

July 27, 1965

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3,196,929

IGNITION AND CONTROL SYSTEM FOR GAS-FUELED HEATING DEVICES

Filed April 25, 1960

3 Sheets-Sheet 1

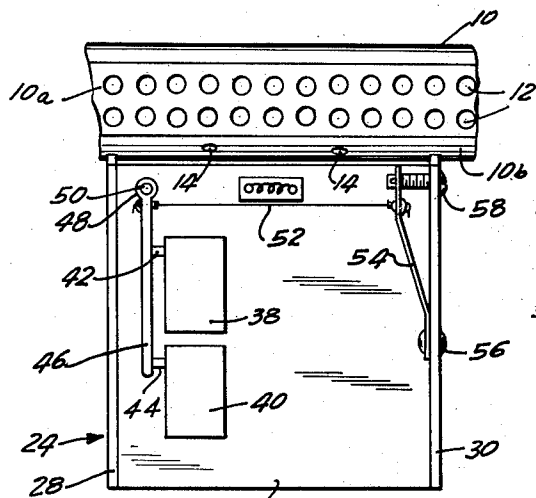


FIG. 1

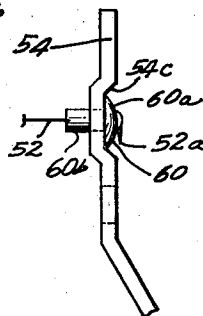


FIG. 3

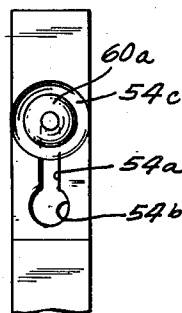


FIG. 4

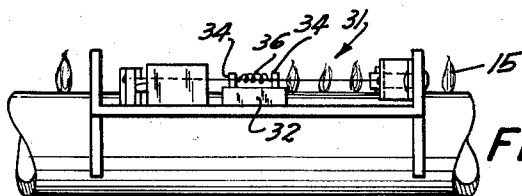


FIG. 2

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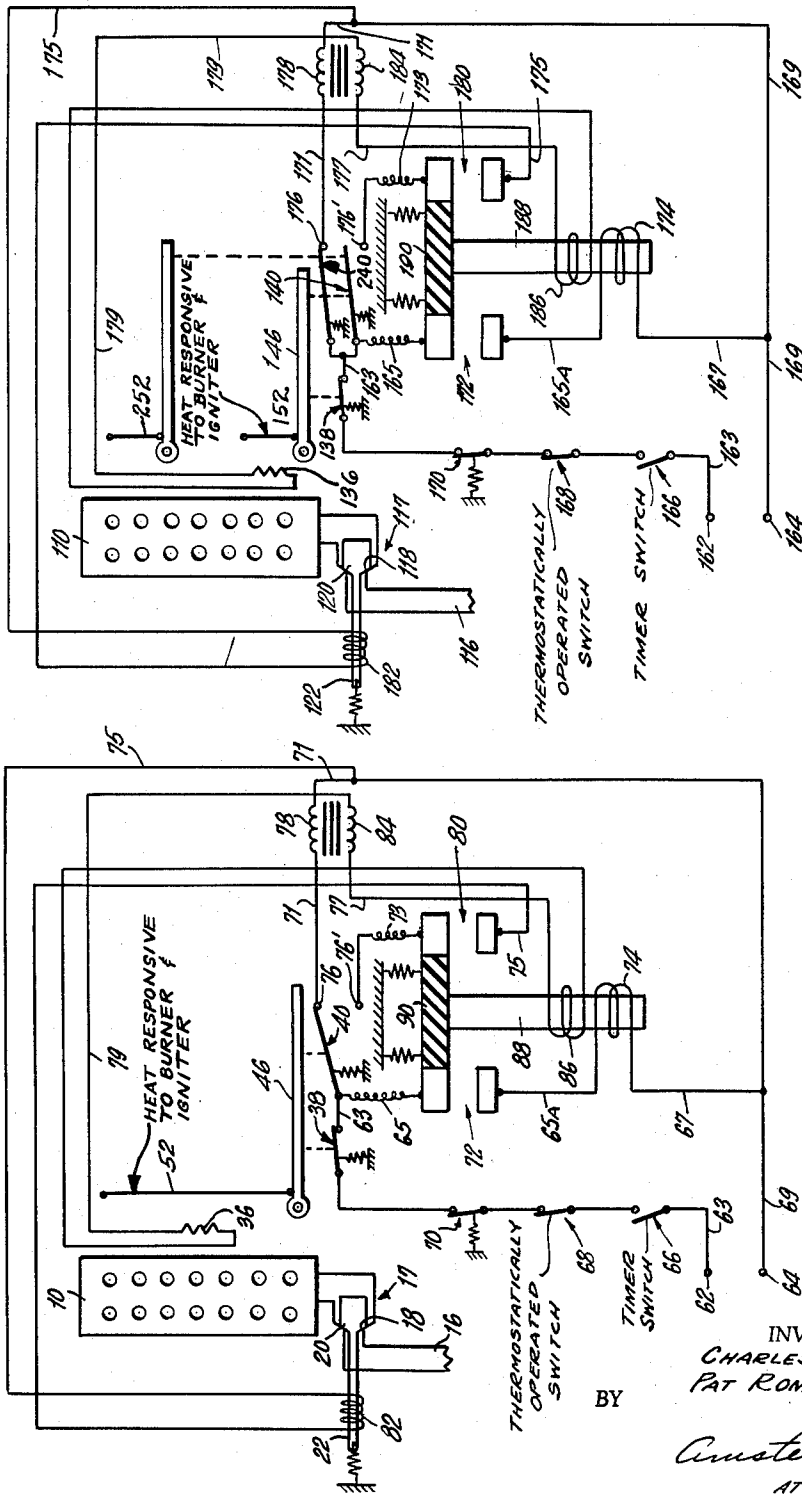
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IGNITION AND CONTROL SYSTEM FOR GAS-FUELED HEATING DEVICES

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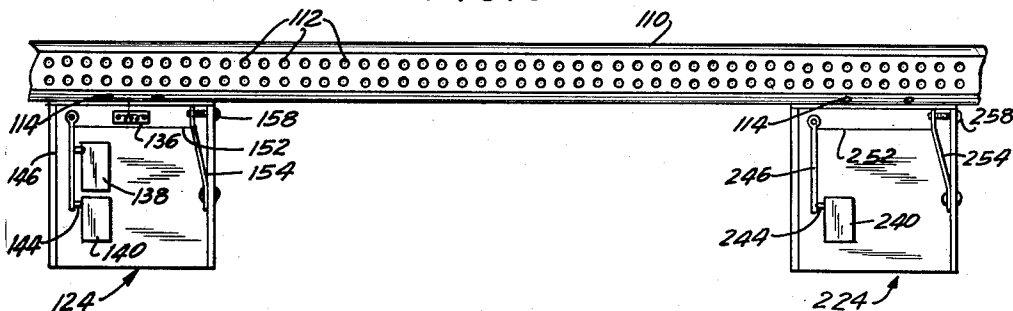
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IGNITION AND CONTROL SYSTEM FOR GAS-FUELED HEATING DEVICES

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FIG. 6



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3,196,929

IGNITION AND CONTROL SYSTEM FOR GAS-FUELED HEATING DEVICES

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4 Claims. (Cl. 158—124)

The present invention relates generally to gas-fueled heating devices such as furnaces, automatic clothes driers, and the like, and in particular to an improved ignition and control system for use with such heating devices.

Recent changes in the safety standards for gas-fueled heating devices such as furnaces, clothes driers, and the like, have placed great emphasis on speed of ignition. The object is to achieve ignition as rapidly as possible after the gaseous fuel has begun to flow through the burner so as to prevent spillage of unburned fuel into the area around the heating device. The mixture of combustible fuel gases and atmospheric oxygen may be highly explosive. The possibility most feared is that an ignition system which operates with a substantial time delay may at first permit quantities of unburned gaseous fuel to escape from the burner to produce an explosive mixture, and then later ignite the escaped fuel to cause a disastrous explosion. In addition to the problem of spillage of unburned fuel occurring upon initial ignition of the heating device, there are also various problems occasioned by different types of ignition system malfunctions which may cause spillage during subsequent operation when the flow of fuel is turned off and then on again, for example in response to normal operating conditions such as thermostatic or timer control. Therefore, it is extremely important to develop an ignition system which always operates to ignite gaseous fuel with the least possible delay after the flow of fuel to the burner has started, and which also is effective at each and every stage of operation of the heating device to prevent spillage of unburned gaseous fuel.

Accordingly, it is broadly an object of this invention to provide an improved ignition and control system for various types of heating devices, particularly those burning gaseous fuel, which will prevent the spillage of unburned fuel. More particularly, it is an object of this invention to prevent such spillage by providing an ignition system which is capable of extremely rapid ignition once the fuel has been allowed to flow through the burner.

In the past, most commercial ignition systems employed in conjunction with heating devices that burn gaseous fuel have been of the type including a gas-fueled main burner which provides the operating heat and a gas-fueled pilot light burner which is mounted adjacent to the main burner so as to be in igniting proximity thereto. The remainder of such an ignition system has typically included means, usually electrically actuated, for igniting the pilot light and for controlling the flow of fuel to the pilot light and the main burner. Such systems also have typically included a fairly complex system of safety relays designed to prevent spillage of unburned fuel during normal operation, and to some extent also during malfunction, of the heating device and the ignition system. It is characteristic of such prior art ignition systems that the pilot light remains lit during continued normal operation of the heating device and serves to ignite the main burner whenever the latter is then turned off and on again in the course of a normal operating cycle. This system of lighting the main burner through the intermediary of a pilot burner, which we may refer to as indirect ignition, is wasteful of fuel because the pilot burner is continuously in operation. In addition,

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it has proved to be rather slow in igniting the fuel and thus allows more unburned fuel to escape from the main burner than is desirable.

A far more rapid system of ignition is achieved by mounting the electrically actuated ignition device adjacent to the main burner so as to be in directly igniting proximity thereto, thus dispensing entirely with the wasteful and slow pilot light. Electrically actuated ignition devices, which generally comprise some sort of high resistance heated by the passage of an electric current there-through, are capable of far exceeding the burning temperature of a typical gaseous fuel, which is around 1700° F. A pilot burner fueled by the same gas necessarily achieves igniting temperatures of the same order. In contrast, the type of electrically actuated ignition device commonly referred to as a "glow coil" is capable of achieving ignition temperatures in the neighborhood of 2200–2400° F. With ignition temperatures of this order present in directly igniting proximity to the main burner, as soon as the first "wave front" of fuel gas emerges from the main burner and approaches the nearby glow coil, nearly instantaneous ignition thereof will take place.

It is therefore specifically an object of this invention to provide a novel direct ignition system in which an electrically actuated ignition device is placed in directly igniting proximity to the main burner so as to perform the function of igniting the main burner directly and with a minimum of delay.

Another object is to provide an ignition system which conserves fuel by eliminating the continuously burning pilot light.

A further object of this invention is to provide associated energizing circuitry and operating components to form a control system cooperating with the ignition device to prevent spillage of fuel during the occurrence of a wide variety of operating conditions.

Advantageously, it has been found that extremely effective protection against spillage can be provided in the environment of a direct ignition system with the use of fewer relays than would normally be required by prior art systems. Accordingly, it is an additional object of this invention to provide an ignition system designed to anticipate a great variety of normal and abnormal conditions which may lead to the spillage of unburned fuel and to correct for such conditions to prevent such spillage, at the same time achieving a considerable saving in circuitry and components.

In accordance with an illustrative embodiment demonstrating additional objects and advantages of this invention, there is provided an ignition system for use with a heating device which has a burner fed through a fuel line governed by a fuel valve which is biased closed and has electrically actuated opening means. The ignition system in accordance with this invention comprises means for preventing spillage of unburned fuel including a switch which has a fuel-feeding position and an electrical operating circuit connected to energize the valve-opening means for opening the fuel valve only when the switch is in the aforesaid fuel-feeding position. Means are further provided for preventing the switch from assuming its fuel-feeding position unless the fuel will encounter a fuel-ignition temperature. A thermally responsive member is mounted in temperature-sensing proximity to the burner, and means are operatively connected to move the switch out of its fuel-feeding position to prevent the flow of fuel in response to contraction of the thermally responsive member when the latter senses the absence of a fuel-ignition temperature at the burner.

The foregoing brief summary, as well as additional advantageous features of this invention, may best be appreciated by reference to the following detailed de-

scription of an illustrative embodiment, when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a top plan view of a portion of a burner and ignition system in accordance with this invention;

FIG. 2 is a front elevational view of the portion of the burner and ignition system of FIG. 1;

FIG. 3 is an enlarged top view of an illustrative tensioning arm for use with the ignition system of this invention;

FIG. 4 is an enlarged side view of the tensioning arm of FIG. 5;

FIG. 5 is a schematic diagram of the operating circuit and associated electrical and electromechanical components of the ignition system of this invention;

FIG. 6 is a top plan view, similar to FIG. 1, of a portion of an extra long burner and a further embodiment of the ignition system of this invention especially adapted for use therewith; and,

FIG. 7 is a schematic diagram, similar to FIG. 5, of the operating circuit and associated electrical and electromechanical components of the modified ignition system embodiment of FIG. 6.

Referring in detail to the drawings, the electrical control system is shown by way of example in a form adaptable for use with an automatic gas-fueled clothes drier in which a main burner 10 is used to provide the heat for the drying operation. The burner 10 has a plurality of gas outlet or transfer holes 12 formed in its top surface 10a. In addition, a pair of auxiliary transfer holes 14 are formed in the side wall 10b of the burner slightly below the top surface 10a. Gaseous fuel is delivered to the burner 10 and issues from the transfer holes 12 and 14 where it burns to form standing flames 15 as seen in FIG. 2.

FIG. 5 shows the burner 10 connected to a fuel line 16 which supplies gas thereto. Shown schematically within the fuel line 16 is a fuel valve 17 which includes a valve seat 18, a valve head 20 and a stem 22 carrying the head 20. The valve stem 18 is solenoid-actuated, in a manner to be presently described, to raise and lower the valve head 20 and thereby control the flow of gas to the burner 10.

Secured to the side wall 10b of the burner is a mounting bracket 24 comprising a horizontal table or platform 26 and a pair of vertically disposed side walls 28 and 30 upstanding therefrom. Mounted on the bracket 24 is an electrical ignition unit 31 and various operating elements of the control system.

The electrical ignition unit 31 is preferably of the type which includes a high resistance element capable of heating to an extremely high temperature of the passage of electric current therethrough. As one example, there may be employed a silicon carbide heating element operable directly from a 115 volt supply. In the preferred form illustrated herein, the heating element is in the form of a glow coil 36 which is best energized from a 115 volt power source through a step-down transformer. The ignition unit 31 also includes a refractory block 32 in which is embedded a pair of terminal posts 34, the glow coil 36 being suspended between the latter. The glow coil 36 is preferably of the type which glows at a temperature of between 2200° F. and 2400° F. when suitably energized.

As shown in FIGS. 1 and 2, the refractory block 32 is mounted on the table 26 in such position as to locate the glow coil 36 in such close proximity to the transfer holes 12 and 14 formed in the burner 10, that gas emerging from said transfer holes will be ignited by the energized glow coil. In FIG. 1, the glow coil 36 is shown close to the burner 10 and positioned between the pair of transfer holes 14. To indicate that the glow coil 36 is sufficiently close to the burner transfer holes 12 and 14 to directly ignite the gas emanating therefrom without the use of an intermediary pilot light, the position of the glow coil may be referred to as being in "directly igniting" proximity to

the transfer holes, and such term will be employed hereafter in the specification and claims in that sense.

Also mounted on the horizontal table 26 are a single pole, single throw fail safe switch 38 and a single pole, double throw operating switch 40, the functions of which will subsequently be described in detail. The switches 38 and 40 are enclosed in housings and are mounted substantially in line with each other. Actuating buttons 42 and 44 respectively protrude from the housings of the switches. The physical in-line relationship of the switches 38 and 40 permits the respective actuating buttons 42 and 44 thereof to be depressed simultaneously by a single switching arm 46 which is pivotally mounted on the horizontal table 26. The switching arm 46 runs generally parallel to the line defined by the switches 38 and 40 and is laterally displaced therefrom by the proper distance for slight pivotal motion of the switching arm 46 in either direction to depress or release the buttons 42 and 44. The switching arm 46 terminates in an eye 48 which is turnably mounted on a pin 50 rising vertically from the horizontal table 26, the pin 50 providing a pivot for the turning of switch arm 46 thereabout in such direction as to actuate the switch buttons 42 and 44.

The switching arm 46 is actuated by a thermally responsive wire 52 mounted immediately behind ignition device 31 and in temperature-sensing proximity thereto. The thermally responsive wire 52 is stretched between the switching arm 46 and a leaf spring tensioning arm 54 mounted on the side rail 30 of bracket 24. In order to selectively vary the tension of the thermally responsive wire 52, one end of the tensioning arm 54 is secured to the rail 30 by any conventional type of fastener 56, and the other end bends away from the side rail 30 and stands free thereof. A tension-adjusting screw 58 passes loosely through an opening in the side rail 30 and is threaded to the free end of tensioning arm 54 so that turning of the screw 58 in either direction serves to advance or retract the tensioning arm 54 to increase or decrease the tension exerted thereby on the thermally responsive wire 52.

FIGS. 3 and 4 show in detail the means by which the ends of the thermal wire 52 may be mounted for easy removal and replacement. The end of the wire 52 is secured to a rivet 60 by passing the wire through a longitudinal bore extending through the shank 60b and head 60a of the rivet, and securing the projecting tip 52a of the wire to the rivet head as by bending it over and soldering it thereto. The tensioning arm 54 is formed with an elongated slot 54a which terminates at one end in an enlarged slot extension 54b. The slot extension 54b is sized to permit the rivet head 60a to pass therethrough, while the slot 54a is only of sufficient width to receive the rivet shank 60b. The rivet head 60a is passed through the slot extension 54b and the rivet 60 moved to the opposite end of slot 54a, the tension of wire 52 holding the rivet in mounted position. A circular depression 54c is stamped in the tensioning arm 54 surrounding the end of the slot 54a opposite the extension 54b. This depression 54c receives the rivet head 60a and prevents the mounted rivet 60 from sliding back toward the enlarged slot extension 54b. The other end of wire 52 can be secured to switching arm 46 in a similar manner.

With the glow coil 36 mounted on the bracket 24 in directly igniting proximity to the burner 10, and the thermally responsive wire 52 immediately behind the ignition device 31 and in temperature-sensing proximity thereto, the thermally responsive wire 52 is also in temperature-sensing proximity to the burner 10 as well. This is particularly so if the extra transfer holes 14 are provided as shown in the side wall 10b of burner 10, as in that case the standing flames 15 issuing from the side transfer holes 14 extend somewhat outwardly toward the thermally responsive wire 52 on either side of the glow coil 36 a sufficient distance to assure warming of the thermally responsive wire 52.

The double throw switch 40 is any conventional type of micro switch which is flipped from one position to another by a very small travel of the actuating button 44. Commercially available switches of this type are designed to flip upon a travel of only two thousandths of an inch of the actuating button thereof. The double throw switch 40 is normally biased by internal means (not shown) toward one of its alternative terminals. In order to adjust the ignition system for operation, however, the tensioning adjustment screw 53 is tightened to advance tensioning arm 54 towards side rail 30 until the thermally responsive wire 52 becomes tight enough when at room temperature to pivot the switching arm 46 sufficiently far to depress the actuating button 44 and move the double-throw switch 40 out of its normal position. As a result, the thermally responsive wire 52 when cool will always keep sufficient tension on the switching arm 46 to hold the actuating button 44 in a depressed position and constrain the double throw switch 40. However, when the thermally responsive wire 52 is heated by either the ignition device 31 or the burner 10, it expands and thus relaxes the tension exerted on switching arm 46. The switching arm 46 is then allowed to reduce the pressure it exerts on the switch-actuating button 44, and the biasing means built into the double throw micro-switch 40 will actuate the latter back to its normal position. A preferred material for the wire 52 which has been found to give good switching results is #5 Nichrome wire, the relatively high coefficient of thermal expansion of the Nichrome alloy being desirable because it increases the sensitivity of the switching action.

The single throw fail safe switch 38 is a micro switch, and has internal biasing means (not shown) normally biasing it toward an open position. However, the fail safe switch 38 is preferably one which requires for actuation a considerably larger throw of its actuating button than does double throw switch 40. The fail safe switch 38 is then mounted on the bracket 24 close enough to the switching arm 46 so that any normal operating position of the switching arm 46 as it pivots back and forth in response to expansion and contraction of the thermally responsive wire 52 will always keep the actuating button 42 depressed sufficiently far to close the fail safe switch 38. Fail safe switch 38 is situated closer to the pivot pin 50 than double throw switch 40 so as to experience a shorter thrust against the actuating button 42 thereof owing to the shorter lever arm of switching arm 46 at that location. As a result of all these factors, the switching arm 46 will go through its normal operating travel to actuate the double throw switch 40 back and forth between its alternative position without ever releasing the actuating button 42 to the extent necessary to open the fail safe switch 38. The internal biasing structure of the fail safe switch 38 succeeds in moving the latter to its open position only when the thermally responsive wire 52 breaks completely or is allowed to go slack and thus releases the necessary operating tension on the switching arm 46 so that the latter can no longer depress the actuating button 42. Thus, the fail safe switch 38 opens only in response to breakage or improper adjustment of the thermally responsive wire 52.

Turning to FIG. 5, it is seen that the electrical components of the ignition and control system include a pair of power supply terminals 62 and 64 and a number of single throw switches. The latter may include a timer switch 66 such as is usually provided in automatic clothes driers, a thermostatically controlled switch 68 which turns the burner on and off in response to temperature fluctuations, and a door switch 70 which is closed only when the door of the clothes drier is closed. The previously described switches 38 and 40 are also included in the circuit. In addition there is a pair of ganged solenoid-actuating switches, holding switch 72 and a cut-off switch 80, which control energization of a holding solenoid 74 and a valve-opening solenoid 82 respectively. A switch-

actuating solenoid 86 and valve-opening solenoid 82 are provided to actuate the ganged switches and the fuel valve 17 respectively. The glow coil 36 is energized from a step-down transformer including a primary 78 and secondary 84.

The electromechanical operating components of the system include a switch-actuating and holding armature 88 which is mounted for downward and upward motion, and which carries the movable contacts of both the holding switch 72 and the valve-actuating switch 80 downwardly and upwardly therewith to close and open both switches concurrently, in ganged fashion. The switch-actuating and holding solenoids 86 and 74 are mounted in tandem about the armature so that either is effective upon energization to attract armature 88 downwardly to close the ganged switches 72 and 80. The movable contacts of the holding switch 72 and the valve-actuating switch 80 are mounted on the armature 88 and are electrically insulated from each other by a non-conductive member 90. As an advantageous feature of this invention, only one other solenoid is required for the operation of this ignition system, the valve-opening solenoid 82 which employs valve stem 22 as an armature. The valve-opening solenoid 82 when energized attracts the valve stem 22 to move the valve member 20 away from valve seat 18, thus opening the fuel valve 17 and permitting gas to flow from the fuel line 16 into the burner 10. When the solenoids 74, 82 and 86 are not energized, the armatures 22 and 88 are urged by any conventional spring or other biasing means (not shown) to assume the positions illustrated in FIG. 5. That is, the valve stem 22 is biased outwardly of valve seat 18 to keep the fuel valve 17 closed, and the armature 88 is raised to keep the ganged holding switch 72 and valve-actuating switch 80 open.

Power supply terminal 62 is connected in series through a lead 63 to the succession of switches 66, 68, 70 and 38, which must all be closed in order for the ignition and control system to operate and to open the fuel valve 17.

From lead 63 the operating circuit divides into three separate branch circuits. One of the three branch circuits proceeds from lead 63 through a lead 65 to a holding relay circuit including the solenoid-actuated holding switch 72 and a holding solenoid 74, subsequently returning to the power supply terminal 64 through leads 65A and 67 and a master return lead 69. The other two branch circuits each proceed from lead 63 through the single pole, double throw switch 40 which is mounted upon the bracket 24. This switch selects one of two alternative terminals, an igniting terminal 76, or a fuel-feeding terminal 76'. The second branch circuit proceeds from the igniting terminal 76 of double throw switch 40 through a lead 71 to the transformer primary 78 and then returns through lead 69 to the power supply terminal 64. The third branch circuit proceeds from the fuel-feeding terminal 78 of the double throw switch 40 through a lead 73 to the cut-off switch 80, through a lead 75 to the valve-opening solenoid 82, and then through return lead 69 to the power supply terminal 64. The double-throw switch 40 thus makes a selection as between the second and third branch circuits by being moved to one or the other of the two alternative terminals 76 and 76'.

The transformer secondary 84 is connected through leads 77 and 79 to glow coil 36 and the switch-actuating solenoid 86. The glow coil 36 and the switch-actuating solenoid 86 are connected in series so that energization of the switch-actuating solenoid 86 is impossible unless the glow coil 36 is also energized.

In the event that the glow coil 36 is replaced by a 115 volt silicon carbide ignition element, the latter would be connected in series with solenoid 82 directly between terminal 76 and lead 69, eliminating the transformer 78, 84 entirely.

The foregoing description will now enable an understanding of the operation of this ignition system. Under normal operating conditions and before the burner 10 is lit, the tension of thermally responsive wire 52 will be so adjusted and the temperature thereof will be such that the switching arm 46 depresses actuating button 44 to hold the double throw switch 40 in its igniting position, that is, connected to igniting terminal 76. The actuating button 42 is, of course, also depressed to keep fail safe switch 38 closed. The thermostatically controlled switch 63 will be closed prior to operation of the heating device in response to the resulting low temperature. When the clothes drier is loaded and the loading door closed, door switch 70 will then also be closed. At this point, prior to the start of an operating cycle, all switches and armatures are in the positions shown in FIG. 5. These are the positions to which they are biased or otherwise moved prior to ignition, or, in the case of switches 38 and 40, to which they are constrained prior to ignition by wire 52 against the urging of their internal biasing means when the wire 52 is cool.

The operator then closes the timer switch 66 by setting the timer to initiate operation of the drier. The first result of the closing of all the aforesaid switches is that operating current runs through the branch circuit which proceeds from igniting terminal 76 of double throw switch 40 through the transformer primary 78. This energizes the transformer secondary 84, the glow coil 36, and the switch-actuating solenoid 86. The armature 88 then moves downwardly to close the ganged cut-off switch 80 and holding switch 72. Upon energization, glow coil 36 begins rising rapidly to a fuel-ignition temperature. The closing of cut-off switch 80 completes the circuit between fuel-feeding terminal 76' and power supply terminal 64 valve-actuating solenoid 82. This circuit cannot be energized to open the fuel valve 17 however, until the double throw switch 40 is moved to its fuel-feeding position, that is, connecting to fuel-feeding terminal 76'. The double throw switch 40 is prevented from doing this by the tension of the thermally responsive wire 52 when the latter is cool. However, when the heating of glow coil 36 has proceeded to the point where the latter attains a fuel-ignition temperature, then the thermally responsive wire 52 relaxes its tension against the switching arm 46 and permits the internal biasing means of the double throw switch 40 to move the latter to its fuel-feeding position. At that point the double throw switch 40 connects power supply terminal 62 to the branch circuit proceeding from fuel-feeding terminal 76' through the now closed cut-off switch 80 and the valve-opening solenoid 82, with the result that the fuel valve 17 is opened. Fuel then passes from fuel line 16 into the burner 10 and is ignited by the hot glow coil 36.

In switching from the igniting terminal 76 to the fuel-feeding terminal 76', the double throw switch 40 energizes the valve-opening solenoid 82 and opens fuel valve 17 at the expense of simultaneously deenergizing glow coil 36 and switch-actuating solenoid 86. However, de-energization of glow coil 36 is immaterial at this point because the latter remains at a more than adequate fuel-ignition temperature during the short time that it takes for the fuel to be ignited after the glow coil 36 is de-energized and the fuel valve 17 is simultaneously opened.

The de-energization of the switch-actuating solenoid 86 would cause re-opening of the cut-off switch 80, since the armature 88 is biased in that direction, but the holding solenoid 74 is provided to prevent this. This solenoid is energized through holding switch 72. Initial closing of the cut-off switch 80 when the double throw switch 40 moves to its fuel-feeding position is effective to close the holding switch 72 ganged therewith. Once the latter has closed, the holding solenoid 74 is energized to keep the armature 88 down and cut-off switch 80 closed for as long as the operating circuit continues to draw current from the power supply terminals 62 and 64.

As an important safety feature of this invention, if de-energization of the operating circuit should occur, as for example if the timer opens switch 66, the thermostat opens switch 63, or the door of the heating device is opened to open switch 70, then the holding solenoid 74 will be de-energized, immediately opening the holding switch 72 so that the holding solenoid 74 remains de-energized. The cut-off switch 80 will also be opened and will remain open, de-energizing valve-actuating solenoid 82 to close the fuel valve 17. The flow of fuel is then terminated until re-ignition occurs.

When the switches 66, 63 and 70 are all closed again re-ignition will occur in the following manner. The shutting off of the flame at the burner 10 caused by de-energization of valve-actuating solenoid 82 in turn causes the thermally responsive wire 52 to cool down. Until such cooling is achieved the double throw switch 40 remains biased to its fuel-feeding position because the still thermally expanded wire 52 does not exert the necessary tension on switching arm 46 to depress switch-actuating button 44. However, no fuel flows because the cut-off switch 80 is open and cannot be reclosed without re-energizing switch-actuating solenoid 86, and that event must in turn await the flipping of double throw switch 40 to its igniting position when the thermally responsive wire 52 cools down. Once the thermally responsive wire 52 has cooled sufficiently, it will once again exert tension on the switching arm 46, and the latter will then depress actuating button 44, moving the double throw switch 40 back to its igniting position to energize the glow coil 36 and the switch-actuating solenoid 86, and thus starting another operating cycle.

If at any time the fuel issuing from the burner 10 should fail to be ignited by the ignition element 36, as for example due to a strong draft or perhaps to some malfunction of the heating device or ignition system, the ignition system will recycle until the burner 10 is ignited. The recycling spoken of here consists of continuously reheating the ignition element 36, opening the fuel valve 17, then shutting the fuel valve 17 if the fuel fails to ignite, and then reheating the ignition element once again. The recycling operates in the following manner. When the attainment of a fuel-ignition temperature by the glow coil 36 causes the double throw switch 40 to move to the fuel-feeding terminal 76', this necessarily causes the double throw switch to leave the igniting terminal 76 and thus de-energize the ignition element 36. The latter begins to cool down because it is no longer supplied with power. Normally, the fuel which begins to issue from the burner 10 upon movement of the double throw switch 40 to the fuel feeding terminal 76' is ignited immediately by the cooling but still very hot glow coil 36, ignition is thus achieved, and the thermally responsive wire 52 is subsequently kept in a state of thermal relaxation by the flames 15 issuing from the transfer holes 12 and 14. The glow coil 36 then cools and remains dormant until called upon the next time it is necessary to ignite the burner 10. The temperature of the glow coil 36 does not affect the thermally responsive wire 52, however, for the latter continues to be heated by the flames 15. If, however, the burner 10 fails to ignite, then there are no flames 15 to maintain the thermally responsive wire in an expanded condition. Then, the cooling of the glow coil 36 becomes important. Such cooling allows the thermally responsive wire 52 to cool and contract which causes the double throw switch 40 to be returned by switching arm 46 to its igniting position once again, thus re-energizing glow coil 36 to start another cycle and another attempt at igniting the burner 10.

Referring in detail to FIGS. 6 and 7, a modified embodiment of the ignition and control system will now be described. In these figures elements corresponding to elements of the previously described embodiment are given reference numerals differing by an increment of

one or two hundred to illustrate the correspondence therebetween. This modified embodiment is particularly suited to use with heating devices having especially long burners. A portion of such a burner 110 is illustrated in FIGS. 6 and 7. A problem arises in adapting the ignition system of this invention to burners of this length, owing to the fact that when one part of the burner 110 is lit by a glow coil 136 located at the left end thereof, some delay occurs until the flame travels along the burner 110 to light the right end thereof. In the meantime, the glow coil will have been de-energized if the ignition system must leave its igniting phase in order to enter its fuel-feeding phase, as described above. With a shorter burner 10 all of which ignites substantially at once, de-energization of the glow coil 36 at the moment the fuel is fed is of no consequence since the glow coil 36, although cooling, continues to glow during the brief moment required to light the entire burner 10. But with the long burner 110, the ignition element 135 may cool down below fuel-ignition temperature before the flame has advanced across the entire burner if it is de-energized when the fuel is turned on. It would therefore be preferable to continue to energize the glow coil 136 between the turning on of the fuel and the subsequent lighting of the right end of burner 110.

In order to achieve this, the operating circuit of the ignition and control system is modified as shown in FIG. 7. As indicated by the matching reference numerals, the circuit there illustrated is identical with that of FIG. 5 as to the components employed and their interconnection and interaction, except that the double throw operating switch 40 of FIG. 5 is replaced in FIG. 7 by a pair of single throw operating switches 140 and 240. Lead 163 is connectable to the fuel-feeding terminal 176 through a fuel-feeding switch 140, and to the igniting terminal 176 through an igniting switch 240. Fuel-feeding switch 140 performs the fuel-feeding function of double throw switch 40, while igniting switch 240 performs the igniting function of double throw switch 40. The advantage gained by the modification is that the two single throw switches 140 and 240 can perform the fuel-feeding and igniting functions independently instead of alternatively, and thus can switch at different times. This permits de-energization of the glow coil 136 by igniting switch 240 at a time subsequent to the turning on of the fuel by fuel-feeding switch 140.

As seen in FIG. 6, the fuel-feeding switch 140 is mounted on a first bracket 124 at the left end of burner 110. This switch is an enclosed micro switch normally biased closed by internal biasing mechanisms (not shown) and actuated by a very small travel of its actuating button 144. Switch 140 is similar to switch 40 except that it is a single rather than double throw switch. It is held open by a first, or fuel-controlling, thermally responsive wire 152 when such wire is cool. The wire 152 is identical to the wire 52 of the first embodiment, and operates in conjunction with a switching arm 146, tensioning arm 152, adjusting screw 158, etc. in the manner previously described, the numbering system specifically illustrating the applicability of the previous description to this embodiment. The glow coil 136 is also mounted on this first bracket 124, so that the wire 152 senses the temperature of glow coil 136 and initially opens the fuel valve 117 only when the glow coil is at a fuel-ignition temperature. The wire 152 is also in temperature-sensing proximity to the flames at the left end of burner 110, so as to remain in a state of thermal expansion and thereby keep the fuel valve 117 open once the burner 110 is lit. Fail safe switch 138 is also mounted on the first bracket 124 and opens to de-energize the entire operating circuit upon failure of the fuel-controlling wire 152 so as to prevent release of fuel when that wire is inoperative and thus cannot transmit the information that the glow coil 136 or burner 110 is not at a fuel-ignition temperature.

A second bracket 224 is mounted at the right end of

elongated burner 110, and carries the igniting switch 240, which is a single throw enclosed micro switch actuated by a button 244 just like the fuel-feeding switch 140 except that it is normally biased open by its internal mechanism (not shown). A second, or de-energizing, thermally responsive wire 252 is mounted by members 246, 254, and 258 of the type previously described to hold the switch 240 closed when the wire is cool. Wire 252 is positioned to sense any flames issuing from the right end of burner 110, and opens the switch 240 in response thereto to de-energize glow coil 136. A second fail safe switch to inactivate the ignition system in the event of breakage of the wire 252 is not necessary because of an inherent fail safe feature. The switch 240, unlike switch 140, is biased open when the tension of wire 252 on switching arm 246 is relaxed, so that the power supply to the glow coil 136 and switch-actuating solenoid 186 is disrupted. Consequently, in the event of a failure of wire 252, the glow coil 136 will not light and the fuel valve 117 will not initially open because solenoid 186 cannot close cut-off switch 130.

Auxiliary transfer holes 114 may be provided as in the previous embodiment, one pair aimed at each of the wires 152 and 252 to assure warming thereof when the burner 110 is lit.

Just prior to the start of an operating cycle, all switches and armatures are in the positions illustrated in FIG. 7. These are the positions to which they are biased or otherwise moved prior to ignition, or, in the case of switches 138, 140 and 240, to which they are constrained prior to ignition by wires 152 and 252 respectively against the urging of the internal biasing means of these switches when the wires 152 and 252 are cool. When timer switch 166 is closed, current flows through the closed switch 240 to energize the glow coil 136 and close the valve-actuating switch 130. When the glow coil 136 heats to a fuel-ignition temperature, it expands fuel-feeding wire 152, which allows fuel-feeding switch 140 to close. The valve-opening solenoid 182 is then energized through the closed switches 140 and 130 to open the fuel valve 117. However, de-energizing switch 240 remains constrained to the closed position by the wire 252, and thus glow coil 136 remains energized as the fuel begins to flow. It is not de-energized until the flame front started at the left end of burner 110 advances to the right end and expands the de-energizing wire 252, allowing the switch 240 to open and thereby cut off the power supply of glow coil 136. In all other respects, this embodiment functions in the same manner as the embodiment fully described above.

It will now be appreciated that the present invention provides an extremely fast ignition system which operates in accordance with the spirit of the new safety standards for gas-operated heating devices to ignite the gaseous fuel before substantial spillage of unburned fuel can take place. In addition, this device provides many control features which prevent such spillage during all operating phases and which provide in general for the safe operation of a gas-fueled heating device, while at the same time using fewer relays and circuits than prior art devices. In addition, this system achieves a saving of the fuel ordinarily wasted by the pilot light of indirect ignition systems.

The particulars of the foregoing description are provided merely for purposes of illustration and are subject to a considerable latitude of modification without departing from the novel teachings disclosed herein. Accordingly, the scope of this invention is intended to be limited only as defined in the appended claims, which should be accorded a breadth of interpretation consistent with this specification.

What I claim is:

1. In combination with a heating device having a burner fed through a fuel line governed by a fuel valve having means biasing it closed and electrically actuated opening means, a direct ignition system comprising an electrically

energized ignition device, means for mounting said ignition device in directly igniting proximity to said burner, an electrical operating circuit, means for preventing spillage of unburned fuel including operating switch means connectable for fuel feeding and igniting, a safety relay including a cut-off switch, said operating circuit being connected to energize said valve-opening means only when said cut-off switch is closed, means biasing said cut-off switch open to prevent opening of said fuel valve, and a switch-actuating solenoid operable upon energization to close said cut-off switch to permit opening of said fuel valve, said operating circuit connecting said ignition device and said switch-actuating solenoid in series whereby to prevent energization of said switch-actuating solenoid for opening said fuel valve unless said ignition device is energized concurrently therewith, said operating circuit being connected to energize said switch-actuating solenoid for opening said fuel valve only when said operating switch means is connected for fuel feeding, means for preventing said operating switch means from being connected for fuel feeding unless the fuel will encounter a fuel-ignition temperature including thermally responsive means, means for mounting said thermally responsive means in temperature-sensing proximity to both said burner and said ignition device, and switching arm means operatively connected to prevent said operating switch means from being connected for fuel feeding and to connect said operating switch means for igniting in response to contraction of said thermally responsive means upon the sensing thereby of the absence of a fuel-ignition temperature, said operating circuit being connected to energize said ignition device to heat the same to a fuel-ignition temperature to light said burner only when said operating switch means is connected for igniting, said operating switch means being biased to be connected for fuel feeding and to be prevented from being connected for igniting in response to expansion of said thermally responsive means upon the sensing thereby of a fuel-ignition temperature, a holding relay including a holding solenoid operable during energization to keep said cut-off switch closed to permit a continued flow of fuel when said operating switch means is not connected for igniting, and a holding switch, said operating circuit being connected to energize said holding solenoid when said holding switch is closed, means ganging said cut-off switch and said holding switch for concurrent closing and opening whereby initial closing of said cut-off switch is effective to permit a continued flow of fuel as long as said operating circuit remains continuously energized and whereby de-energization of said operating circuit de-energizes said holding solenoid and thereby terminates the flow of fuel until re-ignition occurs, a pair of power supply terminals for said operating circuit, a fail safe switch in series with said terminals and said operating circuit and biased open whereby to interrupt the power supply of said operating circuit to close said fuel valve, and means arranged to close said fail safe switch when said thermally responsive means is capable of exerting an operating force on said switching arm.

2. An ignition system in combination with a heater having a burner, an electrically operated fuel valve for selectively delivering fuel to the burner, and an electric ignition coil, said system comprising a first circuit connected to said ignition coil, a second circuit connected to said fuel valve, a power source, operating switch means for selectively connecting said power source to said first circuit and said second circuit for selectively heating said ignition coil and opening said fuel valve, thermally re-

sponsive means in proximity to said burner and in proximity to said ignition coil and operatively connected to said operating switch means for deenergizing said ignition coil in response to the attainment of fuel igniting temperature in proximity to said heat responsive means and for energizing said fuel valve for opening same in response to the attainment of fuel igniting temperature in proximity to said heat responsive means, and safety means including a double-pole, single-throw normally-open switch, an actuating solenoid and a holding solenoid each independently operable to close said switch, one of the poles of said switch being connected in series with said second circuit, the actuating solenoid being in series with said ignition coil in said first circuit, said holding solenoid being connected through the other pole of said switch to said power source in a holding circuit, and a fail safe switch in series with said first circuit and said holding circuit and operable to maintain said fuel valve closed and said ignition coil deenergized in response to incapacity of said thermally responsive means to control said operating switch means.

3. The combination of claim 2 wherein said operating switch means comprises a double throw switch having alternative fuel-feeding and igniting positions, said double throw switch in said fuel feeding position connecting said power source to said second circuit and deenergizing said first circuit, said double throw switch in said igniting position connecting said power source to the first circuit and deenergizing the second circuit.

4. In combination with a heater having an elongated burner, an ignition system according to claim 2 wherein said operating switch means includes a first switch in series in said first circuit for controlling said ignition coil, and a second switch in series in said second circuit for controlling said fuel valve, said thermally responsive means including first and second thermally responsive wires operatively controlling said first and second switches respectively, said first thermally responsive wire being in proximity to said burner at a location removed from said ignition coil for deenergizing said ignition coil when a fuel igniting temperature is attained at a burner location proximate to said first thermally-responsive wire, said second thermally responsive wire being in proximity to both said ignition coil and said burner for opening said fuel valve in response to the attainment of fuel igniting temperature at either said burner or said ignition coil, and said fail safe switch being mounted in operative relation to said second thermally responsive wire to open said first circuit and said holding circuit in response to incapacity of said second thermally responsive wire to prevent the flow of fuel when fuel igniting temperature is achieved at neither said ignition coil nor at said burner.

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