

Oct. 1, 1940.

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2,216,556

BURNER CONTROL SYSTEM

Filed Aug. 4, 1938

4 Sheets-Sheet 1

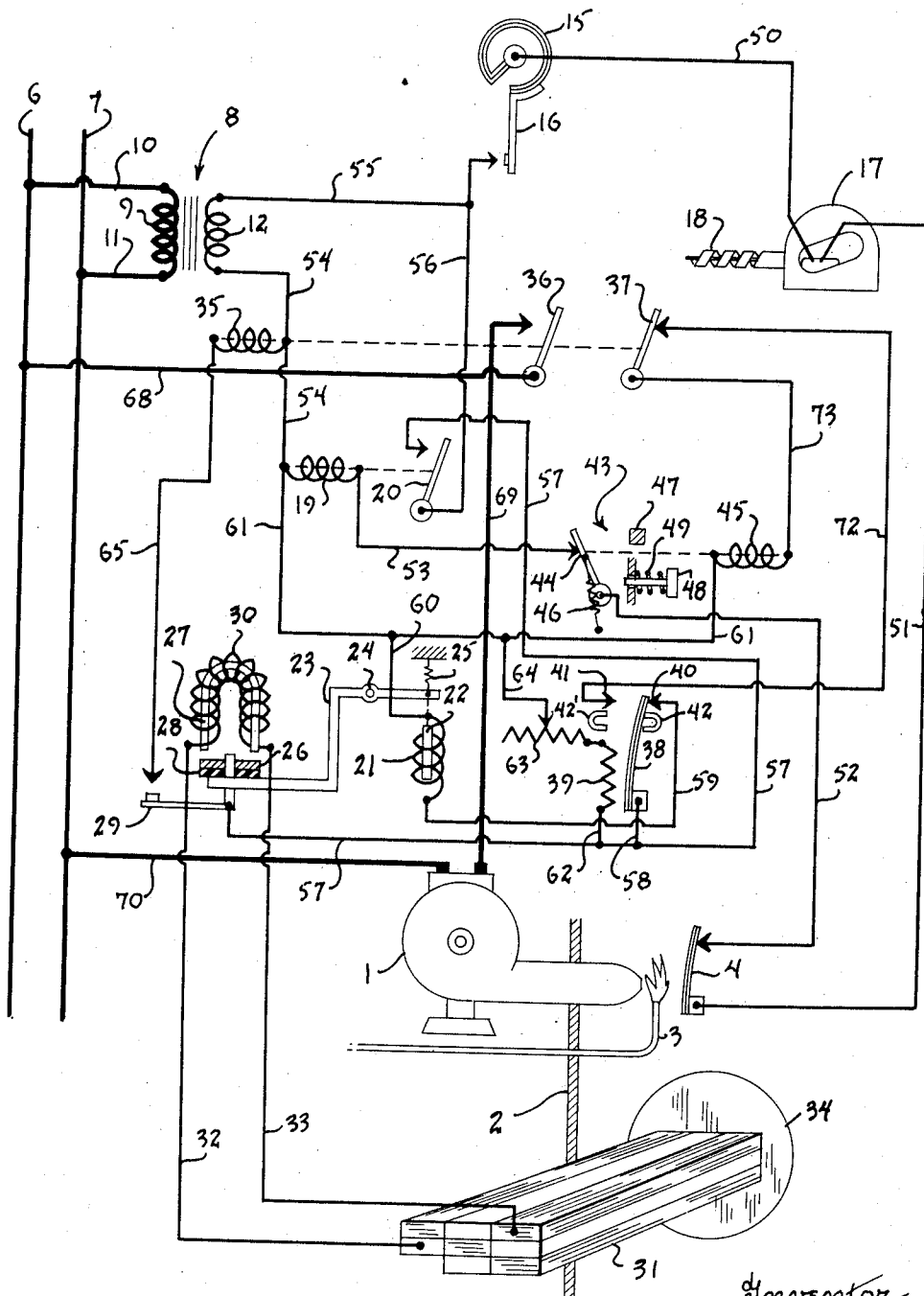


Fig. 1

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4 Sheets-Sheet 2

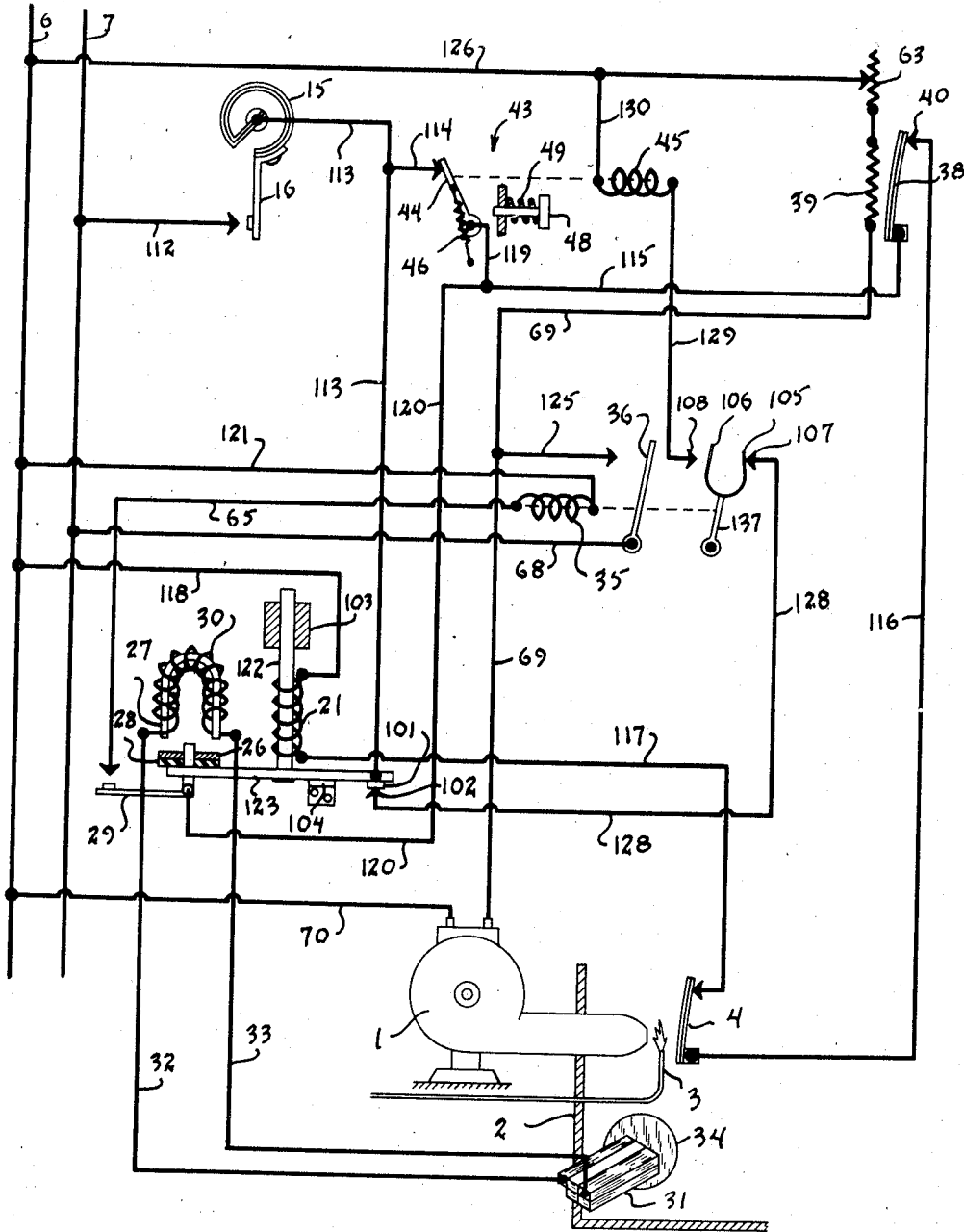


Fig. 2

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4 Sheets-Sheet 3

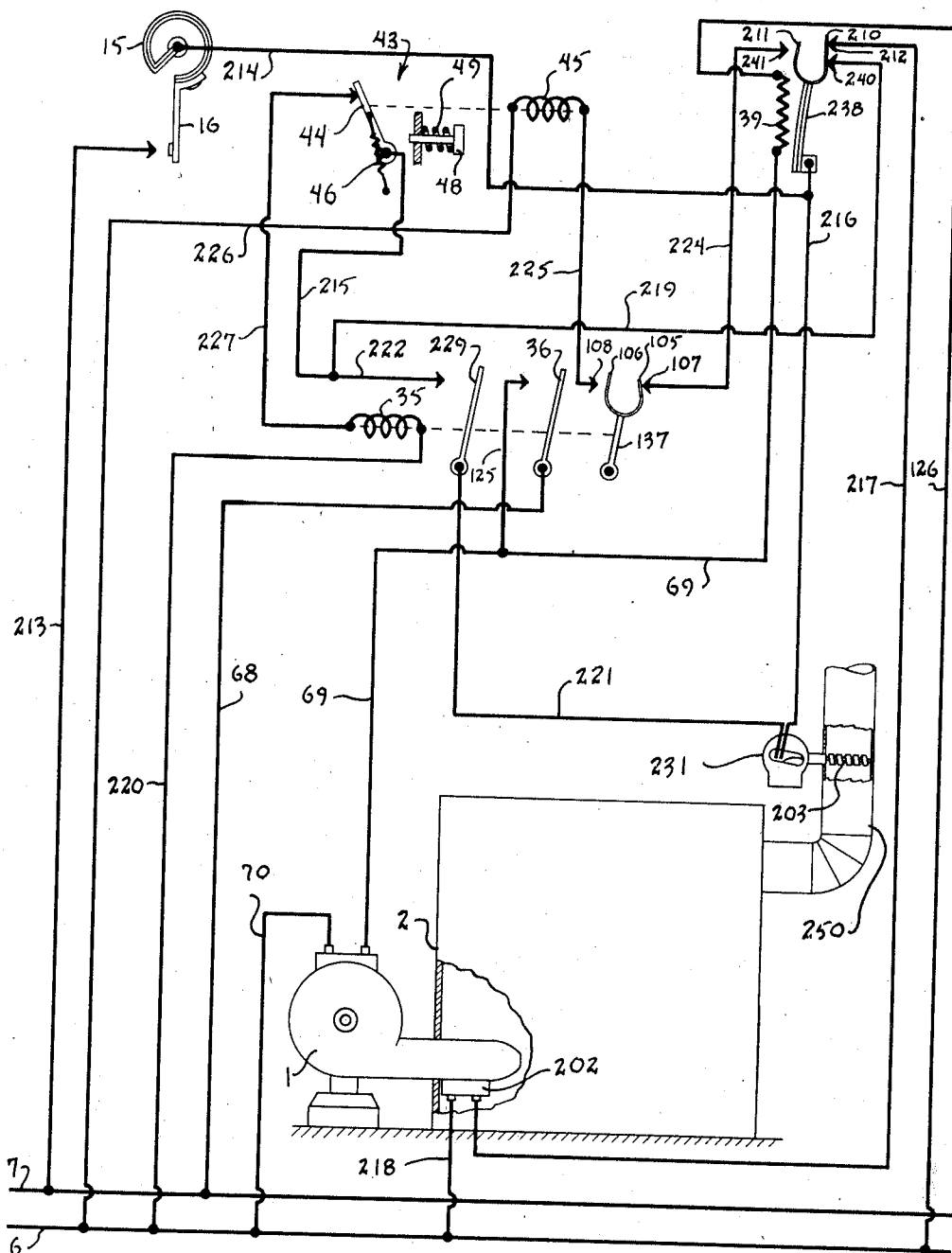


Fig. 3

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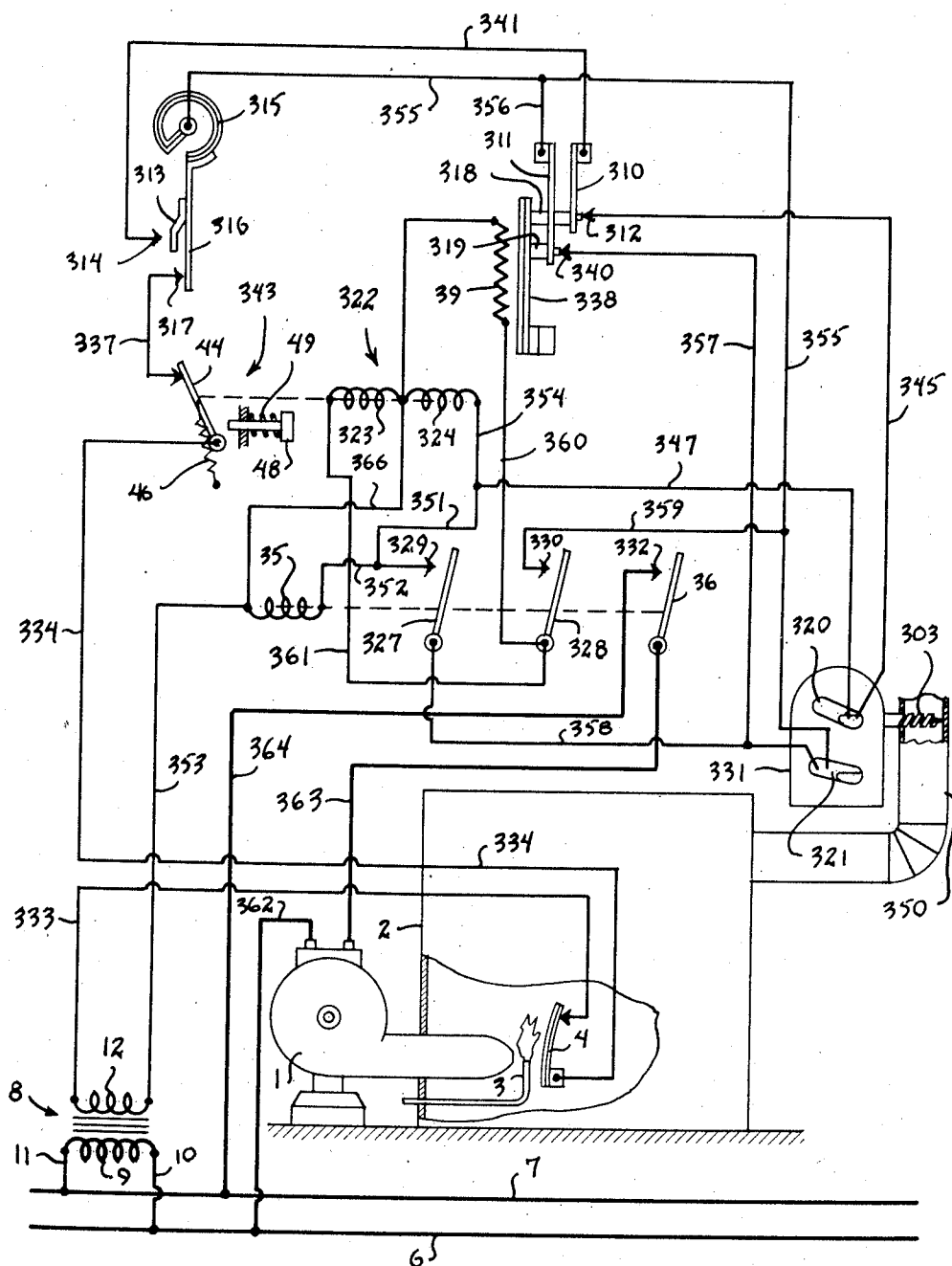
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,216,556

BURNER CONTROL SYSTEM

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Application August 4, 1938, Serial No. 223,047

15 Claims. (Cl. 158—28)

My invention relates to automatic control mechanism for fluid fuel burners and the like and is directed more particularly to improvements in temperature responsive control apparatus having novel and unusual safety features incorporated therein.

Referring broadly to the art, fuel burners are usually controlled primarily by a thermostat in conjunction with a safety pilot or electrical ignition means and some type of combustion responsive device for stopping the burner if flame does not appear upon starting or upon flame failure at any time during operation. Thermal timing devices are commonly used to interrupt the starting circuit of the burner and put the burner under control of a holding circuit through the thermostat and combustion responsive device. In the past also, safety shutdown devices requiring manual reset have been used to deenergize the control system in the event of flame failure.

My invention contemplates the use of a thermopile combustion responsive device in some forms of the invention wherein operation of the burner becomes dependent on the thermopile after starting of the burner. My invention also contemplates the distinct improvement of instantaneously shutting down and automatically locking out the system in the event of flame failure.

These and other improvements characterize my invention as well as the accomplishment of the ends set forth in the following objects.

A primary object of my invention is to provide a control device for a fuel supply device which is moved to one position in response to manual or condition responsive means and is maintained in that position dependently upon a thermopile mechanism.

Another object of my invention is to provide a control system of the type described embodying simplicity and economy of construction and capable of safely and efficiently adapting itself to all operating contingencies thus providing those employing it with greater security and requiring only a minimum of attention from them.

Another object of my invention is to provide in a system of the type described, an instantaneous lockout device for shutting down the system in the event of flame failure, the device being so incorporated in and cooperating with the system that safety shutdown does not occur except in the event of such a contingency as would call for inspection and possibly repair of the system.

Another object of my invention is to provide a control system for a heating apparatus wherein

a thermostat moves a relay device to a starting position of a fuel supplying device and the relay device is maintained in position by current generated in a thermopile.

Another object is the provision of improved and reliable safety mechanism for fuel control systems and the like.

Figure 1 is a diagrammatic view of one form of my improved control and wiring arrangement,

Figure 2 is a diagrammatic view of a second form of my improved control and wiring arrangement,

Figure 3 is a diagrammatic view of a third form of my improved control and wiring arrangement, and

Figure 4 is a diagrammatic view of a fourth form of my improved control and wiring arrangement.

Referring to Figure 1 of the drawings I have shown a form of my invention adapted for application to a fluid fuel burner and employing a combustion responsive device comprising a thermopile. Numeral 1 indicates the fuel burner which is of the gun type having its nozzle extending through the wall of a furnace or boiler indicated at 2. Numeral 3 indicates a constantly burning pilot burner as conventionally used with fluid fuel burners and adjacent the burner 3 is a temperature responsive bimetal safety switch of the type commonly used with pilot burners. The switch 4 is closed at all times except in the event of the extinguishment of the pilot burner.

The burner 1 is driven by an electric motor and my entire control system is supplied with power from electrical conductors 6 and 7. Numeral 8 represents a step-down voltage transformer which may be of conventional type having a primary winding 9 connected to the electrical conductors 6 and 7 by wires 10 and 11 respectively as shown. The transformer 8 has a secondary 12 for supplying power at suitable voltage for the various elements of my control system.

The system is primarily controlled by a thermostat 15 which may be of conventional type and is preferably located in spaces being supplied with heat from the furnace or boiler indicated at 2. The thermostat 15 has a movable switch arm 16 adapted for closing an electrical circuit through an associated fixed contact as shown. The oil burner 1 is additionally controlled by a mercury type boiler high limit switch indicated at 17. The switch 17 is controlled by a helical temperature responsive element 18 which is preferably located so as to be responsive to boiler water temperatures and which keeps the switch 17 closed at

all times except when the boiler water temperature reaches a relatively high temperature value at which it shuts down the burner.

I employ a number of relays of conventional type in my control system which may be energized in response to the thermostat 15 for bringing about various operating functions in my system. Numeral 19 indicates a relay coil winding arranged to operate a switch 20. At 21 I have indicated a winding having an armature 22 associated therewith and arranged to rotate the pivoted angular lever arm 23 about a pivot 24 when the coil winding is energized. The lever arm 23 is biased in a counter-clockwise direction by a coil spring 25 and carries an armature 26 arranged to engage with an electromagnet indicated at 27. The armature 26 is spaced from the arm 23 by a resilient insulating member 28. The arm 23 also carries a switch arm 29 which assumes closed position when the relay coil 2 is energized. Associated with the electromagnet 27 is a coil winding 30 the ends of which are connected to a thermopile 31 by wires 32 and 33. The thermopile 31 comprises a number of thermo-couple elements combined in the conventional manner for producing a thermopile and is arranged so as to be responsive to combustion within the furnace whereby the thermopile may produce an energizing current for the coil winding 30. One corresponding junction of each thermo-couple is of course exposed to furnace heat while the other junction is not. A lens 34 may be provided to concentrate heat upon the junctions exposed to furnace heat. While the thermopile 31 does not have sufficient capacity to energize the winding 30 enough to cause the armature 26 to be drawn upwardly it will cause the armature 26 to be held in the "in" position if it has been moved to that position by energization of the relay winding 21. Numeral 35 indicates another relay coil arranged to operate switches 36 and 37 in the conventional manner and which is energized normally upon switch 29 becoming closed.

Numeral 38 indicates a thermal timer having an electrical heating resistance 39 associated therewith which I employ for producing a particular sequence of operation in my system. The thermal timer 38 comprises a snap acting bimetal switch element so arranged that a fixed contact 40 is made when the timer is deenergized and a fixed contact 41 is made when the timer is energized, the movement of the bimetal element between the fixed contacts taking place with a snap action, by reason of permanent magnets 42 and 42' placed as shown.

Numeral 43 indicates generally a safety shutdown switch having a manual reset mechanism and which comprises a switch arm 44 and a relay coil winding 45 for operating the switch. Associated with the switch arm 44 is an over-center spring 46 which in the position of the parts shown holds the switch in closed position and which operates to hold the switch in open position whenever the coil winding 45 is energized causing the switch arm 44 to move in opening direction past its dead center position with respect to spring 46. A stop 47 limits the movement of switch arm 44 in opening direction and a manual knob 48 is provided for reclosing the switch 44 after it has been opened. The manual knob 48 may be forced inwardly against the switch arm 44 against the force of the coil spring 49 encircling the stem of the knob 48.

I will now describe the operation of my improved control system and the various electrical

circuits which I employ in producing my particular sequence of operation. With the parts in the position shown, the thermostat is satisfied and the burner 1 is not in operation. Upon a call for heat by the thermostat an electrical circuit is completed from secondary 12, wire 55, wire 56, thermostat 15, wire 50, switch 17, wire 51, safety pilot 4, wire 52, safety switch 43, wire 53, relay coil 19, and wire 54 to one end of the secondary winding 12 of transformer 8. It will be seen that the thermostat 15 is connected to the secondary winding 12 by a wire 55 and a portion of wire 56. Upon energization of relay coil 19, switch 20 closes completing a circuit through relay coil 21 which is as follows: from the secondary winding 12 through wires 55 and 56 to switch 20, through wire 57, a wire 58, thermal timer 38, contact 40, wire 59, relay coil 21, and wires 60, 61, and 54 to the opposite end of winding 12. When switch 20 closes, a circuit for the electrical heating resistance 39 is also completed which is as follows: from the secondary winding 12 through wires 55 and 56, switch 20, wire 57, wire 62, heater 39, a variable resistance 63, wire 64, and wires 61 and 54 back to the secondary winding 12.

Immediately upon energization of relay coil 21 arm 23 is rotated in a clockwise direction causing armature 26 to engage with the electromagnet 27 and causing switch 29 to close. Upon closure of switch 29 an electrical circuit for energizing relay coil 35 is completed which is as follows: from secondary winding 12 through wires 55 and 56, switch 20, wire 57, switch 29, wire 65, the relay coil 35 and the wire 54 back to the secondary winding 12. Immediately upon energization of relay coil 35, the switch 36 is closed and switch 37 is opened, closure of switch 36 completing an electrical circuit for oil burner 1 from conductor 6 through a wire 68, the switch 36, a wire 69, the oil burner and wire 70 back to the other line conductor 7.

The above mentioned events take place practically instantly upon a call for heat by the thermostat, the burner 1 should begin to supply heat and the electrical resistance 39 begins to heat the thermal timer. At a predetermined time after starting, for example, one minute, the thermal timer 38 will snap from fixed contact 40 to fixed contact 41. Obviously this will break the above described energizing circuit for the relay coil 21. If now combustion has been properly initiated within the furnace the heat will have caused the thermopile 31 to have produced a sufficiently great energizing current for the winding 30 to hold the armature 26 in the "in" position with switch 29 closed. Under these circumstances the system will function in a normal manner for supplying heat to the spaces being heated under the control of the thermostat 15 and switch 17.

If at the time the thermal timer 38 breaks the circuit through relay coil 21, combustion had not been properly initiated within the furnace or flame had not appeared so as to cause the thermopile 31 to energize relay coil 30, the armature 26 will drop away from electromagnet 27 opening the switch 29. Under these conditions, this will happen instantly upon the thermal timer 38 snapping to the left, and opening of switch 29 will instantly deenergize relay coil 35 causing switch 36 to open stopping the burner 1, and causing switch 37 to close. Instantly upon closure of switch 37, an energizing circuit for relay coil 45 will be formed which is as follows: through

wires 55 and 56, switch 20, wires 57 and 58, thermal timer 38, fixed contact 41, wire 72; switch 37, wire 73, the relay coil 45 and wires 61 and 54 back to the secondary winding 12. Upon energization of relay coil 45, switch arm 44 will be moved to the right past its dead center position breaking the circuit therethrough. Switch arm 44 will engage stop 47 and can only be reclosed by manually forcing it to the left past its dead center position by means of the knob 48. Opening of switch 44 deenergizes the relay coil 19 which it will be remembered was energized upon closing of the thermostat 15. Switch 20 will now open and it will be seen that opening of this switch will cause deenergization of relay coil 45 as well as the heating resistance 39. The entire system will now be shut down and cannot be reenergized in any way until the safety switch 43 has been manually reset.

From the foregoing it should be obvious that I have provided a control system for oil burners or the like which instantaneously shuts down and locks out in the event of flame failure, this operation occurring either in the event of a flame never having appeared or in the event of flame failing at any time during operation of the burner. The advantage gained is apparent inasmuch as no time delays are disposed between the indication of a contingency or casualty and the ensuing shutdown and safety lockout. Considerable hazard and danger which was present in previously known devices by reason of the time delay before operation of the safety lockout is therefore eliminated. From the description it will be seen that by my thermal timer arrangement I make operation of the burner dependent upon the thermopile at a predetermined time after the burner is started in response to the thermostat. The thermopile arrangement provides a safe and reliable device which will result in a quick response to an indication of flame failure in the furnace, which in cooperation with the other element of the circuit causes instantaneous operation of the system and the lockout. It will be seen that in the event of power failure with the burner running the thermal timer 38 will be in its energized position, contact 41 being made and therefore the system will not recycle until a predetermined time when the thermal timer has cooled and snapped to its original position as in Figure 1.

In Figure 2 I have shown a modified form of my invention in which I have made several changes over the form of Figure 1 but which employs similar operating principles. The elements of the apparatus in Figure 2 which are the same and correspond to the elements of Figure 1 are numbered the same and therefore need not be described again. The elements of Figure 2 which are different than what is shown in Figure 1 are numbered 100 higher and I will explain the details of their construction and cooperation with the elements corresponding to those of Figure 1. It will be seen in Figure 2 that the relay comprising the relay coil 21 has a modified construction including two switches, one of them being the switch 29 and the other formed by electrical contacts 101 and 102. The coil winding 21 is operable to move the armature 122 vertically in a guide 103. The element 123 in Figure 2 comprises a horizontal bar secured to the lower end of armature 122 carrying at one end the switch 29 and armature 26 and at the other end a fixed contact 101 as shown. When the coil winding 21 is deenergized the

armature 122 and bar 123 are in the position shown in the drawing with the bar 123 resting upon a support member 104. In this position the contact 101 engages the fixed contact 102. When the relay coil 21 is energized armature 122 and bar 123 are reciprocated vertically, contacts 101 and 102 being broken and switch 29 becoming closed. The electro-magnet 27 may, when winding 30 is energized by the thermopile 31, hold the armature 26, bar 123, and armature 122 in their uppermost position in the same manner as described with respect to the structure of Figure 1.

In Figure 2 I have modified the construction of switch 137 which corresponds to the switch 37 of Figure 1. It will be seen that switch 137 comprises a resilient U-shaped member forming two electrical contacts indicated at 105 and 106. The contact member 105 cooperates with a fixed contact 107 and the contact member 106 cooperates with the fixed contact 108. With the parts in the position shown the relay coil 35 is deenergized and contacts 105 and 107 are made. When the relay coil 35 is energized the contacts 106 and 108 are made and contacts 105 and 107 are broken. The construction of the relay switch 137 is such that by reason of the resilient contact blade members 105 and 106 that whenever the relay coil 35 is energized or deenergized moving switch 137 to the left or right, respectively, both pairs of contacts are made for an instant during the movement of the switch. This operation of the switch 137 can be understood from an inspection of the drawing. It will be seen that the contact member 105 is flexed to the left somewhat by reason of its engagement with the fixed contact 107. Upon movement of switch 137 to the left contact member 106 will engage fixed contact 108 before contact member 105 disengages from fixed contact 107 by reason of the tension in the contact member 105. The pull of coil 35 will cause contact member 106 to flex somewhat causing contact member 105 to be disengaged from fixed contact 107. Thus it is seen that fixed contacts 107 and 108 are connected for an instant upon energization or deenergization of the relay coil 35.

The thermal timer 38 which I employ in Figure 2 is the same as that in Figure 1 except that there is only one fixed contact 40 associated therewith.

I will now describe the operation and the various electrical circuits which I employ in the apparatus of Figure 2. With the parts in the position shown the thermostat is satisfied and the burner 1 is at rest, the various relays and switches being in the position as shown. Upon a demand for heating in the spaces being heated the thermostatic switch closes completing a circuit through the relay coil 21 which is as follows: from line conductor 7 through a wire 112, thermostat 15, wire 113, wire 114, safety switch 43, wire 119, wire 115, thermal timer 38, wire 116, safety pilot switch 4, wire 117, the relay coil 21, and a wire 118 back to the line conductor 6. In the apparatus of Figure 2 I do not use a transformer but utilize line voltage in all circuits which I employ. Immediately upon energization of the relay coil 21 the armature 122 and bar 123 are moved vertically separating contacts 101 and 102 and causing armature 26 to engage electro-magnet 27 closing switch 29. Immediately upon switch 29 becoming closed the circuit for energizing relay coil 35 is completed which is as follows: from line conductor 7 through wire 112, 75

thermostat 15, wires 113 and 114, switch 43, wire 119, wire 120, switch 29, wire 65, the relay coil 35, and a wire 121 back to the line conductor 6. Immediately upon relay coil 35 being energized switch 36 is closed and switch 137 is moved to its left position in the manner which has already been described. Closure of switch 36 energizes the burner 1 through the following circuit: from line conductor 7 through a wire 68, switch 36, wire 125, wire 69, the fuel burner 1, and a wire 70 back to the line conductor 6. Starting of the burner should now begin to supply heat to the spaces being heated in the normal manner. When the switch 36 closes, a circuit energizing the electrical heating resistance 39 is also completed which is as follows: from line conductor 7 through wire 68, switch 36, wire 125, wire 69, the heater 39, variable resistance 63, and a wire 126 back to the line conductor 6. Heater 39 being energized, after a predetermined time the bimetal thermal timer element 38 will warp in a direction so as to disengage from fixed contact 40 and thus break the above described circuit through which the relay coil 21 was energized upon closure of the thermostat. This will take place at a predetermined time of approximately one minute for example after starting of the burner and if combustion had in the meantime been properly initiated the thermopile 31 will have been heated sufficiently so as to energize winding 30 whereby the electromagnet 27 acting upon armature 26 will hold the bar 123 and armature 122 in their uppermost position. This function of the thermopile 31 is the same as that already described in connection with Figure 1.

If at the time when the thermal timer element 38 disengages from the fixed contact 40, flame has not properly appeared within the furnace 2 the coil winding 30 will not be energized and the armature 122 and bar 123 will drop to their lowermost position opening switch 29 and causing contacts 101 and 102 to engage with each other. Upon switch 29 opening relay coil 35 will be deenergized so that switch 36 will open stopping the burner 1 and switch 137 will move to the position in which it is shown in the drawings. As above described as switch 137 moves to its righthand position fixed contacts 107 and 108 will be connected for an instant and will complete an energizing circuit for relay coil 45 which is as follows: from line conductor 7 through the wire 112, thermostat 15, wire 113, contacts 101 and 102, wire 128, contact 107, blades 105 and 106, contact 108, wire 129, the relay coil 45, wire 130, and wire 126 back to the line conductor 6. Immediately upon energization of the relay coil 45 the safety lockout switch 43 will be opened in the same manner as has already been described in connection with Figure 1. Upon opening of this switch the entire system is deenergized and cannot be recycled until the switch 44 has been closed by manually resetting it through the knob 48.

It will be understood that when the armature 122 is permitted to drop downwardly by reason of failure of energization of winding 30 by thermopile 31, contacts 101 and 102 become engaged slightly before the instantaneous connection is made between fixed contacts 107 and 108. On the other hand upon starting of the burner when armature 122 is moved upwardly for energizing relay coil 35 the contacts 101 and 102 are separated slightly before the instantaneous connection is made between contacts 107 and 108 upon

switch 137 moving to its leftward position. I provide this sequence of operation as respects the various electrical contacts so that safety shutdown and lockout will not occur upon closure of the thermostat to start a heating cycle in the normal manner. It is only upon failure of flame to appear in the furnace upon starting of the burner or upon failure of flame at any time during operation that my safety lockout device operates to instantaneously shutdown and lockout the system so as to require manual reset.

By reason of the instantaneous contact feature of switch 137 I gain certain important advantages in my apparatus. As already described shutdown and safety lockout occur instantaneously in response to such a contingency or casualty as is indicative of a dangerous condition of the furnace. My arrangement is such that the apparatus will not go on safety at undesirable times when it is not intended that it should. Thermostats as normally used are sensitive and may at times especially when they are near a closed position become closed due to vibration which may be set up by various causes. In my apparatus if after the termination of a normal heating cycle the thermostat 15 should be vibrated to a closed position before the heater 39 has had time to cool causing the timer 38 to engage fixed contact 40, the device will not assume safety lockout position by reason of the instantaneous contacting feature of switch 137. Closure of the thermostat under these conditions will not bring about energization of relay coil 35 because of the thermal timer switch 38 not being closed and consequently there will be no instantaneous connection of contacts 107 and 108. By reason of the above described arrangement I have avoided the occurrence of safety shutdowns at unnecessary times such as was a common occurrence in similar apparatus heretofore known.

Cooperatively with the above it will be seen that my electrical heating resistance 39 does not become energized until closure of the switch 36 as I have above described. Thus in the event of closure of thermostat 15 caused by vibrations or the like, and before the thermal timing element 38 has cooled the heater 39 will not become reenergized. It will be obvious that if it did become energized under these circumstances it would stay heated as long as the thermostat was closed and would never permit thermal timer 38 to engage the fixed contact 40. Thus my system is adapted to cope with all operating contingencies which might otherwise bring about erratic and undesirable results.

In the event of failure of the power supply for my system all the relay coils and the heater 39 become deenergized and the system cannot recycle until the thermal timer has had time to cool.

In Figure 3 I have shown another modification of my system in which I adapt the apparatus to the use of a stack switch as a combustion responsive device instead of using the thermopile as in the previous modifications. A number of the elements of Figure 3 are identical with those of Figure 1 and are numbered the same and need not be described again. Also it will be seen that in Figure 3 I employ a switch 137 with associated contacts which is identical with switch 137 of Figure 2 and therefore need not be described again in detail. A few of the electric wires of Figure 3 are connected identically with similar wires of previous modifications and are therefore

numbered the same. Other features of Figure 3 are numbered 200 greater than the elements of Figure 1 so that they may be distinguished from the previous modifications. Instead of using a constantly burning pilot burner for purposes of ignition in furnace 2 of Figure 3 I employ an electrical igniter indicated at 202 which becomes energized at the same time as the burner 1. The numeral 231 indicates a mercury type switch controlled by a helical thermostatic element 203 which is positioned so as to be responsive to stack temperatures. The thermostatic element is connected, as is conventional in oil burner stack controls, to the switch 231 by a slip friction connection so that the switch is actuated upon a rise or fall in temperature rather than at any predetermined temperatures. The switch 231 is arranged to complete a holding circuit through a switch 229, the latter switch being operated by the relay coil 35. Operation of the burner 1 becomes dependent upon this holding circuit through the switch 231 at a predetermined time depending upon the thermal timer which I employ. In the present modification my thermal timer is indicated at 238 and comprises a U-shaped resilient element forming two contacting members 210 and 211 somewhat similar to the contacting members of switch 137. The contacting member 210 cooperates with two fixed contacts 212 and 240 as shown. The contacting member 211 cooperates with the fixed contact 241. As shown the thermal timer 238 is in its cold position with contacting member 210 engaging both the fixed contacts 212 and 240. Upon energization of the resistance 39 the element 238 warps to the left causing contacting member 211 to engage the fixed contact 241. By reason of the resiliency of the contacting members 210 and 211 member 211 engages with the fixed contact 241 before member 210 disengages from the fixed contacts 212 and 240. The reason for this overlapping operation of the contacts will become apparent from the description of operation to follow.

Referring to the operation of the modification of Figure 3 when the thermostat closes indicating a need for heat a circuit energizing the igniter 202 is completed as follows: from line conductor 7 through a wire 213, thermostat 15, wire 214, a portion of wire 216, thermal timer 238, contacting member 210, contact 212, wire 217, igniter 202, and a wire 218 back to the line conductor 6. At the same time as the above circuit is completed a parallel branch circuit for energizing the relay coil 35 is completed which is as follows: from line conductor 7 through wire 213, thermostat 15, wire 214, the upper portion of wire 216, thermal timer 238, contact 240, a wire 219, wire 215, switch 43, wire 227, the relay coil 35, and a wire 220 back to the line conductor 6. Immediately upon energization of relay coil 35 switches 229, 36, and 137 are moved to their leftward positions. Closure of switch 36 completes a circuit energizing the oil burner 1 which is the same, the wires being numbered the same, as in the two previous modifications already described. Closure of switch 36 also energizes the heating resistance 39 through the following circuit: from line conductor 7 through wire 68, switch 36, wire 125, wire 69, resistance 39, and a wire 126 back to the line conductor 6. As soon as heater 39 becomes energized the thermal timer 238 begins warping at the left and at the expiration of a predetermined time, one minute for example, contacting member 211 engages fixed con-

tact 241, the contacting member 210 not yet having become disengaged from its associated contacts. If at this time combustion has properly been initiated in the furnace 2 the stack temperature will have risen sufficiently to cause closure of switch 231 completing a holding circuit for the relay coil 35 which is as follows: from line conductor 7, through wire 213, thermostat 15, wire 214, wire 216, switch 231, wire 221, switch 229, wire 222, wire 215, switch 43, wire 227, the relay coil 35 and wire 220 back to the line conductor 6. A few seconds after contact member 211 engages fixed contact 241 the contact member 210 will disengage from contacts 212 and 240 breaking the circuit for igniter 202 and also breaking the circuit as above described through which relay coil 35 was initially energized. If now as pointed out above, the holding circuit for relay coil 35 has been completed by closure of switch 231 burner operation will continue normally under control of the thermostat 15 and the stack switch 231. If however upon interruption of the original circuit for energizing relay coil 35 combustion has not properly been initiated so as to cause closure of switch 231 the relay coil 35 will immediately become deenergized, the switches 229, 36, and 137 assuming the position shown in Figure 3. Instantaneously upon this occurring a circuit for energizing relay coil 45 will be established as follows: from line conductor 7 through wire 213, thermostat 15, wire 214, the upper portion of wire 216, thermal timer 238, fixed contact 241, wire 224, contact 107, contact members 210 and 211, contact 108, wire 225, the relay coil 45 and a wire 226 back to the line conductor 6. It will be understood of course at the time relay coil 35 is deenergized an instantaneous connection is made between contacts 107 and 108 in the same manner as described in connection with the modification of Figure 2. As soon as relay coil 45 is energized switch 43 will assume shutdown and safety lockout position in the same manner as has already been described in connection with previous modifications.

From the above it will be seen that the apparatus of Figure 3 is adapted for use with a stack switch as shown and has among other advantages to those already pointed out in connection with Figure 2 that the apparatus will not assume safety position at improper times and may not be recycled after power failure until the thermal timer has had an opportunity to cool.

From the foregoing it should be apparent to those skilled in the art that I have provided a control system having outstanding advantages comprising an instantaneous shutdown feature as well as numerous other desirable characteristics which have been made apparent from the specification. My system provides the ultimate in safety inasmuch as it assumes a safety lockout position instantaneously in response to indication of a contingency or casualty which may involve a dangerous condition of the apparatus. My arrangement is such that I accomplish this result without introducing erratic or undesirable control functions into the operation of the system which have been known to be present in previously employed systems under various unusual circumstances which may occur.

Referring to Figure 4 of the drawings, I have shown another modification of my invention embodying certain principles differing from those of the previously described modifications. Those elements of Figure 4 which are identical with previously described elements of other modifica-

tions are numbered the same and will not again be described. In the present embodiment the system is primarily controlled by a thermostat 315 of the double switch type. Thermostat 315 has pair of resilient switch blades 313 and 316 cooperating with fixed electrical contacts 314 and 317, respectively. The blade 316 is less widely spaced from contact 317 than blade 313 is from contact 314. Upon a temperature fall, blade 316 is first engaged with contact 317 and blade 313 is then engaged with contact 314.

The thermal timer in the present embodiment comprises a bimetal element 338 adjacent to which is the electrical resistance heater 39. The bimetal element 338 is arranged to actuate resilient switch blades 310 and 311 by means of insulating members 318 and 319, respectively. The switch blades 310 and 311 cooperate with fixed electrical contacts 312 and 340, respectively.

Numeral 331 designates a stack responsive control instrument comprising two mercury switches 320 and 321 both of which are arranged to be actuated by a helical thermostatic element 333 disposed in the stack 250 of the furnace. When the furnace is cold the mercury switches are in the position shown but whenever there is heat in the furnace so as to cause the stack temperature to rise the switch 321 closes and the switch 320 opens. As is conventional in the art, the thermostatic element 303 is connected to its switches by a slip friction connection so that these switches are actuated in accordance with change in temperature.

The safety shutdown switch 343 which I employ in the present embodiment has certain elements which are identical with corresponding elements of the safety switch of previously described modifications but in the present form of the invention it is operated by a relay generally designated at 322. This relay has an armature comprised of two portions, one associated with each of two windings 323 and 324, the two portions being connected by non-magnetic material. The coil 323 is disposed and arranged so as to act to pull on the armature in a direction tending to open the switch 44 while the winding 324 is disposed and arranged so as to act to push on the armature in a direction tending to maintain the switch 44 in closed position. The windings 323 and 324 are energizable through separate electrical circuit which I will presently describe as well as the complete operation of the safety shutdown switch 443.

Numeral 35 designates a relay coil associated with an armature which is arranged to actuate the switch arms 327, 328, and 36 which cooperate with fixed electrical contacts 329, 330, and 332, respectively. Arm 328 and contact 330 are constructed and arranged so that they remain in engagement for an appreciable time after coil 35 is deenergized and blade 328 starts moving to the right. The purpose of this will presently become apparent.

With the parts of the present embodiment in the position shown the thermostat 315 is satisfied and heating is therefore not taking place within the furnace 2. When the temperature to which the thermostat 315 is responsive falls to a predetermined value the switch blade 316 will engage the contact 317. Nothing will happen however as a result of this until at a predetermined lower temperature which may be one or two degrees below the temperature at which blade 316 engaged contact 317, the blade 313 will engage with contact 314. Immediately upon this occurring the

relay coil 35 will be energized through the following circuit: from secondary winding 12 of transformer 8 through wire 333, safety pilot 4, wire 334, switch 44, wire 337, fixed contact 317, thermostat blades 316 and 313, fixed contact 314, wire 341, switch blade 310, fixed contact 312, wire 345, mercury switch 320, wire 347, wire 351, wire 352, coil 35, and wire 353 back to the secondary winding 12. At the same time that coil 35 is energized the push coil 324 will be energized by a parallel circuit which is the same as the circuit just described above as far as wire 347 and which then continues through a wire 354, push coil 324, wire 366, and wire 353 back to the secondary winding 12. Immediately upon energization of the coil 35 the switch arms 327, 328, and 36 will engage with their respectively associated fixed contacts. Upon closure of the switch 327 a holding circuit for the relay coil 35 will be set up as follows: from secondary winding 12 through wire 333, safety pilot 4, wire 334, switch 44, wire 337, fixed contact 317, thermostat 315, wire 355, wire 356, switch blade 311, fixed contact 340, wire 357, wire 358, switch arm 327, fixed contact 329, wire 352, coil 35, and wire 353 back to the secondary winding 12. At the same time as this maintaining circuit for coil 35 is completed by closure of switch 327 an additional circuit energizing push coil 324 is completed which is the same as the maintaining circuit for coil 35 as far as the wire 352 and then continues through wire 351, wire 354, coil 324, wire 366, and wire 353 back to the secondary winding 12. From the above it will be apparent that in my system no circuits become energized until both the contact blades of thermostat 315 engage their associated fixed contacts. As soon as the coil 35 is energized causing closure of its associated switches maintaining circuits are established for the coil 35 and coil 324 which do not extend through the blade 313 and its associated fixed contact. It will be seen therefore that the maintaining circuits are independent of the blade 313 of the thermostat and cannot be interrupted by the thermostat until the temperature again rises above the value at which blade 316 engaged its associated contact.

Immediately upon energization of coil 35 and consequent closure of switch 328 the heating element 39 is energized through the following circuit: from secondary winding 12 through wire 333, safety pilot 4, wire 334, switch 44, wire 337, fixed contact 317, thermostat 315, wire 355, wire 359, fixed contact 330, switch blade 328, wire 360, heater 39, wire 366, and wire 353 back to the secondary winding 12. At the same time as this circuit energizing heater 39 is completed a circuit is completed energizing the pull coil 323 which is the same as the circuit just described as far as the switch blade 328 and then continues through a wire 361, pull coil 323, wire 366, and wire 353 back to the secondary winding 12. When both the coils 323 and 324 are energized there is no resultant effect to cause the armature associated therewith to move the switch 344 in one direction or the other.

At the same time that switches 327 and 328 closed, switch 36 engaged with its associated contact completing an energized circuit for the burner 1 as follows: from line conductor 6 through wire 362, burner 1, wire 363, switch blade 36, fixed contact 332, and wire 364 back to line conductor 7. Normal heating should now begin within the furnace 2, the fuel having been ignited by the flame of the pilot burner 3 assuming that the pilot was properly burning.

As soon as the heater 39 becomes energized the bi-metal element 338 will begin to flex to the left and at the end of a predetermined time which may be one minute, for example, after energization of the heater, the switch blades 310 and 311 will disengage from their associated fixed contacts interrupting the circuits therethrough. If within the predetermined period of one minute, flame had properly appeared within the furnace 2 to cause the stack temperature to rise the mercury switches 320 and 321 will be actuated by the stack responsive element 303 in a manner to open the switch 320 and close the switch 321. Under normal conditions these latter switches will be so actuated. Assuming that the switches 320 and 321 have been properly actuated within the one minute interval, upon disengagement of the switch blades 310 and 311 from their associated contacts the original energizing circuits for the coils 35 and 324 will be interrupted as will the maintaining circuit for these coils extending through the switch 327. (The original circuits through which heater 39 and coil 323 were energized will not be interrupted because they do not extend through the switches 310 and 311.) However, coil 35 will continue to be energized and will be under control of the switch 321 through the following circuit: from secondary winding 12 through wire 333, safety pilot 4, wire 334, switch 44, wire 337, fixed contact 317, thermostat 315, wire 355, mercury switch 321, wire 358, switch blade 327, fixed contact 329, wire 352, coil 35, and wire 353 back to the secondary winding 12. Push coil 324 will continue to be energized through an additional circuit which is the same as the circuit just described as far as the wire 352 and which then continues through wire 351, wire 354, coil 324, wire 355, and wire 353 back to the secondary winding 12. If now for any reason there should be a flame failure within the furnace 2 causing the stack temperature to fall the system of the present embodiment will instantaneously assume safety shutdown position requiring manual reset. This shutdown is brought about by the interruption of a circuit in a manner which I am about to describe. Upon a drop in stack temperature causing opening of switch 321, the above described circuit therethrough which extended through the switch 327 and which energized the coils 35 and 324 will be interrupted. Thus the relay coil 35 and the push coil 324 will be simultaneously deenergized but the pull coil 323 the circuit of which extends through switch 328 will not be deenergized until the switches 327, 328, and 36 have had an opportunity to open after deenergization of coil 35 inasmuch as switch 328 remains closed for an appreciable time after deenergization of coil 35. During this time interval the pull coil 323 will have had an opportunity to move the switch 34 over center to its open position in which it remains until manually reset by the plunger 48. Upon opening of switch 44 all the circuits of the system are deenergized and the system is in a safety shutdown position and cannot be again rendered operative until personal attention has been given to it and the safety shutdown switch 343 manually repositioned. Thus opportunity is provided for a human operative to interfere and correct any fault in the system before fuel can again be admitted to the furnace and causing possible explosions or other dangerous contingencies. It is an important feature of the present embodiment that in order to bring about this instantaneous shutdown requiring manual reset

that an electrical circuit in the system is interrupted rather than it being necessary to complete an electrical circuit to accomplish this result. This obviously adds an additional increment of safety inasmuch as when reliance is had upon the completion of an electrical circuit to bring about safety shutdown there is always the danger that some agency may have created an additional gap in that circuit preventing its completion and thus precluding the desired safety shutdown.

Let it be assumed now for purposes of further explanation of operation of the system that flame never properly appeared within the furnace 2 within the predetermined time interval of one minute before the bimetal element 338 causes the switch blades 310 and 311 to disengage from their associated fixed contacts. As above described the original energizing circuits for coils 35 and 324 will be interrupted by disengagement of blade 310 from contact 312 and also the maintaining circuits for these coils will be interrupted by disengagement of blade 311 from contact 340. Switch 321 not now being closed there will be no energizing circuit to coils 35 and 324 upon disengagement of blades 310 and 311 from their associated contacts and as described above in connection with flame failure after its once having been established, pull coil 323 will not be deenergized until the switch 328 has had an opportunity to open. During this interval of time the switch 44 will be moved past its dead center position to open position in which it will remain until manually reset in the manner already described.

Under normal operating conditions when no casualties have occurred the system will be shut down whenever the thermostat 315 becomes satisfied causing the blade 316 to disengage from contact 317. As above described, with this particular type of thermostat after it has initially energized the system, further control is independent of the blade 313 and is dependent only upon the blade 316. From the previous description of the thermostat 315 it is obvious that it provides a positive operating differential which may be one or two degrees for example and it will not shut down the system until the temperature rises above the value at which blade 316 engages its associated contact.

From the foregoing description it is apparent that in the last described embodiment of my invention I have provided a particularly advantageous control system embodying unusual and high reliable safety features. The dependability of this system from the safety standpoint is apparent from its nature as I have explicitly pointed out above.

While I have disclosed and described in detail several embodiments of my invention it is to be appreciated that various changes will appear to those skilled in the art which are intended to fall within the spirit and scope of the invention. It is therefore understood that my disclosures are for illustrative purposes only and that the limits of my invention are to be determined only by the scope of the appended claims.

I claim as my invention:

1. In a control system of the type described, in combination, a fuel burner, relay means energizable at command of a condition responsive device for starting said fuel burner, said relay means being also energizable by a heat responsive thermo-couple device, timing means for rendering said condition responsive device ineffective to energize said relay means at a predetermined time

after starting the burner, and lockout means for shutting down the system at the end of said predetermined time if said thermo-couple device fails to energize said relay means.

2. In a control system of the type described in combination, a fuel burner, relay means energizable at command of a condition responsive device for starting said fuel burner, said relay means being also energizable by a heat responsive thermo-couple device, timing means for rendering said condition responsive device ineffective to energize said relay means at a predetermined time after starting the burner, and lockout means comprising a momentarily completed electrical circuit arrangement for instantaneously shutting down the system at the end of said predetermined time if said thermo-couple device fails to energize said relay means.

3. In a temperature control system, in combination, a fuel burner, a thermostat controlling an energizing circuit for said burner, combustion responsive means for controlling said burner, timing means for rendering said burner dependent on said combustion responsive means for energization, and safety lockout means comprising electrical contact mechanism instantaneously and momentarily closed for completing an electrical circuit for shutting down the system after the operation of said timing means if said burner is not energized in response to said combustion responsive means, said contact mechanism normally keeping said circuit open whereby operation of said timing means is ineffective to shut down the system without operation of said contact mechanism to momentarily close said circuit.

4. In a temperature control system, in combination, a fuel burner, a thermostat for starting said burner, combustion responsive means operable to maintain said burner in operation, a thermal timer operable to render operation of said burner dependent on said combustion responsive means, and safety lockout means comprising a circuit including electrical contacting means closed momentarily upon stopping of the burner and a switch actuated by the thermal timer for shutting down the system in the event burner operation is not maintained by the combustion responsive means, said momentary electrical contacting means normally being open whereby the operation thereof is required for shut down.

5. In a temperature control system, in combination, a fuel burner, a thermostat for starting said burner, combustion responsive means operable to maintain said burner in operation, a thermal timer operable to render operation of said burner dependent on said combustion responsive means, safety lockout means comprising a circuit including electrical contacting means momentarily closed upon stopping of the burner and a switch actuated by the thermal timer for shutting down the system in the event burner operation is not maintained by the combustion responsive means, said switch being open when the burner starts and closed when the burner becomes dependent on the combustion responsive means.

6. In a fuel control system of the character described, heat generating means, control means comprising a condition responsive device for energizing and deenergizing said heat generating means, a device responsive to the temperature of said heat generating means and comprising a switch closed upon the existence of a temperature indicating the proper operation of said heat generating means, said control means causing

operation of the heat generating means to become dependent upon the temperature responsive device after operation of the heat generating means has been initiated by the condition responsive device, safety shut-down means operable to shut down the system in the event said temperature responsive device fails to support operation of the heat generating means, said safety shut-down means comprising a relay device having an electrical circuit therethrough controlled by said switch of said temperature responsive device, said relay device rendering the system inoperative instantaneously upon interruption of the said circuit by the opening of said switch of the temperature responsive device.

7. In a fuel control system of the character described, heat generating means, control means comprising a condition responsive device for energizing and deenergizing said heat generating means, a device responsive to the temperature of said heat generating means and comprising a switch closed upon the existence of a temperature indicating the proper operation of said heat generating means, said control means causing operation of the heat generating means to become dependent upon the temperature responsive device after operation of the heat generating means has been initiated by the condition responsive device, safety shutdown means operable to shut down the system in the event said temperature responsive device fails to support operation of the heat generating means, said safety shutdown means comprising a relay having a pair of windings, one of said windings being controlled by said switch of said temperature responsive device and said safety shutdown means rendering the system inoperative upon deenergization of said one winding instantaneously upon the opening of said switch.

8. In a control system, in combination, heating means having fuel supplying means, control apparatus comprising an electrical device controlling the heating means, means for energizing the device to start the heating means, means comprising a thermopile responsive to the heating means operable to maintain the device in energized position, means whereby maintenance of the device in energized position becomes dependent on the thermopile, and mechanism for instantaneously shutting down the system and requiring manual reset upon movement of said device when it is dependent on the thermopile.

9. In a control system, in combination, safety switch means operable in response to completion of an electrical circuit, a first switch controlling said circuit, electrically operated contacting mechanism controlling said circuit and controlled by said first switch, said contacting mechanism having means forming a normally open gap and a normally closed gap in said circuit, closure of said first switch operating said contacting mechanism to open said normally closed gap, said circuit not becoming completed, condition responsive means operatively associated with said contacting mechanism operable to cause actuation of said contacting mechanism in a manner whereby said normally closed gap is closed and said normally open gap is momentarily closed for completing said circuit and operating said safety switch.

10. In a control system of the type described, a fuel burner, relay means biased to one position and movable to a second position upon energization thereof, means for causing operation of said fuel burner only when said relay is in its ener-

gized position, a device responsive to a condition indicative of the demand for burner operation, a combustion responsive device, a first energizing circuit for said relay means controlled by said condition responsive device, a second energizing circuit controlled by said combustion responsive device, timing means for interrupting said first energizing circuit a predetermined period of time after establishment thereof, lockout means for terminating operation of the system, and means for rendering said lockout means operable upon deenergization of said relay at the end of said predetermined period of time due to the failure of said combustion responsive device to establish said second energizing circuit.

11. In a control system of the type described, a fuel burner, relay means biased to one position and movable to a second position upon energization thereof, means for causing operation of said fuel burner only when said relay is in its energized position, a device responsive to a condition indicative of the demand for burner operation, a combustion responsive device, a first energizing circuit for said relay means controlled by said condition responsive device, a second energizing circuit controlled by said combustion responsive device, timing means for interrupting said first energizing circuit a predetermined period of time after establishment thereof, lockout means for terminating operation of the system, and means controlled by said condition responsive device for rendering said lockout means operable upon deenergization of said relay at the end of said predetermined period of time due to the failure of said combustion responsive device to establish said second energizing circuit.

12. In a control system of the type described, a fuel burner, relay means biased to one position and movable to a second position upon energization thereof, means for causing operation of said fuel burner only when said relay is in its energized position, a device responsive to a condition indicative of the demand for burner operation, a combustion responsive device, a first energizing circuit for said relay means controlled by said condition responsive device, a second energizing circuit controlled by said combustion responsive device, electrothermal timing means for interrupting said first energizing circuit a predetermined period of time after establishment thereof, lockout means for terminating operation of the system, and means for rendering said lockout means operable upon deenergization of said relay at the end of said predetermined period of time due to the failure of said combustion responsive device to establish said second energizing circuit.

13. In a control system of the type described, a fuel burner, relay means biased to one position and movable to a second position upon energization thereof, means for causing operation of said fuel burner only when said relay is in its energized position, a device responsive to a condition indicative of the demand for burner operation, a combustion responsive device, a first energizing

circuit for said relay means controlled by said condition responsive device, a second energizing circuit controlled by said combustion responsive device, timing means for interrupting said first energizing circuit a predetermined period of time after establishment thereof, electrically operated lockout means for terminating operation of the system, switching means positioned by said relay means and movable to a predetermined controlling position only momentarily during the movement of said relay means between said first and second position, and means controlled by said condition responsive device and said switching means for energizing said lockout means during the movement of said relay means to its deenergized position at the end of said predetermined period of time due to the failure of said combustion responsive device to establish said second energizing circuit.

14. In a control system of the type described, a fuel burner, relay means biased to one position and movable to a second position upon energization thereof, means for causing operation of said fuel burner only when said relay is in its energized position, a device responsive to a condition indicative of the demand for burner operation, thermo-couple means responsive to the establishment of combustion, a first energizing circuit for said relay means controlled by said condition responsive device, a second energizing circuit for said relay means controlled by said thermo-couple means upon the establishment of combustion, timing means for interrupting said first energizing circuit a predetermined period of time after establishment thereof, lockout means for terminating operation of the system, and means for rendering said lockout means operable upon deenergization of said relay at the end of said predetermined period of time due to the failure of said thermo-couple means to cause energization of said second circuit.

15. In a control system of the type described, a fuel burner, relay means biased to one position and movable to a second position upon energization thereof, means for causing operation of said fuel burner only when said relay is in its energized position, a device responsive to a condition indicative of the demand for burner operation, a combustion responsive device, a first energizing circuit for said relay means controlled by said condition responsive device, a second energizing circuit controlled by said combustion responsive device, timing means for interrupting said first energizing circuit a predetermined period of time after establishment thereof, lockout means for terminating operation of the system, and means controlled by said timer and said condition responsive device for rendering said lockout means operable upon deenergization of said relay at the end of said predetermined period of time due to the failure of said combustion responsive device to establish said second energizing circuit.

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