

[54] FAIL-SAFE ELECTRIC IGNITION SYSTEMS

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 [22] Filed: **June 12, 1970**
 [21] Appl. No.: **45,645**

[52] U.S. Cl. 431/66, 317/98
 [51] Int. Cl. F23n 5/00
 [58] Field of Search 431/66; 317/98

[56] References Cited

UNITED STATES PATENTS

3,434,788 3/1969 Wright 431/66

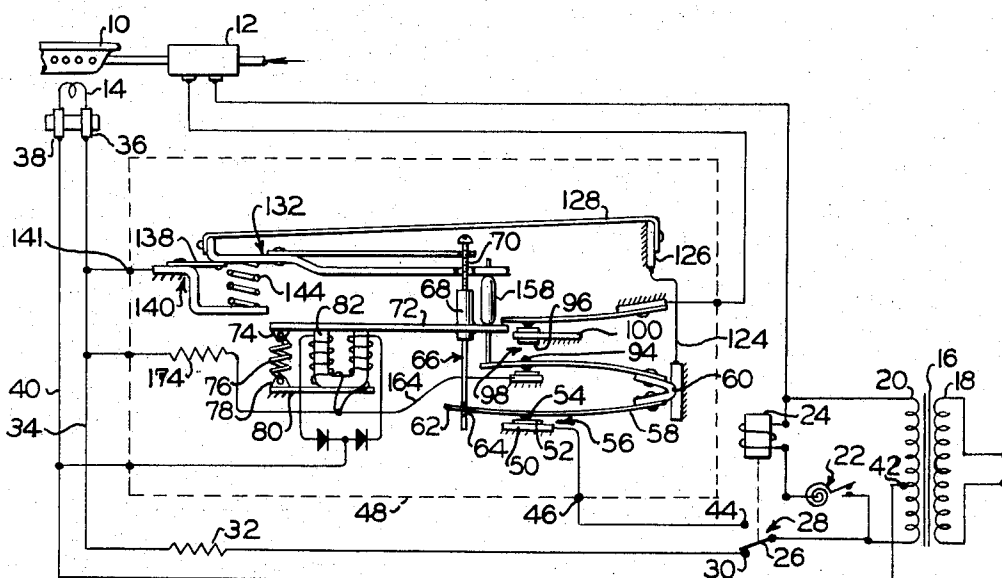
3,488,133 1/1970 Perl 431/66

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[57] ABSTRACT

Electric ignition systems utilizing a holding coil in parallel with an electric igniter having a temperature responsive resistance, a heat expansible wire in series with the igniter, first and second switches controlled by the coil and the wire, respectively, to control the operation of a fuel valve, a dropping resistor to maintain the igniter at least partially energized at all times, and a flame proving network for partially deenergizing the igniter after ignition whereby the system assumes a fail-safe state in response to burner flame outage or any electrical or mechanical failure.

37 Claims, 11 Drawing Figures



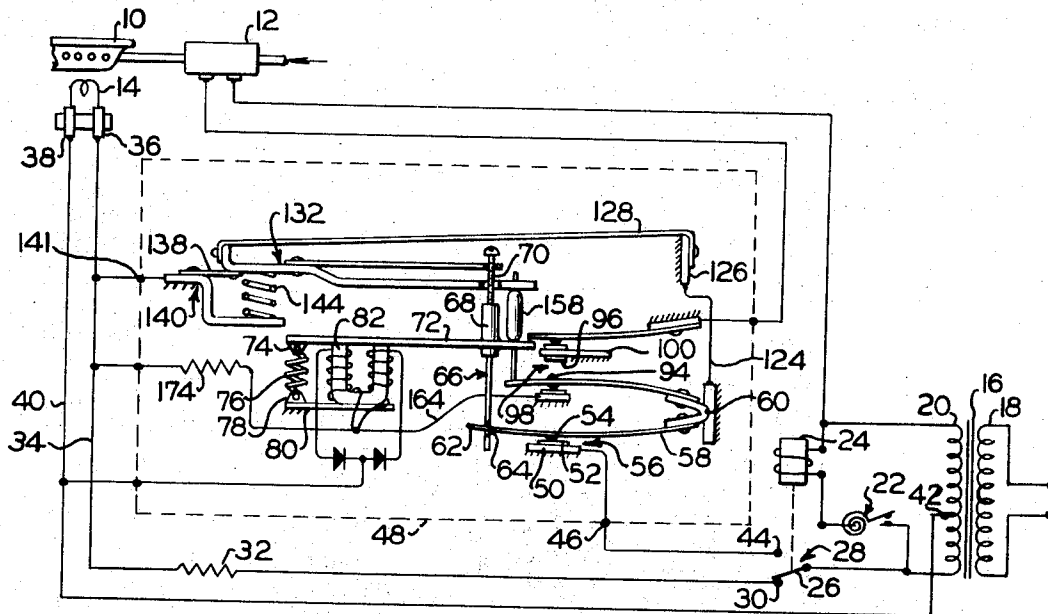


Fig. 1

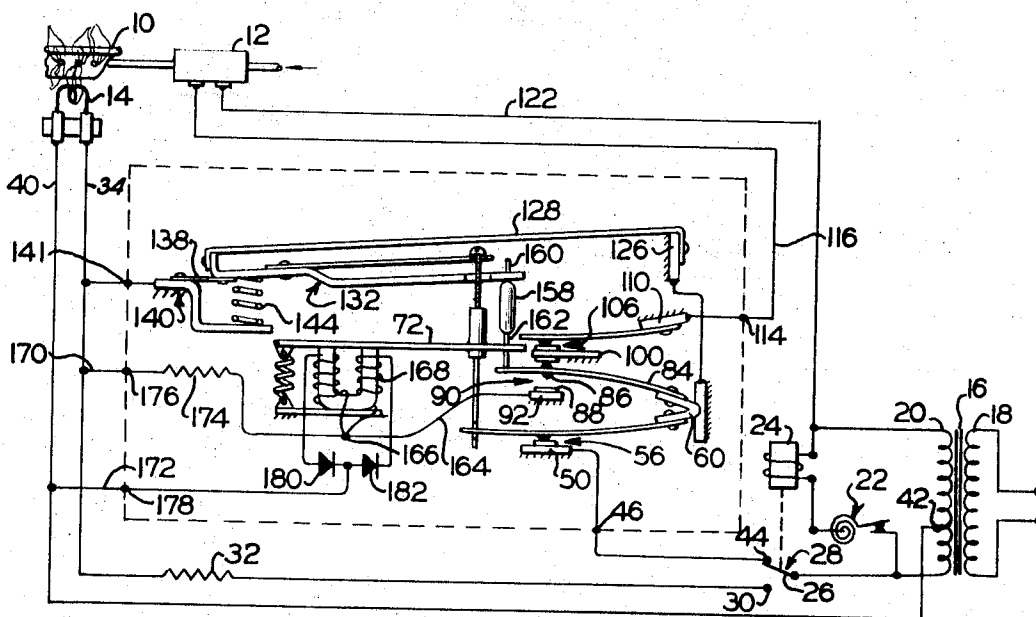


Fig. 2

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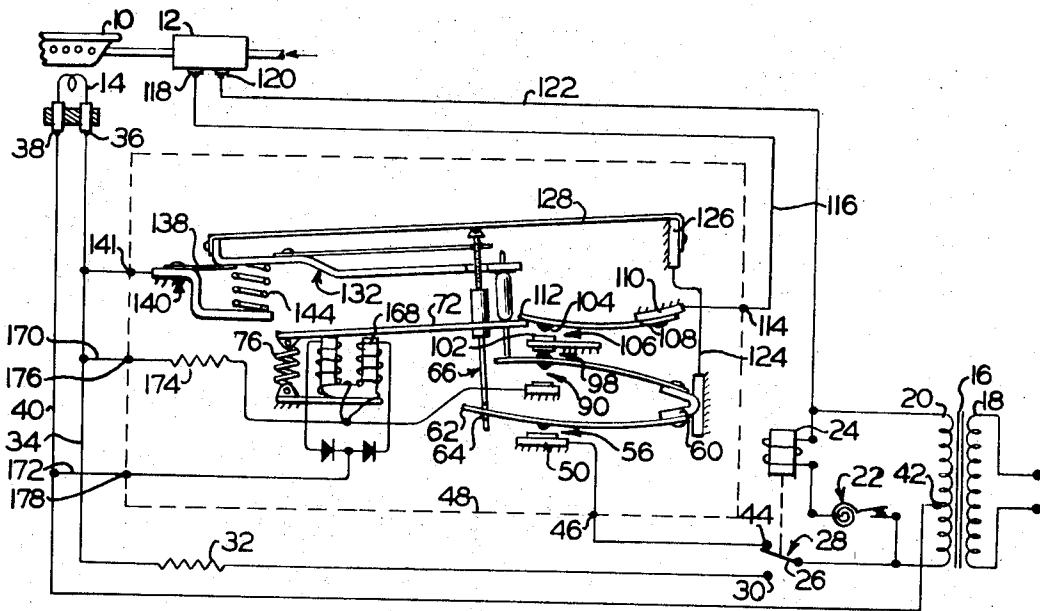


Fig. 3

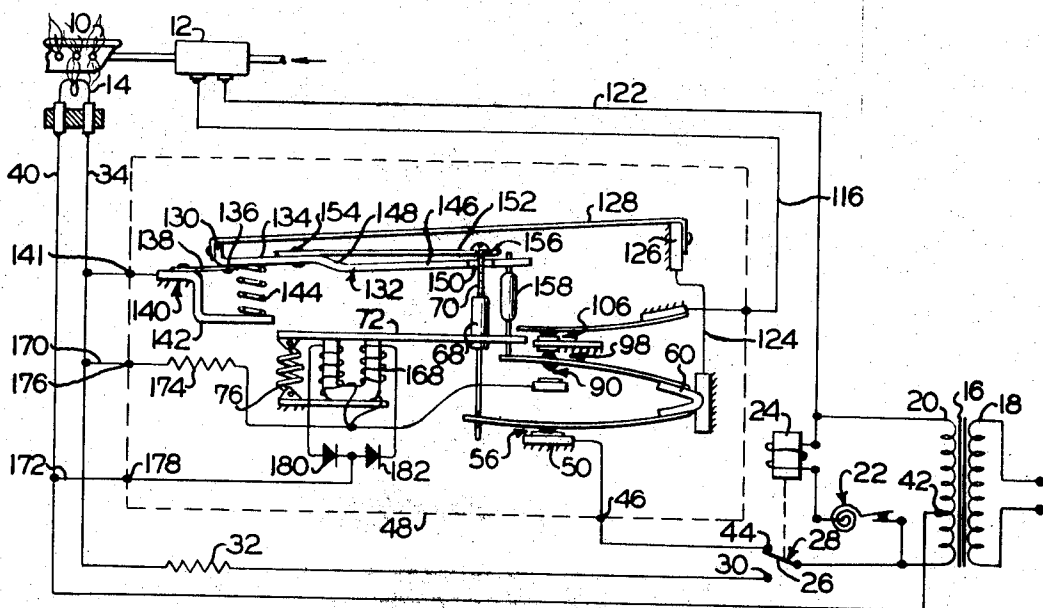


Fig. 4

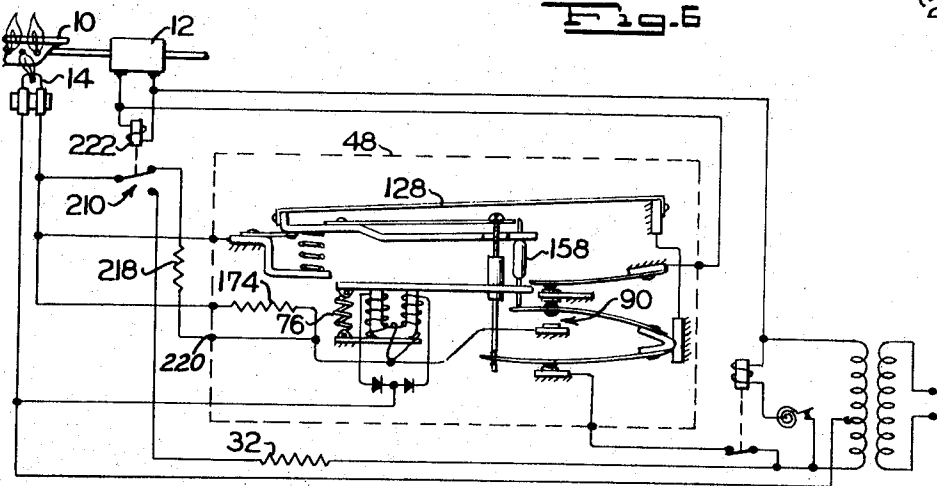
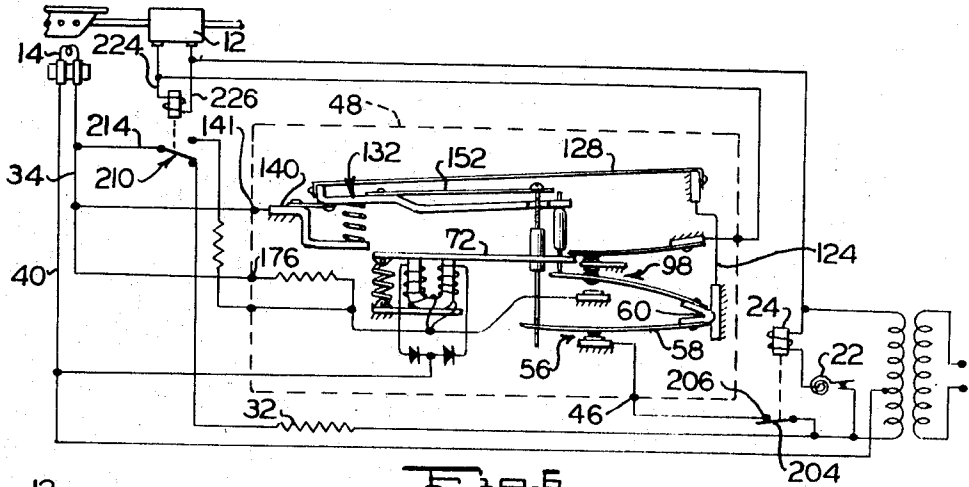
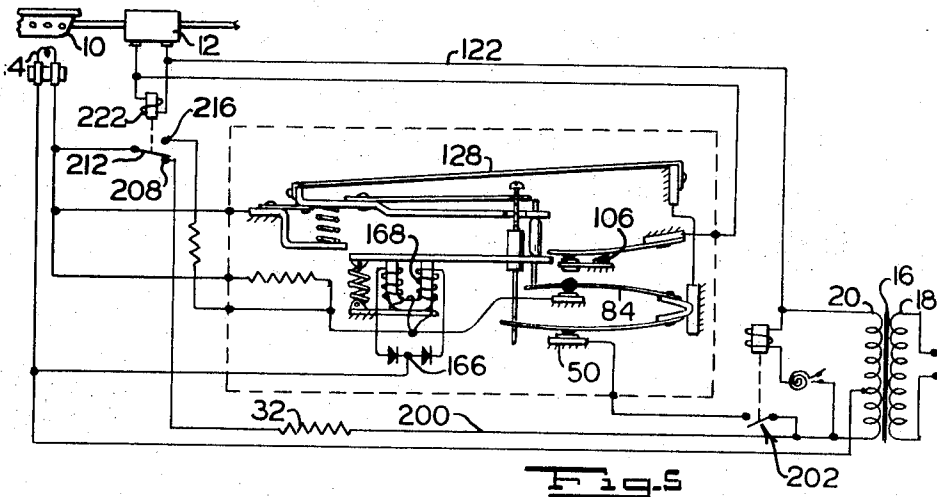
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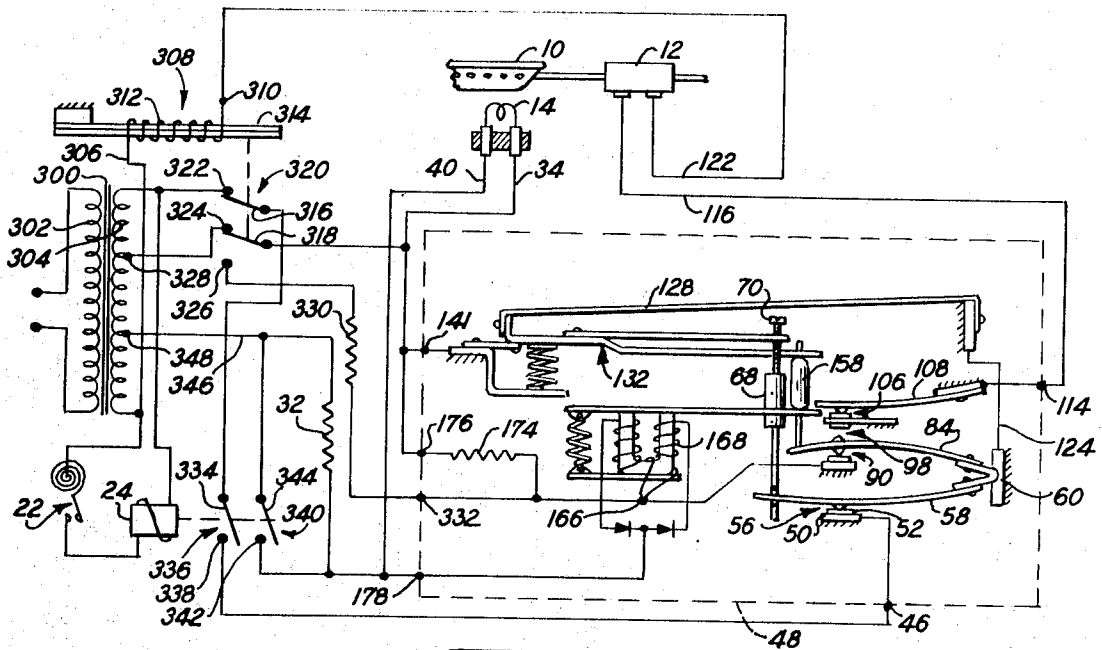


Fig. 8

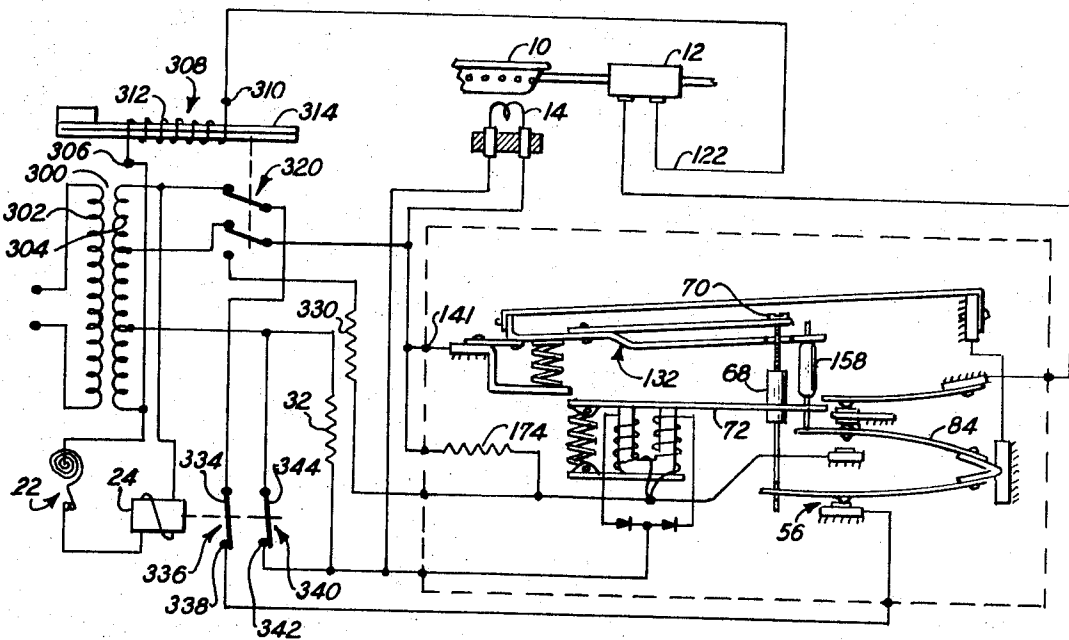


Fig. 9

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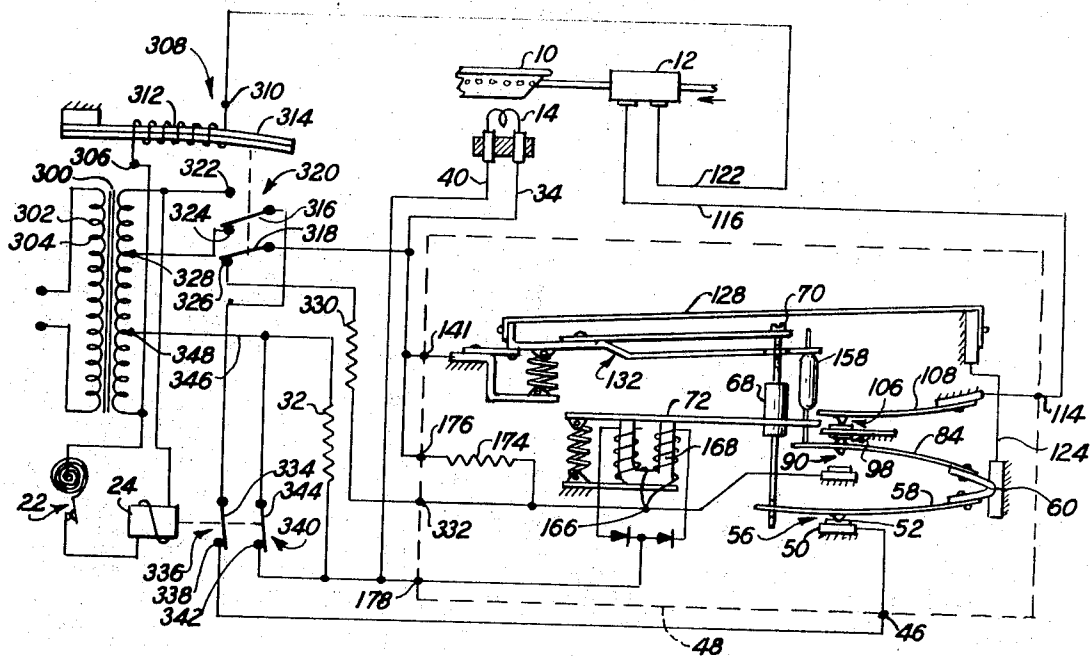


Fig. 10

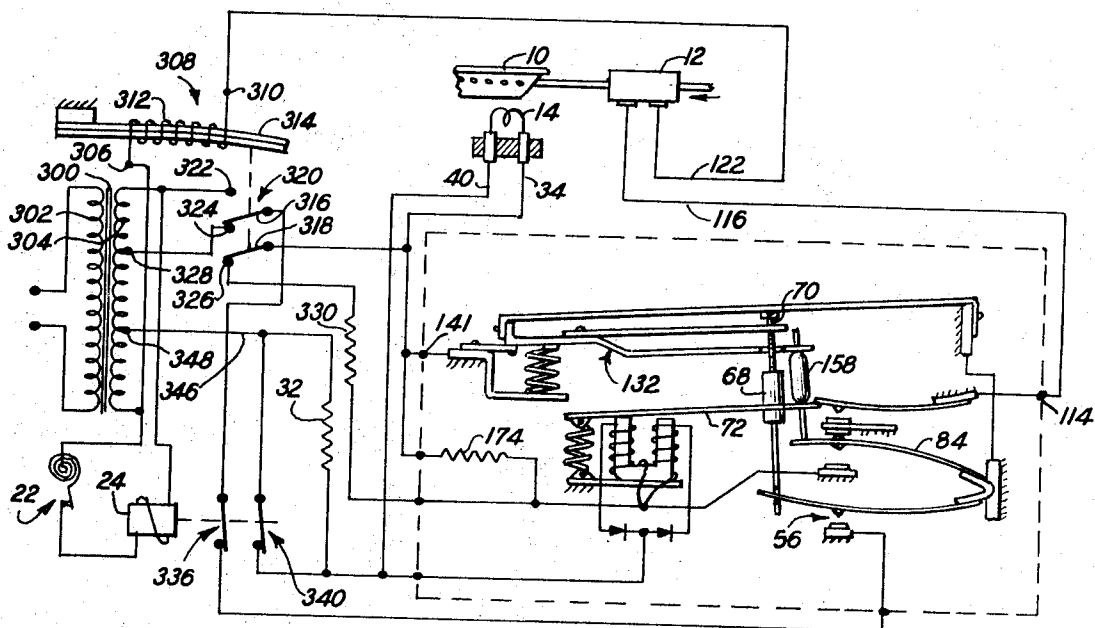


Fig. 11

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FAIL-SAFE ELECTRIC IGNITION SYSTEMS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to ignition systems and more particularly to fail-safe electric ignition systems utilizing an electric igniter element having a positive temperature coefficient of resistance.

2. Description of the Prior Art

A direct outgrowth of recent research and development efforts pertaining to materials exhibiting a thermal coefficient of resistance has been the utilization of such materials as an electric igniter in place of standing pilot flames in such devices as fuel burners. It has been found that burner operation can be monitored by sensing the resistance of an electric igniter constructed of such materials, and by controlling the actuation of an electrically operated fuel valve in response to the sensed resistance, the operation of the igniter and the burner may be proved.

Due to the inherently dangerous conditions resulting from improper operation of ignition systems for fuel burners, it is desirable to utilize a recycling system which automatically cuts-off fuel flow to the system burner in the event of either an electrical or a mechanical failure of any of the component parts of the system or an interruption of electricity. Furthermore, it is beneficial to provide such ignition systems with a flame-proving feature such that fuel flow will be terminated subsequent to a successful ignition in the event of burner outage due to drafts, clogged fuel lines, etc. It is also desirable to have the electric igniter maintained in a partially energized condition during periods when no demand for burner operation exists so as to reduce the thermal shock experienced thereby when a call for heat is signaled.

While the above mentioned features as well as others are desirable, if not necessary, a simple network having few components and high fail-safe standards of operation has not heretofore been available. Different attempts to provide such an electric ignition system have resulted in circuits which are only partially satisfactory due to either their complexity, their difficulty of production, or their lack of sufficient safety characteristics. Furthermore, such prior art ignition systems have not taken full advantage of the temperature variable resistance characteristics of presently available electric igniter elements.

SUMMARY OF THE INVENTION

The present invention is summarized in electric ignition systems for a fuel burner, one embodiment thereof being generally characterized as including an input network adapted to be connected with a source of electricity, an electric igniter having a positive temperature coefficient of resistance and adapted to be disposed within igniting proximity of the burner, a valve adapted to control a flow of fuel to the burner, a switch connecting the electric igniter and the valve with the input network, a first control circuit connected with the electric igniter and the switch and responsive to the resistance of the electric igniter to control the operation of the switch, and a second control circuit connected with the input network and the electric igniter to selectively place the electric igniter in a fully energized condition in response to a demand for burner operation and a partially energized standby condition when no such demand exists whereby thermal shock to the igniter is reduced.

It is an object of the present invention to construct an electric ignition and proving system which utilizes the varying resistance of an electric igniter with temperature for temperature sensing.

Another object of the present invention is to utilize an igniter having a positive temperature coefficient of resistance as a sensor and control element as well as for ignition.

The present invention has a further object in the utilization of an electric igniter element having a positive temperature coefficient of resistance as a temperature sensor, a control element, and a flame-proving element as well as for ignition.

A further object of the present invention is to construct an electric ignition system providing a fully energized mode and a partially energized standby mode for an electric igniter element so as to reduce thermal shock during cyclic operation thereof.

Another object of the present invention is to sense the current through and the voltage across an igniter having a positive temperature coefficient of resistance, to provide low voltage standby operation for the igniter, and to reduce the power applied to the igniter subsequent to ignition in a fail-safe electric ignition system.

The present invention has a further object in the construction of an electric ignition system utilizing a holding coil in parallel with an igniter to control a switch, a heat expansible wire in series with the igniter to control another switch, with both switches controlling the operation of a valve, a dropping resistor in series with the igniter during standby periods, and a power reducing resistor connected in circuit with the igniter subsequent to ignition for providing flame-proving.

The electric ignition system of the present invention is advantageous over conventional electric ignition systems in that an electric igniter element is utilized as an igniter, a temperature sensing element, a fuel valve controlling element, and a flame-proving element, and that the overall system is fail-safe, exhibits redundant safety characteristics, is recycling, and increases the useful life of the electric igniter element by providing a standby mode of operation at an elevated temperature so as to reduce thermal shock during system operation.

Further objects and advantages of the present invention will become more fully apparent from the following description of the preferred embodiments when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of an embodiment of a fail-safe electric ignition system constructed in accordance with the present invention;

FIG. 2 is a schematic diagram of the ignition system of FIG. 1 after successful ignition;

FIG. 3 is a schematic diagram of the ignition system of FIG. 1 in a fail-safe state;

FIG. 4 is a schematic diagram of the ignition system of FIG. 1 immediately prior to its assuming another fail-safe state;

FIG. 5 is a schematic diagram of another embodiment of the fail-safe electric ignition system of the present invention;

FIG. 6 is a schematic diagram of the ignition system of FIG. 5 after successful ignition;

FIG. 7 is a schematic diagram of the ignition system of FIG. 5 in a flame-proving mode;

FIG. 8 is a schematic diagram of a further embodiment of the fail-safe electric ignition system of the present invention;

FIG. 9 is a schematic diagram of the ignition system of FIG. 8 after successful ignition;

FIG. 10 is a schematic diagram of the ignition system of FIG. 8 in a flame-proving mode; and

FIG. 11 is a schematic diagram of the ignition system of FIG. 8 in a fail-safe state.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A fail-safe electric ignition system constructed in accordance with the present invention is illustrated in a first embodiment in FIGS. 1, 2, 3 and 4 for use with a fuel burner 10.

An electrically operated fuel valve 12, which may be controlled by any suitable electrical operator such as a solenoid or a heat motor, communicates with burner 10 and a source of fuel (not shown) to control the flow of fuel to burner 10. An electric igniter 14 is disposed in igniting proximity to the ports of burner 10 and is constructed of a material having a positive temperature coefficient of resistance, such as molybdenum disilicide.

A transformer 16 has a primary winding 18 connected to a suitable source of electricity (not shown) and a secondary winding 20 which is connected across the series circuit formed

by a thermostatic switch 22 and a relay coil 24. The secondary winding 20 of transformer 16 is additionally connected at one end to the pole 26 of a single-pole double-throw switch 28 which is controlled by relay coil 24.

It is noted that transformer 16 may be of any suitable type such as a conventional step-down transformer and may also be a saturable transformer which, with its primary winding in series with a ballast resistor, cooperates to provide voltage regulation such that maximum igniter temperatures are limited to thereby improve igniter life.

Switch 28 has a contact 30 which is connected through a dropping resistor 32 to a lead 34 which is, in turn, connected to a terminal 36 of igniter 14, the igniter having a second terminal 38 which is connected via line 40 to a low voltage tap 42 of secondary winding 20 of transformer 16. Switch 28 has a second contact 44 which is connected to an input terminal 46 of a housing, indicated by dashed lines 48. Terminal 46 is connected to a stationary contact arm 50 which is secured to and electrically insulated from housing 48 and carries a contact 52 which cooperates with a contact 54 to provide a switch generally indicated at 56. Contact 54 is carried upon flexible, resilient contact arm 58 which has one end fixedly mounted by any suitable means, such as spot welding, to a lower leg of a generally V-shaped member 60 which is secured to and electrically insulated from housing 48. The free end 62 of flexible contact arm 58 is disposed within an aperture 64 defined by the lower end of a semi-rigid linkage member 66 which has a generally cylindrical enlarged upper portion 68 having an internally threaded axial bore within which a bolt 70 is adjustably disposed. Linkage member 66 is rigidly mounted upon one end of a lever arm 72 which has an eyelet 74 mounted upon the undersurface of its other end for receiving a tension spring 76. The other end of spring 76 is inserted in an eyelet 78 which is carried upon a mounting bar 80 attached to and insulated from housing 48. A generally U-shaped electromagnet core 82 is mounted upright upon the uppersurface of member 80, as illustrated, so that lever arm 72 is rotatable about the upper surface of the left leg of the core which acts as a fulcrum.

Affixed to the upper leg of V-shaped member 60 is another flexible, resilient contact arm 84 upon which is mounted a contact 86 which cooperates with a contact 88 to provide a switch indicated generally at 90. Contact 88 is carried upon a stationary contact arm 92 which is secured to housing 48 and electrically insulated therefrom. Flexible contact arm 84 carries a second contact 94 on its upper surface for cooperation with a contact 96 to form a switch 98. Contact 96 is mounted upon the bottom surface of a stationary contact arm 100 which is fixedly attached to and electrically insulated from housing 48 and which further carries a contact 102 upon its upper surface. A contact 104 cooperates with contact 102 to form a switch indicated generally at 106 and is carried upon a third flexible, resilient contact arm 108 which is rigidly mounted to housing 48 by an electrically insulated stationary contact arm 110. The distal end 112 of flexible contact arm 108 is disposed adjacent the upper surface of lever arm 72 for enabling the control of switch 106 in response to the position of the lever arm. Stationary contact arm 110 is electrically connected through a terminal 114 of housing 48 and a line 116 to a terminal 118 of fuel valve 12. Valve 12 has a second terminal 120 which is connected by a line 122 to the upper end of secondary winding 20 of the transformer 16.

The V-shaped member 60 is electrically connected by a line 124 to an insulated stationary mounting member 126 upon which is rigidly secured one end of a hot wire 128 which has a thermal expansion characteristic such that it expands as it heats and contracts as it cools. The other end of hot wire 128 is attached to a short leg 130 of a generally L-shaped lever 132. L-shaped lever 132 has a long leg 134 which is attached to point 136 to one end of a flexible, resilient connecting link 138 having its other end secured to a contact arm 140 which is rigidly mounted to and electrically insulated from housing 48 and is connected to igniter terminal 36 through a terminal 141

in the housing and lead 34. In this manner, hot wire 128 is connected in series with the igniter across the low voltage tap of transformer 16.

Contact arm 140 has an offset leg 142 upon which is carried a helical spring member 144 which is mounted in compression between the offset leg and the undersurface of long leg 134 of L-shaped lever 132. The long leg 134 has an arm 146 which is offset at 148 and which defines an aperture 150 for permitting free movement of bolt 70 therethrough. A leaf spring 152 has its proximal end mounted to the long leg of L-shaped lever 132 at 154 and defines an aperture 156 through its free end. Aperture 156 is sufficiently large to accommodate the threaded body of bolt 70 so as to permit free movement of the bolt therethrough; however, the head of bolt 70 is designed to be larger than aperture 156 so as to engage leaf spring 152 during operation, as illustrated in FIG. 4.

A generally cylindrical spacing member 158 is disposed between the free ends of lever arm 72 and L-shaped lever 132 and includes an upper mounting finger 160 which is positioned within an aperture in the distal end of offset arm 146 and is freely movable therethrough. Spacing member 158 includes a lower mounting finger 162 which fits through an aperture in lever arm 72 and abuts against the upper surface of the free end of the flexible, resilient contact arm 84 for actuation thereof, as will be described below.

A lead 164 connects stationary contact arm 92 to the center tap 166 of a holding coil 168 which has its two legs wound around the U-shaped core 82. The holding coil 168 is connected in parallel with igniter 14 through leads 170 and 172 which are respectively connected to leads 34 and 40. Lead 170 is connected to the center tap 166 of holding coil 168 through a calibration resistor 174 and a terminal 176 of housing 48 while lead 172 is coupled through a terminal 178 of housing 48 and oppositely poled full-wave rectifying diodes 180 and 182 to the two legs of the coil.

In operation, thermostatic switch 22 will normally be open and the ignition system will have an initial state as illustrated in FIG. 1. With switch 22 open, the voltage appearing across secondary winding 20 of transformer 16 will not be supplied to relay coil 24 so that switch 28 will remain in its unactuated position as shown. Since pole 26 is separated from contact 44 no power will be supplied to the switching and sensing mechanism of housing 48 so that fuel valve 12 will be closed and no fuel will flow from the source (not shown) to burner 10. Hot wire 128 is cold at this time, since no current is flowing therethrough, and is therefore contracted to pivotally move L-shaped lever 132 clockwise against the force of spring 144 such that the lower mounting finger 162 of spacing member 158 flexes contact arm 84 down to close contacts 86 and 88 of switch 90 and open contacts 94 and 96 of switch 98. The clockwise movement of L-shaped lever 132 also causes spacing member 158 to rotate lever arm 72 in a clockwise direction against the force of tension spring 76 to permit the resilient spring force of flexible contact arms 58 and 108 to close contacts 52 and 54 of switch 56 and contacts 102 and 104 of switch 106, respectively.

When switch 22 is open, and relay coil 24 deenergized, switch 28 will be in the position illustrated in FIG. 1 so as to provide a current flow path from the bottom end of secondary winding 20 through pole 26 and contact 30 of switch 28, dropping resistor 32, line 34 and terminal 36 to the igniter 14. The other terminal 38 of igniter 14 is connected by line 40 back to the tap 42 of winding 20 of transformer 16 so as to complete the energization path for the igniter. Since dropping resistor 32 is connected in series with the igniter 14, the igniter will only be partially energized when no demand for heat exists. Thus, when the system is off, i.e., when no demand for heat exists, fuel valve 12 is closed to block the flow of fuel to the burner 10, hot wire 128 is cold and contracted, switch 98 is open and switches 56, 90 and 106 are closed. In addition, the igniter 14 is in a partially energized standby condition due to its connection through dropping resistor 32 and switch 28 to the tapped winding of transformer 16.

Once thermostatic switch 22 is closed, signaling a need for burner operation, current will flow from the secondary winding 20 of the transformer through switch 22 to energize relay coil 24. As shown in FIG. 2, when relay 24 is energized pole 26 of switch 28 is moved upwardly so as to engage contact 44 and apply operating potential through terminal 46 of housing 48 to the stationary contact arm 50. When pole 26 of switch 28 is actuated by relay coil 24, it moves away from contact 30 so as to remove dropping resistor 32 from the circuit therefore terminating the standby mode of igniter 14.

Since hot wire 128 was in a cold contracted state just prior to the operation of thermostatic switch 22, the initial position of the switching elements of housing 48 is as illustrated in FIG. 1. Thus, when switch 22 is first closed and relay 24 becomes energized, current will flow from secondary winding 20 through terminal 46, switch 56, contact arm 58, V-shaped member 60, lead 124, hot wire 128, connecting link 138, terminal 141, lead 34, igniter 14 and lead 40 back to the transformer to fully energize the igniter and begin heating hot wire 128. It is noted that during the initial period after the need for burner operation is signaled, when the switches of housing 48 are in the positions shown in FIG. 1, calibration resistor 174 is connected in parallel with hot wire 128 from connecting link 138 through terminal 141, lead 34, resistor 174, line 164, switch 90, flexible contact arm 84, V-shaped member 60 and line 124. Thus, while a percentage of the current flowing through hot wire 128 is bypassed through calibration resistor 174, a sufficient amount of current flows through the relatively low impedance hot wire to initiate its expansion by heating. It should also be understood, that during the initial sequence described above subsequent to the closure of the thermostatic switch 22, valve 12 will remain closed since switch 98 is normally held open by spacing member 158 so as to electrically isolate the valve from transformer 16. Since igniter 14 has a positive temperature coefficient of resistance, the initial voltage drop thereacross is small and is insufficient to pull-in the parallel connected coil 168 so that most of the initial voltage drop appears across the series connected hot wire 128. Since coil 168 is not required to pull-in lever arm 72 to close switches 56 and 106, but must merely hold lever arm 72 in its fully clockwise position at the start of operation, the holding coil 168 may be made very sensitive to the voltage across igniter 14.

Referring to FIG. 2, the current flowing through hot wire 128 causes it to heat and expand thereby permitting spring 144 to rotate L-shaped lever 132 counterclockwise. The movement of lever 132 permits spacing member 158 to move in an upward direction so as to allow resilient contact arm 84 to move up under its own spring force to open switch 90 and thereafter close switch 98 as seen in FIG. 2. If igniter 14 has reached ignition temperature by the time spacing member 158 moves up, the resistance of igniter 14 will be high due to its positive temperature coefficient of resistance and, accordingly, the voltage drop thereacross will be sufficient to energize holding coil 168 and maintain switches 56 and 106 closed. That is, since coil 168 is connected in parallel with igniter 14, it experiences the same voltage drop, and coil 168 will be sufficiently energized to hold lever arm 72 only when igniter 14 is at ignition temperatures. Diodes 180 and 182 provide full-wave rectified current to holding coil 168 to eliminate noise and chatter when the coil is near its drop out point.

When contact arm 84 moves up to close switch 98, valve 12 becomes energized by current flowing from terminal 46 through switch 56, contact arm 58, V-shaped member 60, contact arm 84, switch 98, switch 106, contact arm 108, stationary member 110, terminal 114, lead 116, valve 12 and lead 122 to the transformer secondary winding 20. Thus, when igniter 14 reaches ignition temperature within the predetermined time between closure of thermostatic switch 22 and expansion of hot wire 128, valve 12 will be opened to supply fuel to burner 10.

If for any reason igniter 14 fails to reach ignition temperature by the time the current through hot wire 128 heats the wire sufficiently such that expansion permits spring 144 to move L-shaped lever 132 counterclockwise, switches 56 and 106 will become opened by the counterclockwise movement of lever 72 under the bias force of spring 76, as will be more fully explained below. With switches 56 and 106 open, the current flow path from secondary winding 20 of transformer 16 becomes interrupted, and accordingly, valve 12 is closed. Thus, it can be seen that valve 12 depends on the operation of series connected switches 56, 98 and 106 which are controlled by hot wire 128 and holding coil 168 in response to the resistance, and thus temperature, of igniter 14.

If during normal operation of the fail-safe ignition system, as shown in FIG. 2, any type of electrical interruption occurs, holding coil 168 will be deenergized to drop out lever arm 72 and permit the force from bias spring 76 to open switches 56 and 106 thereby disconnecting the igniter 14, closing the valve 12 and discontinuing the flow of current through hot wire 128. The system is thus placed in a fail-safe state, as shown in FIG. 3. Since no current passes through hot wire 128 after lever arm 72 has dropped out, the wire will cool and contract causing L-shaped lever 132 to move clockwise to recycle the system back to its initial state shown in FIG. 1. Thereafter, if thermostatic switch 22 remains closed when the electrical interruption is corrected, the burner will be reignited in the same manner as previously described.

The circuit of the present invention illustrated in FIGS. 1-4 is: fail-safe in that rapid closure of fuel valve 12 occurs upon the failure of any of the individual components of the network. For example, if igniter 14 is ruptured once the system is in its operating state shown in FIG. 2, the voltage across holding coil 168 will increase substantially preventing switches 56 and 106 from opening; however, since hot wire 128 is in series with igniter 14, the current flowing through the wire will be interrupted to permit the wire to cool and contract. As previously mentioned, the contraction of hot wire 128 will cause lever 132 to move clockwise causing finger 162 of spacing member 158 to move contact arm 84 down thereby opening switch 98 (as in FIG. 1) and deenergizing valve 12. The system will remain in this condition until igniter 14 is replaced.

If igniter 14 should become short circuited, the voltage thereacross will decrease to zero and the current therethrough will increase; accordingly, the current flowing through the series connected hot wire 128 will increase causing the hot wire to expand such that lever 132 is rotated counterclockwise. At this same time, the energization potential of holding coil 168 will fall to zero causing lever arm 72 to drop out as shown in FIG. 3. When lever arm 72 drops out, bias spring 76 causes counterclockwise movement thereof such that switch 106 is directly opened and member 66 is moved up causing the free end 62 of contact arm 58 to be lifted up thereby opening switch 56. In this manner, valve 12 will become deenergized to block the flow of fuel to burner 10.

As depicted in FIG. 3, if hot wire 128 is broken, the current path through igniter 14 will be opened to drop out holding coil 168 and permit lever arm 72 to move counterclockwise under the biasing force of spring 76. As a result, switches 56 and 106 are opened and resilient contact arm 84 is permitted to move contact 86 up so as to open switch 90. If a short circuit occurs across hot wire 128, the wire will become cooled and contracted thereby opening switch 98 under the force of finger 162 of spacing member 158, as illustrated in FIG. 1.

If holding coil 168 becomes open or shorted, the magnetization of core 82 will drop to zero permitting lever arm 72 to rotate counterclockwise under the force of spring 76 causing switches 106 and 56 to drop out as illustrated in FIG. 3. Similarly, if diodes 180 and 182 become shorted, alternating current is applied to holding coil 168 causing it to lose magnetization and drop out lever arm 72. Furthermore, if diodes 180 and 182 become open, no current will flow through holding coil 168 to release the lever arm 72 and produce closure of valve 12.

In the event of ignition failure due to igniter 14 being cooled such as by the fuel stream, the voltage across igniter 14 and holding coil 168 will be reduced due to the drop in resistance exhibited by the igniter as a result of its positive temperature coefficient of resistance. The reduction in resistance also causes the current flowing through hot wire 128 to increase beyond its normally expected upper limit causing it to become over expanded. It has been found that igniter cooling can occur to the extent that ignition is prevented while the decreased voltage drop across igniter 14 is insufficient to drop out holding coil 168. To render the system of the present invention fail-safe for such igniter cooling, leaf spring 152 is mounted upon L-shaped lever 132 so as to engage the head of bolt 70 whenever the overexpanded condition of hot wire 128 permits the lever 132 to rotate in a counterclockwise direction beyond its normal limit of travel. In this manner, the resilient biasing force of spring 152 adds to the force exerted by tension spring 76 to pull lever arm 72 away from holding coil 168. The addition of the biasing forces exerted by leaf spring 152 and spring 76 causes lever arm 72 to be released from the holding coil 168 even though the voltage across the coil is at a higher-than-normal value for a drop out condition.

Thus, it can be seen that the system of the present invention is extremely sensitive to external conditions that might cool the igniter 14 since leaf spring 152 cooperates with bolt 70 to provide an additional feedback force to release lever arm 72 and place the system in the condition depicted in FIG. 3. The system is therefore responsive to both a decrease in voltage across the igniter 14 and an increase in current therethrough to deenergize valve 12 and block the flow of raw fuel to the area adjacent the burner 10. For this reason, the system of the present invention can assume a fail-safe state in response to the failure of any component utilized in the system as well as an external failure which would cause the supply voltage to be increased or decreased below normal values. That is, an increase in supply voltage will increase the current through hot wire 128 and a decrease in supply voltage will tend to drop out holding coil 168 which, in either case, causes switches 56 and 106 to become opened.

Referring to FIG. 3, the system of the present invention is recycling and will immediately begin to reset itself for a subsequent ignition attempt immediately after a drop out condition has occurred. Since holding coil 168 is constructed so as to be very sensitive to direct current and to have a precise drop out point, the clockwise movement of lever arm 132 caused by the contraction of hot wire 128 upon cooling is transmitted to lever arm 72 by the spacing member 158 so as to assist the pull-in operation of holding coil 168. In this manner, the holding coil itself is not required to generate a pull-in force sufficient to reset lever arm 72 and can thus be made highly sensitive without degrading the safety characteristics of the overall system. In addition, as the hot wire 128 begins to contract, causing spacing member 158 to move down, switch 90 is closed so as to apply the full tapped potential from the secondary winding of transformer 16 to the holding coil 168 to help insure satisfactory holding by the coil 168 while the igniter is being heated before the next ignition attempt. It is noted that the increased holding coil potential caused by the direct connection thereof through switch 90 is removed subsequent to proper ignition by the opening of switch 90 as illustrated in FIG. 2.

After the demand for burner operation has ceased, and thermostatic switch 22 has opened, relay coil 24 will become deenergized and will release switch 28 which will thereafter assume its normal unactuated position as illustrated in FIG. 1. Thus, when relay coil 24 becomes deenergized, pole 26 of switch 28 will move from contact 44, thereby deenergizing fuel valve 12 and removing operating potential from hot wire 128, to contact 30 so as to complete the low potential standby energization circuit for igniter 14 through dropping resistor 32. In this manner, when the ignition system of the present invention is turned off by the opening of thermostatic switch 22, the electric igniter 14 is not completely deenergized but rather

is placed in a partially energized standby condition by operating potential from the secondary winding 20 of transformer 16 through the dropping resistor 32. By maintaining the igniter 14 in at least a partially energized state at all times, the temperature excursions experienced by the igniter element as the system cyclically operates are reduced so as to prevent thermal shock from materially shortening the life of the igniter. Igniter life is therefore increased to reduce maintenance costs as well as to increase the safety characteristics of the system.

A modification of the ignition system of FIG. 1 is illustrated in FIGS. 5, 6 and 7 and parts identical to parts in FIG. 1 are given identical reference numerals and are not described again for the sake of brevity.

The electric ignition system of FIG. 5 differs from that embodied in FIG. 1 in that dropping resistor 32 is directly connected to the lower terminal of secondary winding 20 of transformer 16 by a line 200. Also, relay coil 24 operates a normally open switch 202 which has a pole 204 connected to secondary winding 20 and a stationary contact 206 which is connected to stationary contact arm 50 through terminal 46 of housing 48. In addition, dropping resistor 32 is not connected directly to line 34, as in FIG. 1, but rather is connected to fixed contact 208 of relay controlled switch 210 which has a pole 212 connected to line 34 by a line 214. Switch 210 has a second fixed contact 216 which is connected through a second calibration resistor 218 and a terminal 220 of housing 48 to the center tap connection 166 of holding coil 168. Switch 210 is actuated by a time delay relay 222 which is directly connected in parallel with valve 12 through line 224 and 226. Relay 222 is characterized by a delayed action so that switch 210 will not be actuated until a timed interval has elapsed subsequent to the energization of the valve 12.

In operation, switches 56, 90, 98 and 106 as well as holding coil 168 and hot wire 128 of the ignition system of FIGS. 5, 6 and 7 function in a similar manner to that of FIG. 1 and thus will not be described again.

Referring to FIG. 5, when thermostatic switch 22 is open, relay coil 24 is deenergized and switch 202 is in its normally open position as illustrated. In addition, since valve 12 receives no energization potential due to switch 98 being open, the parallel connected time delay relay 22 is off permitting switch 210 to remain in its unactuated position with pole 212 in engagement with contact 208. Thus, while fuel valve 12 is deenergized, thereby blocking the flow of fuel to burner 10, igniter 14 is maintained in a partially energized standby state by current flowing from transformer 16 through line 200, dropping resistor 32, contact 208 and pole 212 of switch 210, line 214, line 34, igniter 14, and line 40 back to the transformer.

When a demand for burner operation is signaled, thermostatic switch 22 will become closed thereby energizing relay coil 24 and closing switch 202 as shown in FIG. 6. When switch 202 is closed, current flows through terminal 46, switch 56, member 60, line 124, hot wire 128, and thence through terminal 141, line 34, igniter 14, and line 40 back to transformer 16. It is pointed out that dropping resistor 32 initially remains connected to the igniter 14 by switch 210 and is directly in parallel with hot wire 128. Since the resistance exhibited by the hot wire 128 is relatively low, the parallel combination of dropping resistor 32 and hot wire 128 exhibits a similar low resistance so that the igniter element 14 receives full energization potential subsequent to the closure of thermostatic switch 22. At this same time, current will flow through hot wire 128 causing it to heat and expand thereby permitting contact arm 84 to move up and open switch 90 while closing switch 98. As described above with respect to the ignition system embodied in FIGS. 1 through 4, when switch 98 closes, current will flow through switches 56, 98 and 106 to energize valve 12. A flow of fuel will thereafter be established through the energized valve to burner 10 wherein the fuel is ignited by the now fully energized igniter 14.

As soon as valve 12 becomes energized, the time delay relay 222, which is connected directly in parallel with valve 12,

receives operating potential to initiate the timed actuation of switch 210. Thus, after a preselected short time interval has elapsed, which is of sufficient duration to insure ignition of fuel from burner 10, pole 212 of switch 210 will move away from contact 208 and into engagement with contact 216 as shown in FIG. 7. The actuation of switch 210 serves to remove dropping resistor 32 from the circuit and simultaneously connect a second calibration resistor 218 in parallel with calibration resistor 174. Since the network formed by the series connection of resistor 174 and holding coil 168 is coupled in parallel with igniter 14, the additional parallel connection of calibration resistor 218 with resistor 174 reduces the overall parallel resistance seen by the igniter element 14. With a reduced value of resistance placed across the igniter 14, the voltage drop thereacross is decreased to a value which is insufficient to energize coil 168 and hold lever arm 72 in its clockwise position unless a burner flame exists. That is, when the burner flame is present, it will heat the igniter causing its temperature, and therefore its resistance, to increase to the point where even with the additional resistance of calibration resistor 218 in the circuit, a sufficient voltage drop will be provided to energize holding coil 168 and maintain the fuel valve 12 on. If for any reason the burner flame should become extinguished, however, the resistance of the igniter will decrease and the potential across the holding coil 168 will be reduced so as to cause a drop out condition similar to that depicted in FIG. 3 with respect to the first embodiment of the ignition system of the present invention. In this manner, the burner flame is effectively proved such that valve 12 rapidly closes upon burner flame outage to prevent raw fuel leakage.

After the demand for burner flame has ceased, thermostatic switch 22 will open and relay 24 will become deenergized causing switches 202 and 210 to return to their normally open positions shown in FIG. 5. In this manner, fuel valve 12 and hot wire 128 are removed from the circuit and dropping resistor 32 is placed in series with igniter 14 so that the flow of fuel becomes cut off and the igniter reverts to its partially energized standby state.

The ignition system embodied in FIGS. 5, 6 and 7 is fail-safe in the same manner as previously described with respect to FIGS. 1 through 4 and therefore will not be repeated for the sake of brevity.

Another modification of the ignition system of FIG. 1 is illustrated in FIGS. 8, 9, 10 and 11 and parts identical to parts in FIG. 1 are given identical reference numerals and are not described again for the sake of brevity.

The electric ignition system of FIG. 8 includes a transformer 300 having a primary winding 302 connected to a suitable source of electricity (not shown) and a secondary winding 304 which is connected across the series circuit formed by thermostatic switch 22 and relay coil 24. The secondary winding 304 of transformer 300 is additionally connected at its upper end to terminal 306 of a time delay relay 308 which is connected in series with fuel valve 12 via a second terminal 310 and line 122. The time delay relay 308 may be of any suitable construction and may include a heating coil 312 which is connected between terminals 306 and 310 and is located within heating proximity of a suitable bimetal operator 314 having one end rigidly attached to a frame with its distal end communicating with a pair of poles 316 and 318 of a double-pole double-throw switch 320.

Switch 320 may be of the snap-acting type and includes first, second and third fixed contacts 322, 324 and 326 which are respectively connected to an upper end of secondary winding 304, a tap 328 of secondary winding 304 and one end of a second calibration resistor 330. The other end of calibration resistor 330 is connected through a terminal 332 of housing 48 to the center tap connection 166 of holding coil 168. Pole 318 of switch 320 is connected via line 34 to the igniter 14 while pole 316 is connected to a pole 334 of a normally open switch 336 which is controlled by relay coil 24. Switch 336 has a fixed contact 338 which is connected through terminal 46 of housing 48 to contact 52 of stationary contact arm

50. Relay coil 24 also controls a second normally open switch 340 which has a fixed contact 342 connected via line 40 to the igniter 14 and a pole 344 which is coupled by a line 346 to another tap 348 of secondary winding 304. Dropping resistor 32 is connected in parallel with switch 340 so as to selectively provide partial energization of igniter 14 during standby intervals when no demand for heat exists.

In operation, switches 56, 90, 98 and 106 as well as holding coil 168 and hot wire 128 of the ignition system of FIGS. 8, 9, 10 and 11 function in a similar manner to that of FIG. 1 and thus will not be described again.

Referring to FIG. 8, when thermostatic switch 22 is open, relay 24 is deenergized and switches 336 and 340 are in their normally open positions as illustrated. In addition, since switch 98 within housing 48 is open at this time, the series circuit of fuel valve 12 and relay 308 is deenergized such that switch 320 is unactuated with pole 316 in engagement with contact 322 and pole 318 in engagement with contact 324. Thus, when no demand for heat exists, the fuel valve 12 is deenergized and igniter 14 receives partial energization potential from tap 328 of secondary winding 304 of the transformer through contact 324 and pole 318 of switch 320, line 34, igniter 14, line 40, dropping resistor 32 and line 346 back to the tap 348 of transformer 300.

When burner operation is desired, thermostatic switch 22 will become closed thereby energizing relay coil 24 and closing switches 336 and 340 as shown in FIG. 9. The closure of switch 336 upon energization of the relay coil 24 applies operating potential to hot wire 128 by providing a current flow path from the upper terminal of secondary winding 304 through contacts 322 and pole 316 of switch 320, switch 336, terminal 46 of housing 48, switch 56, contact arm 58, V-shaped member 60, line 124, hot wire 128, terminal 141 of housing 48, line 34, and pole 318 and contact 324 of switch 320 back to tap 328 of the transformer 300. At this same time, the energized relay coil 24 closes switch 340 so as to provide a shunt path around dropping resistor 32 such that the igniter 14 becomes fully energized by current flowing from tap 348 of transformer 300 through line 346, switch 340, line 40, igniter 14, line 34, and pole 318 and fixed contact 324 of switch 320 back to tap 328 of the transformer. Thus, upon receipt of a command for burner operation, thermostatic switch 22 closes so as to energize relay coil 24 and close switches 336 and 340 resulting in the following system conditions:

1. hot wire 128 is connected between the upper terminal of secondary winding 304 and tap 328 thereof so as to establish a current flow through the hot wire, and

2. dropping resistor 32 is bypassed by switch 340 which completes the direct connection of the igniter across taps 328 and 348 of the secondary winding of transformer 300 causing the igniter to come up to fuel igniting temperatures.

As in previous embodiments, with a current flow path established to the hot wire 128, the wire expands and lever 132 is permitted to rotate in a counterclockwise direction whereupon switch 98 becomes closed so as to complete an energization path for the series connected fuel valve 12 and time delay relay 308. Thus, after a time delay caused by the rate of expansion characteristics of hot wire 128 and of sufficient duration to assure igniter heating to fuel igniting temperatures, a flow of fuel to the fuel burner 10 will be established for ignition by the now fully energized igniter 14. Since the heating coil 312 of time delay relay 308 is connected in series with fuel valve 12, the heating coil 312 will begin to heat the bimetal operator 314 whenever the fuel valve is energized such that after a preselected time delay which is of a sufficient duration to assure the proper establishment of a flame at the system burner 10, the switch 320 will be moved from its normal position to its actuated position illustrated in FIG. 10. It is noted that switch 320 is preferably of the snap-acting type such that a positive and predictable delay will be provided between the time of energization of the heating coil 312 and the time at which poles 316 and 318 move to their energized positions. Of course it should also be understood that any of

various time delay relay devices may be substituted for that illustrated herein depending upon desired operational characteristics of the overall system.

When switch 320 is actuated by bimetal operator 314, the hot wire 128 is placed in series with igniter 14 from tap 328 of transformer 300 through contact 324 and pole 316 of switch 320, switch 336, terminal 46 of housing 48, switch 56, contact arm 58, V-shaped member 60, line 124, hot wire 128, terminal 141 in housing 48, line 34, igniter 14, line 40, switch 340, and line 346 back to tap 348 of the secondary winding 304 of transformer 300. In addition, the movement of pole 318 from contact 324 to contact 326 connects a second calibration resistor 330 in parallel with calibration resistor 174. With the igniter now connected in series with hot wire 128, the voltage across the igniter is reduced causing it to assume a partially energized state. At this same time, since calibration resistor 330 is now connected in parallel with resistor 174, the total resistance which is in series with holding coil 168 across the igniter 14 is reduced such that the holding coil 168 is recalibrated to sense the lower voltage of the igniter. In other words, when switch 320 is actuated, the igniter is placed in series with hot wire 128, its voltage is reduced, and the holding coil 168 is recalibrated such that the voltage drop thereacross will be insufficient to energize coil 168 and hold lever arm 72 in its clockwise position (FIG. 10) unless a burner flame exists. That is, when the burner flame is present, it will heat the igniter causing its temperature, and therefore its resistance, to increase to the point where holding coil 168, as recalibrated by resistor 330, is sufficiently energized to maintain fuel valve 12 on. If for any reason the burner flame should become extinguished, however, the resistance of the igniter will decrease and the potential across holding coil 168 will be reduced so as to cause a drop-out condition as seen in FIG. 11. It is noted that as in the preceding embodiments, drop-out of lever arm 72 under these conditions is aided by the current increase through the now series connected hot wire 128 which over-expands to generate a feedback force acting through bolt 70 to pull lever arm 72 away from holding coil 168.

Subsequent to the occurrence of the drop out of lever arm 72 by holding coil 168, energization potential will be removed from both the fuel valve 12, causing its immediate closure, and heating coil 132 of time delay relay 308. The bimetal operator 314 will thereafter begin to cool such that switch 320 will be released to its normal position as shown in FIG. 8. Thereafter, if the thermostatic switch 22 is still closed, the system will automatically recycle by immediately attempting to reignite the system burner in the manner described above.

After the demand for burner operation has ceased, thermostatic switch 22 will open and relay 24 will become deenergized causing switches 336 and 340 to return to their normally open positions shown in FIG. 8. In this manner, fuel valve 12, heating coil 312 of time delay 308, and hot wire 128 are effectively removed from the circuit and the shunt across dropping resistor 32 is removed. As a result, the flow of fuel to the system burner is cut off and the igniter is placed once again in its partially energized standby state.

To briefly summarize the operation of the circuit illustrated in FIGS. 8 through 11, when thermostatic switch 22 is open and no demand for burner operation exists, the fuel valve 12 will be deenergized and igniter 14 will receive partial operating potential through dropping resistor 32. Subsequent to a call for heat, dropping resistor 32 will be shunted, igniter 14 will be fully energized, and hot wire 128 will receive energizing current directly from transformer 300. Thus, immediately after closure of thermostatic switch 22, both the igniter and the hot wire 128 are fully energized by direct connections to the secondary winding of transformer 300. Thereafter, the hot wire 128 will become heated and will expand, and if the igniter has reached ignition temperatures as sensed by holding coil 168 and hot wire 128, the fuel valve 12 will become energized to establish a flow of fuel to the system burner 10. At the same time that valve 12 becomes energized, heating coil 312 of time delay relay 308 receives operating current such that after a

preselected time interval, the igniter 14 will be placed in series with hot wire 128 and will assume a partially energized flame-proving mode whereupon the continued energization of fuel valve 12 is dependent upon the heating of igniter 14 by the burner flame as sensed by the parallel connected hot wire 128.

It is important to reiterate that in the electric ignition system embodied in the circuit of FIGS. 8, 9, 10 and 11, the igniter 14 and the hot wire 128 are initially energized independently of each other by a parallel-like connection across respective pairs of taps of the secondary winding 304 of transformer 300. Subsequent to the closure of thermostatic switch 22 and the operation of time delay relay 308, however, the igniter and hot wire are placed in series with each other in a manner similar to that shown and described with respect to the previous embodiments of the present invention. In this manner, that is, by independently energizing the igniter and hot wire prior to the establishment of burner flame and thereafter reconnecting the igniter and hot wire in series, the current levels throughout the system are lowered during flame-proving such that the ignition system is more sensitive to the presence of a flame at the main burner 10. It is additionally noted that while igniter 14 is energized at any of three different operating levels, i.e., a low standby level, a high ignition level, and a low flame-proving level, the current flowing through the hot wire 128 is substantially constant during all normal modes of operation of the system. In other words, when thermostatic switch 22 first becomes closed, the igniter 14 is energized independently of the hot wire 128 such that a preselected current level is established through the hot wire at the same time that full energization potential is applied across the igniter. Subsequent to ignition, however, the igniter is automatically placed in series with the hot wire 128 such that the current level through the hot wire remains at its initial preselected level while the voltage drop across the igniter is substantially reduced for flame-proving. Operating in this manner makes it possible to apply the optimum voltages to the igniter and hot wire under all operating conditions so that a high degree of safety may be assured.

The ignition system embodied in FIGS. 8, 9, 10 and 11 is fail-safe in the same manner as previously described with respect to FIGS. 1 through 4 and therefore will not be repeated again for the sake of brevity.

In summary, it may be seen that the fail-safe ignition systems of the present invention fully utilize the temperature varying resistance of electric igniters by sensing the current therethrough and the voltage thereacross to provide increased safety in operation. Furthermore, by utilizing a dropping resistor as well as a power reducing flame-proving network, thermal shock to the igniter element is reduced so as to increase its useful life while the igniter itself is utilized as a flame-proving element to cause deenergization of the fuel valve upon burner flame outage.

Inasmuch as the present invention is subject to many variations, modifications and changes in detail, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative in nature and not in a limiting sense.

What is claimed is:

1. An electric ignition system for a fuel burner comprising input means adapted to be connected with a source of electricity, an electric igniter having a positive temperature coefficient of resistance and adapted to be disposed within igniting proximity of the burner, valve means adapted to control a flow of fuel to the burner, switch means connecting said electric igniter and said valve means with said input means, first control means connected with said electric igniter and said switch means and responsive to the resistance of said electric igniter to control the operation of said switch means, and second control means connected with said input means and said electric igniter selectively placing said electric igniter

in a fully energized condition in response to a demand for burner operation and in a partially energized standby condition when no such demand exists whereby thermal shock to said igniter is reduced.

2. The invention as recited in claim 1 wherein said second control means includes a dropping resistor connected in series with said electric igniter.

3. The invention as recited in claim 2 wherein said second control means includes a thermostat connected with said dropping resistor for selectively shunting said dropping resistor in response to a demand for burner operation.

4. The invention as recited in claim 1 wherein said second control means includes a dropping resistor.

5. The invention as recited in claim 4 wherein said dropping resistor is selectively connected in series with said electric igniter for placing said electric igniter in its partially energized standby condition.

6. The invention as recited in claim 4 wherein said second control means includes a thermostat connected with said dropping resistor whereby said dropping resistor is connected to said electric igniter by said thermostat during standby intervals and said dropping resistor is disconnected from said electric igniter by said thermostat in response to a demand for burner operation.

7. The invention as recited in claim 1 wherein said first control means includes a first sensing means responsive to the voltage across said electric igniter and a second sensing means responsive to the current through said electric igniter.

8. The invention as recited in claim 7 wherein said switch means includes a first switch controlled by said first sensing means and a second switch controlled by said second sensing means, said first switch and said second switch being connected in series between said input means and said valve means whereby said first switch and said second switch must be closed to open said valve means.

9. The invention as recited in claim 7 wherein said first sensing means is connected in parallel with said electric igniter.

10. The invention as recited in claim 9 wherein said first sensing means includes a holding coil.

11. The invention as recited in claim 7 wherein said second sensing means is connected in series with said electric igniter.

12. The invention as recited in claim 11 wherein said second sensing means includes a heat expansible wire having a low resistance.

13. The invention as recited in claim 12 wherein said second control means includes a dropping resistor and main switch means connected between said input means and said heat expansible wire to selectively place said heat expansible wire in parallel with said dropping resistor in response to a demand for burner operation whereby said dropping resistor is selectively bypassed.

14. The invention as recited in claim 13 wherein said main switching means includes a thermostat.

15. An electric ignition system for a fuel burner comprising input means adapted to be connected with a source of electricity,

an electric igniter having a positive temperature coefficient of resistance and adapted to be disposed within igniting proximity of the burner,

valve means adapted to control a flow of fuel to the burner, switch means connecting said electric igniter and said valve means with said input means,

first control means connected with said electric igniter and said switch means and responsive to the resistance of said electric igniter to control the operation of said switch means,

flame-proving means connected with said electric igniter and said valve means and responsive to actuation of said valve means to place said electric igniter in a flame-proving mode for closing said valve means upon burner flame outage and

second control means connected with said input means and said electric igniter selectively placing said electric igniter in a fully energized condition in response to a demand for burner operation and in a partially energized standby condition when no such demand exists whereby thermal shock is reduced.

16. The invention as recited in claim 15 wherein said control means includes sensing means responsive to the voltage drop across said electric igniter.

17. The invention as recited in claim 16 wherein said switch means is controlled by said sensing means and has a closed position when the voltage drop across said sensing means is above a preselected value to provide an energizing current path to said valve means, and an open position when the voltage drop across said sensing means is below said preselected value to open said energizing current path to said valve means.

18. The invention as recited in claim 17 wherein said flame-proving means includes a resistor selectively coupled with said electric igniter in response to actuation of said valve means whereby the voltage drop across said sensing means is reduced below said preselected value upon burner flame outage.

19. The invention as recited in claim 18 wherein said flame-proving means includes time-delay switching means connected with said valve means and said resistor for selectively connecting said resistor with said electric igniter a predetermined time interval subsequent to actuation of said valve means whereby a burner flame is established prior to connecting said resistor with said electric igniter.

20. The invention as recited in claim 19 wherein said time-delay switching means includes a time-delay relay having a coil connected in parallel with said valve means and a set of normally open contacts connected between said electric igniter and said resistor.

21. The invention as recited in claim 19 wherein said time-delay switching means includes a bimetal operator, a heating coil connected in series with said valve means and disposed within heating proximity of said bimetal operator, and a double-pole double-throw switch controlled by said bimetal operator.

22. An ignition proving system for a fuel burner comprising input means adapted to be connected to a source of electricity,

an electric igniter having a positive temperature coefficient of resistance and adapted to be disposed in igniting proximity to the burner,

valve means adapted to control a flow of fuel to the burner, switch means connecting said electric igniter and said valve means with said input means,

first control means connected in circuit with said electric igniter and said switch means and responsive to the voltage across said electric igniter to control the operation of said switch means,

second control means connected in circuit with said electric igniter and said switch means and responsive to the current through said electric igniter to control the operation of said switch means,

flame-proving means connected with said electric igniter and said valve means and responsive to actuation of said valve means to place said electric igniter in a flame-proving mode for closing said valve means upon burner flame outage, and

third control means connected with said input means and said electric igniter to selectively place said electric igniter in a fully energized condition in response to a demand for burner operation and a partially energized standby condition when no such demand exists whereby thermal shock to said igniter is reduced.

23. The invention as recited in claim 22 wherein said first control means includes a holding coil, and wherein said second control means includes a thermally expansible wire.

24. The invention as recited in claim 22 wherein said input means includes transformer means having a plurality of secondary winding terminals, and wherein said flame-proving means

includes time-delay switching means connected with said valve means, said electric igniter, said transformer means and said second control means for connecting said electric igniter and said second control means to different pairs of said plurality of secondary winding terminals when said valve means is deenergized whereby said igniter is placed in an ignition mode and for connecting said electric igniter in series with said second control means across a particular pair of said plurality of secondary winding terminals a predetermined time interval subsequent to energization of said valve means whereby said igniter is placed in a flame-proving mode.

25. The invention as recited in claim 24 wherein said switch means includes first and second switches connected between said input means and said valve means and controlled by said first control means.

26. The invention as recited in claim 25 wherein said first control means includes a calibration resistor and a holding coil connected in series across said electric igniter, and wherein said holding coil is responsive to at least a preselected voltage drop thereacross to maintain said first and second switches closed.

27. The invention as recited in claim 26 wherein said flame-proving means includes a second calibration resistor selectively connected in parallel with said first calibration resistor by said time-delay switching means in response to energization of said valve means whereby said first and second switches are thereafter released by said holding coil upon burner flame outage.

28. The invention as recited in claim 27 wherein said time-delay switching means includes a coil connected in series with said valve means.

29. The invention as recited in claim 22 wherein said switch means includes first and second switches controlled by said first control means and third and fourth switches controlled by said second control means, said first, second and third switches being connected in series between said input means and said valve means whereby said first, second and third switches must be closed to open said valve means.

30. The invention as recited in claim 29 wherein said second control means is electrically connected in series with said electric igniter between said electric igniter and a point between said first and third switches, and wherein said first control means is connected in parallel with said electric igniter.

31. The invention as recited in claim 29 wherein said third

and fourth switches have a common contact arm and are alternately operated between open and closed positions, and wherein said first and second switches have a connecting link and are simultaneously operated between open and closed positions.

32. The invention as recited in claim 31 wherein said third and fourth switches cooperate to alternately connect said first switch with said second switch and said first switch with said first control means.

33. The invention as recited in claim 29 wherein said first control means includes a calibration resistor and a holding coil connected in series across said electric igniter, and wherein said holding coil is responsive to at least a preselected voltage drop across said electric igniter to maintain said first and second switches closed.

34. The invention as recited in claim 33 wherein said flame-proving means includes a second calibration resistor selectively connected in parallel with said first calibration resistor in response to energization of said valve means whereby the voltage drop across said electric igniter is reduced below the value of said preselected voltage drop upon burner flame outage.

35. The invention as recited in claim 34 wherein said flame-proving means includes time-delay switching means connected with said valve means, said second calibration resistor and said third control means for connecting said third control means to said electric igniter when said valve means is deenergized and for connecting said second calibration resistor in parallel with said first calibration resistor a predetermined time interval subsequent to energization of said valve means whereby said electric igniter is alternately maintained in a partially energized standby condition prior to energization of said fuel valve and a flame-proving condition subsequent to energization of said fuel valve.

36. The invention as recited in claim 35 wherein said time-delay switching means includes a time-delay relay having a coil connected in parallel with said valve means and a relay switch having pole connected to said electric igniter, a first contact connected to said third control means, and a second contact connected to said second calibration resistor.

37. The invention as recited in claim 36 wherein said third control means comprises a dropping resistor connected between said input means and said second contact of said relay switch.

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