance flames. The signal circuit just described provides charging current for the capacitor C7 which is connected between the junction **102** and a junction **105** at the voltage of the terminal A. The capacitor C7 has a rather large capacity and the plate C7*a* of the capacitor C7 is maintained positive with respect to the plate C7*b* during operation of the SCR4.

Should the flame established at the burner **12** flicker or otherwise be of relatively high impedance, several negative half cycles of the power supply may be required to produce a pulse in the primary of the transformer T2. In that event the capacitor C7 discharges through the junction **102**, diode **D16**, resistor **R31**, junctions **62**, **63**, and to the control electrode **51** of the SCR2, junction **46**, resistor R2, junction **47** to the negative plate C7*b* of the capacitor through the junction **105**. The resistor R31 is of relatively high impedance compared to the resistor **R30**. Thus the discharge rate of the capacitor C7 is relatively low in comparison to its charging rate. Discharging of the capacitor C7 prefreably occurs over several cycles so that the SCR2 is maintained conductive between low frequency pulses in the transformer T2.

When room air temperature reaches the preselected temperature, the thermostatic switch **25** opens interrupting the energization circuit for the fuel control valve **14** and terminating the flow of fuel to the burner **12**. Opening of the thermostatic switch also resets the ignition trial circuitry for a succeeding heating cycle. The trial circuitry is reset by discharging of the capacitor **C1**. The capacitor C1 is discharged through the junction **67**, the resistor **R8**, junction **55**, the resistor **R5**, junctions **56**, **57**, **60**, the resistor **R12**, the junction **70** and to the capacitor C1. Even though the capacitor C1 discharges, the transistor Q1 is not rendered conductive since thermostatic switch **25** is opened and the voltage levels at its anode and control electrodes are substantially the same. Thus when the contacts of the switch **25** are opened the transistor Q1 is incapable of conducting pulses to the control electrode of the SCR2 and since the flame is not present at the burner **12** the flame detecting circuitry is ineffective to provide operating signals to the SCR2.

In the illustrated embodiment the capacitor C1 discharges relatively slowly because the resistor R8 is large. This prevents excessive accumulations of unburned fuel in the furnace if ignition is unsuccessful due to malfunction and the user of the furnace attempts frequent ignition trials.

When the room air temperature is reduced sufficiently to cause reclosing of the contacts of the switch **25**, the capacitor C1 is again connected across the terminals B, A through the contacts of the switch **25** and the ignition trial circuitry **50** is rendered effective to open the gas valve and provide ignition arcs.

SELF-CHECKING FEATURES OF THE CIRCUITRY

The present invention additionally provides safety circuitry which permits self-checking operation of the burner control circuitry upon each opening of the contacts of the thermostatic switch **25**. Without the safety circuitry, and if the SCR1 should short out, the control circuitry could operate in a seemingly normal fashion for an indefinite period of time. If during this period, and at a time when the contacts of the thermostatic switch 29 were closed, the flow of gas to the furnace would for some reason be briefly interrupted, the fuel valve 14 would be maintained open even in the absence of flame at the burner. In such circumstances a fire or explosion could result.

The self-checking function of the safety circuitry prevents malfunctioning of the SCR1 from going undetected. Furthermore, the safety circuitry prevents opening of the fuel valve in response to any flame simulating failure in the circuitry tending to maintain the valve open when the thermostat is satisfied.

According to the present invention the safety circuitry provides a check on the operation of the SCR1 upon each opening of the contacts of the thermostatic switch 25. In this manner shorting of the SCR1 results in rendering the circuit incapable of energizing the fuel valve in the same cycle of operation of the burner during which the malfunction occurs. Flame simulating malfunctions in the circuitry tending to open the gas valve when the thermostatic switch contacts are opened also renders the circuit incapable of opening the valve.

The safety circuitry includes a diode D20, and a relay coil 110 connected between the junction 33 at the cathode electrode of the SCR1 and a junction 111 connected to the terminal A. In the preferred embodiment the safety circuitry is connected in parallel with the switch contacts 34, 35 of the switch S1 and if the SCR1 is shorted out, opening of the thermostatic switch 25 results in the relay 110 being energized through the SCR1, junction 31, diode D20, a junction 112, the relay coil 110, a junction 113 and to the junction 111 connected to the terminal A. Energization of the relay 110 opens the normally closed contacts 34, 35 and interrupts the energization circuit for the solenoid 15. The solenoid energizing circuit is thereafter maintained open regardless of whether the thermostatic switch 25 is closed.

As has been previously pointed out the terminals A, B and C are always connected across the power supply while the terminal D can be disconnected from the supply by opening of the thermostatic switch 25. Hence even when the switch 25 is open the power supply voltage is impressed across the terminals C, A and B, A, respectively.

Normally, of course, current does not flow between these terminals when the thermostatic switch is open. However should a component or components of the system malfunction in a manner simulating the presence of flame, the connection of the terminals A, B, C across the power supply will cause such a flame simulating malfunction to occur. For this reason any flame simulating failure in the circuitry will falsely indicate the presence of flame at the burner at the first opening of the contacts of the switch 25 after the failure occurs. Likewise, if the SCR1 or the SCR2 should become short circuited, conduction of the shorted SCR will be maintained after the switch 25 opens. For this reason the relay 110 is continuously energized when such malfunctions occur and when the switch 25 is opened thereby insuring that the solenoid valve remains closed.

One mode of malfunction of an SCR is known as a gate-anode semishort. When such a malfunction occurs the impedance of the relay 110 could cause chattering of the contacts 34, 35. A resistor R35 is connected between the juntcions 112, 113 in parallel with the coil 110 so that the impedance across the junctions 112, 113 is low enough to prevent relay chattering.

The resistance of the relay coil 110 and parallel resistor R35 is enough so that when the SCR1 is shorted as described most of the voltage falls across the relay and resistor and the solenoid 15 cannot be pulled in. The diode D20 prevents energization of the solenoid during negative half cycles of the power supply if the malfunction of the SCR1 is such that full wave current could otherwise be conducted. A diode D21 is connected in parallel with the coil 110 to maintain the contacts 34, 35 open during negative half cycles of the power supply.

When the room air temperature is reduced to a level sufficient to reclose the thermostatic switch 25, the relay coil 110 is maintained energized because the contacts 34, 35 of the switch S1 are open and prevent establishment of an energizing circuit for the solenoid through the thermostatic switch. Thus, the fuel supply valve cannot be reopened regardless of the condition of the contacts of the thermostatic switch. Furthermore, the danger of fire or explosion resulting from unburned gas accumulating in the furnace is eliminated.

In certain constructions of the control circuitry it might be possible for the terminal A to become disconnected from the power supply. In such a case the terminal D could remain connected to the power supply (FIG. 1) and if the thermostatic switch 25 were closed the fuel valve 14 could be energized through the SCR1, switch S1 and the thermostatic switch. Furthermore in such circumstances the relay coil 110 could not be energized in response to conduction of the SCR1 in the absence of a flame.

Under such circumstances the filter capacitors 49 or C6 would render the SCR1 conductive during positive half cycles of the power supply, thereby opening the gas valve and admitting unburned gas into the furnace. A diode D22 connected between the junctions 115, 116 at the cathode electrodes of the diodes D1, D20, connect the capacitors 49, C6 to the terminal D to prevent the SCR1 from conducting as described. The connection of the filter capacitors to the terminal D is traced from the capacitors to the junction 120, through the junctions 47, 121, 105, 111, 113, the diode D21, junctions 112, 115, the diode D22, the junction 116 and to the terminal D through the switches S1, 25. The path through the diodes D21, D22 has a low impedance and thus triggering of the SCR1 is insured against.

Although the invention has been described in its preferred forms with a certain degree of particularity, it is understood that the present disclosure of the preferred forms has been made only by way of example and that numerous changes in the details of the constructions and the combinations and arrangements of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. A system for controlling the temperature of a medium heated by a fuel burner including:
(a) an electric power supply;
(b) an electrically energized fuel control valve which is energizable to an open position wherein fuel flows to said burner and a deenergized closed position;
(c) circuitry for energizing said valve comprising;
(d) switching circuitry including a switching element connected in series with said valve;
(e) a thermostatic switch comprising contacts having a closed position wherein an energization circuit is establishable through said contacts, valve and switching element, and an open position wherein said energization circuit is opened; and,
(f) means responsive to conduction of said switching element when said contacts of said thermostatic switch are open for preventing completion of said valve energizing circuitry upon closing of said contacts of said thermostatic switch.

2. A system as defined in claim 1 and further including flame detecting circuitry coupled to said switching circuitry and operative to maintain said switching element conducting when flame is present at said burner and said thermostatic switch is closed.

3. A system as defined in claim 2 and further including ignition trial circuitry coupled to said switching circuit and operable to render said switching element conductive for a brief interval subsequent to connection of said valve

energization circuit across said power supply through said thermostatic switch.

4. A system as defined in claim 3 wherein said ignition trial circuitry is ineffective to render said switching element conductive at the end of said interval, and further including enabling circuitry operative to render said ignition trial circuitry effective after a second interval subsequent to said first interval.

5. A system as defined in claim 4 and further wherein said ignition trial circuitry includes a semiconductor switch having a control electrode connected to a point in a charging circuit and an output circuit coupled to said switching circuitry, said charging circuit producng a first range of a voltage at said point for maintaining said semiconductor in a conductive state during said interval and a second range of voltages at said point for preventing conduction of said semiconductor after said interval.

6. A system as defined in claim 5 wherein said enabling circuitry includes a discharge circuit for changing the range of voltages at said point to said first range of said second range when said thermostatic switch is open.

7. A system as defined in claim 2 wherein said flame detecting circuitry provides periodic flame signals to said switching circuitry in the presence of flame at said burner and further including a charging circuit coupled to said detecting circuit and to said switching circuitry, said charging circuitry operable to condition said swtching circuitry to maintain said valve open over a range of frequency of said flame signals.

8. A system as defined in claim 1 wherein said means includes a normally deenergized circuit element connected in circuit with said switching circuitry, said circuit element energized in response to conduction of said switching element when said thermostat contacts open, and further including a second switching element operated from said circuit element to prevent energization of said valve when said thermostat contacts reclose.

9. A system as defined in claim 8 wherein said circuit element comprises a relay and said second switching element comprises relay contacts activated by said relay, said relay contacts connected in series with said thermostat contacts and said first switching element and having an open position preventing conduction of said first switching element through said thermostat contacts.

10. A system as defined in claim 9 wherein said relay contacts are opened to establish a circuit through said valve, said first switching element and said relay, said relay maintained energized when said first switching element conducts after said thermostatic contacts open, said relay having an impedance sufficiently large to prevent opening of said valve.

11. A flame monitoring system comprising:

(a) an electrical power supply;

(b) an electrically energizable fuel control valve including an electrically operated actuator which is energized to open said valve and deenergized to close said valve;

(c) switching circuitry having a conductive and a nonconductive condition, said switching circuitry establishing an energizing circuit for said actuator when in one of said conditions and preventing energization of said actuator when in its other condition;

(d) a condition responsive switch in said energizing circuit having a nonconducting condition to interrupt said circuit and a conducting condition to permit energization of said actuator;

(e) flame responsive signal producing circuitry for operating said switching circuitry to said one condition when a flame is established; and,

(f) safety circuitry operative to deenergize said actuator and close said valve in response to any flame simulating malfunction in the system tending to maintain said switching circuitry in said one condition when said condition responsive switch becomes nonconducting;

(g) said safety circuitry maintaining said actuator deenergized thereafter regardless of the condition of the condition responsive switch.

12. A system as defined in claim 11 wherein said system includes a burner for heating a medium, said condition responsive switch comprising a thermostat having a thermally responsive element in heat exchange relationship with said medium and operating said switch between said conditions in response to temperature of said medium.

13. A flame monitoring system as defined in claim 11 wherein said signal producing circuitry includes circuit elements for producing periodic electrical pulses in response to said flame, said switching circuitry including a semiconductor switch in series with said actuator and said condition responsive switch, said semiconductor switch rendered conductive to energize said control valve actuator in response to signals produced by said signal circuit when said condition responsive switch is conductive.

14. A system as defined in claim 13 wherein pulses produced by said signal producing circuitry have a frequency which decreases as the impedance of said flame increases, and further including a charging circuit coupled between said signal circuit and said switching circuitry, said charging circuit operable to maintain said switching circuitry effective at relatively low pulse signal frequencies so that high impedance or flickering flame can be maintained and monitored by said system.

15. Burner control circuitry for operating an electrically actuated fuel valve for a burner comprising:

(a) a power supply;

(b) an electrically actuated fuel valve operable between open and closed positions;

(c) an energizing circuit for the fuel valve established across said power supply between first and second terminals;

(d) said energizing circuit comprising a first switch operable between a conductive condition and a nonconductive condition, said first switch operable to one condition for permitting actuation of said fuel valve in response to the presence of flame and a second switch operable between a conducting condition and a nonconducting condition, said second switch operable to one condition for permitting actuation of said valve in response to sensed temperaure;

(e) a second circuit in series with said fuel valve and said first switch and connected to said power supply through a third terminal; and,

(f) means in said second circuit for interrupting said first circuit in response to said first switch being in said one condition when said second switch is in its other condition, said means maintaining said first circuit interrupted thereafter.

16. Circuitry as defined in claim 15 wherein the impedance of said second circuit is of a magnitude which is sufficient to prevent actuation of said fuel valve to the open position when said second circuit conducts.

17. Circuitry as defined in claim 15 wherein said first switch is a gated semiconductor switch, and further including circuitry connected to a gate electrode of said switch for rendering the switch conductive.

18. A flame monitoring system comprising:

(a) an electrical power supply;

(b) an electrically energizable fuel control valve including an electrically operated actuator which is energized to open said valve and deenergized to close said valve;

(c) switching circuitry effective to establish an energizing circuit for said actuator;

(d) a condition responsive switch in said energizing circuit having a nonconducting condition to interrupt said circuit and a conducting condition to permit energization of said actuator;

(e) flame responsive signal producing circuitry for rendering said switching circuitry effective when a flame is established;

(f) safety circuitry operative to deenergize said actuator and close said valve in response to any flame simulating malfunction in the system tending to maintain said valve open when said condition responsive switch becomes nonconducting; and,

(g) said safety circuitry comprising a relay connected in parallel with said condition responsive switch and in series with said actuator, said relay being energized only when said condition responsive switch is nonconducting and said switching circuitry is effective to establish said actuator energizing circuit and operative when energized to prevent energization of said actuator regardless of the conductive condition of said condition responsive switch.

19. Burner control circuitry for operating an electrically actuated fuel valve for a burner comprising:

(a) a power supply;

(b) an electrically actuated fuel valve;

(c) an energizing circuit for the fuel valve establishable across said power supply between first and second terminals;

(d) said energizing circuit comprising a first switch permitting actuation of said fuel valve in response to the presence of flame and a second switch permitting actuation of said valve in response to sensed temperature;

(e) a second circuit in series with said fuel valve and said first switch and connected to said power supply through a third terminal; and,

(f) means in said second circuit for interrupting said first circuit in response to conduction of said first switch when said second switch is open and preventing continued energization of said fuel valve;

(g) said means comprising a relay connected between said first switch and said third terminal, said relay having contacts in said first circuit between said first and second switches, said contacts opening in response to energization of said relay.

20. Burner control circuitry for operating an electrically actuated fuel valve for a burner comprising:

(a) a power supply;

(b) an electrically actuated fuel valve;

(c) an energizing circuit for the fuel valve establishable across said power supply between first and second terminals;

(d) said energizing circuit comprising a first switch permitting actuation of said fuel valve in response to the presence of flame and a second switch permitting actuation of said valve in response to sensed temperature;

(e) a second circuit in series with said fuel valve and said first switch and connected to said power supply through a third terminal;

(f) means in said second circuit for interrupting said first circuit in response to conduction of said first switch when said second switch is open and preventing continued energization of said fuel valve;

(g) said first switch is a gated semiconductor switch and further includes circuitry connected to a gate electrode of said switch for rendering the switch conductive; and,

(h) further including a unidirectional conductor between said first and second circuits for transmitting false gating signals around said first switch when said second switch is closed and said third terminal is disconnected from the power supply.

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EDWARD G. FAVORS, Primary Examiner

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