April 22, 1952 F. B. AUBERT 2,593,518

ELECTRICAL FUEL BURNER CONTROL SYSTEM AND APPARATUS THEREFOR

Filed July 11, 1947 3 Sheets-Sheet 1

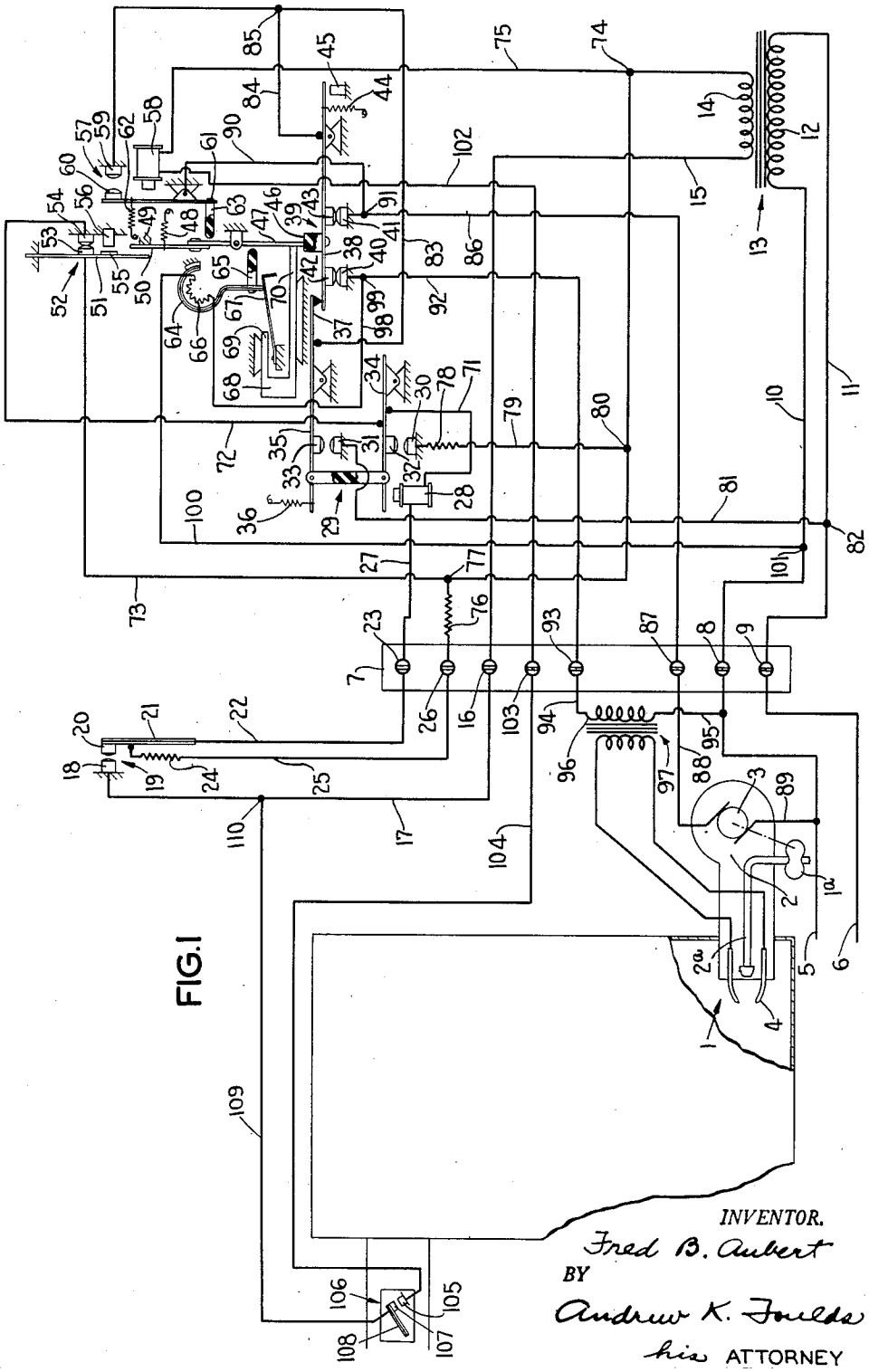


FIG. 1

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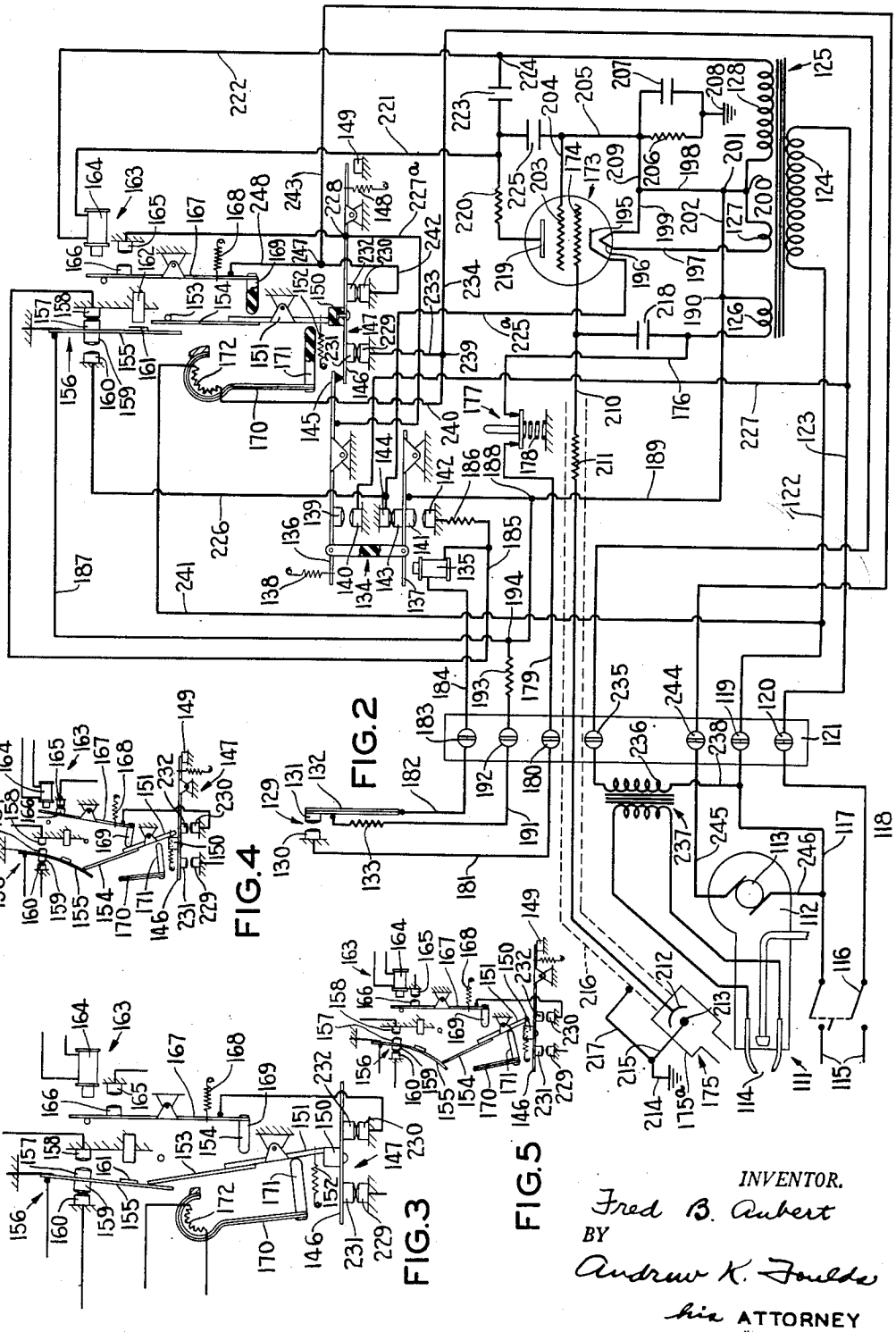


FIG. 2

FIG. 4

FIG. 3

FIG. 5

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ELECTRICAL FUEL BURNER CONTROL SYSTEM AND APPARATUS THEREFOR

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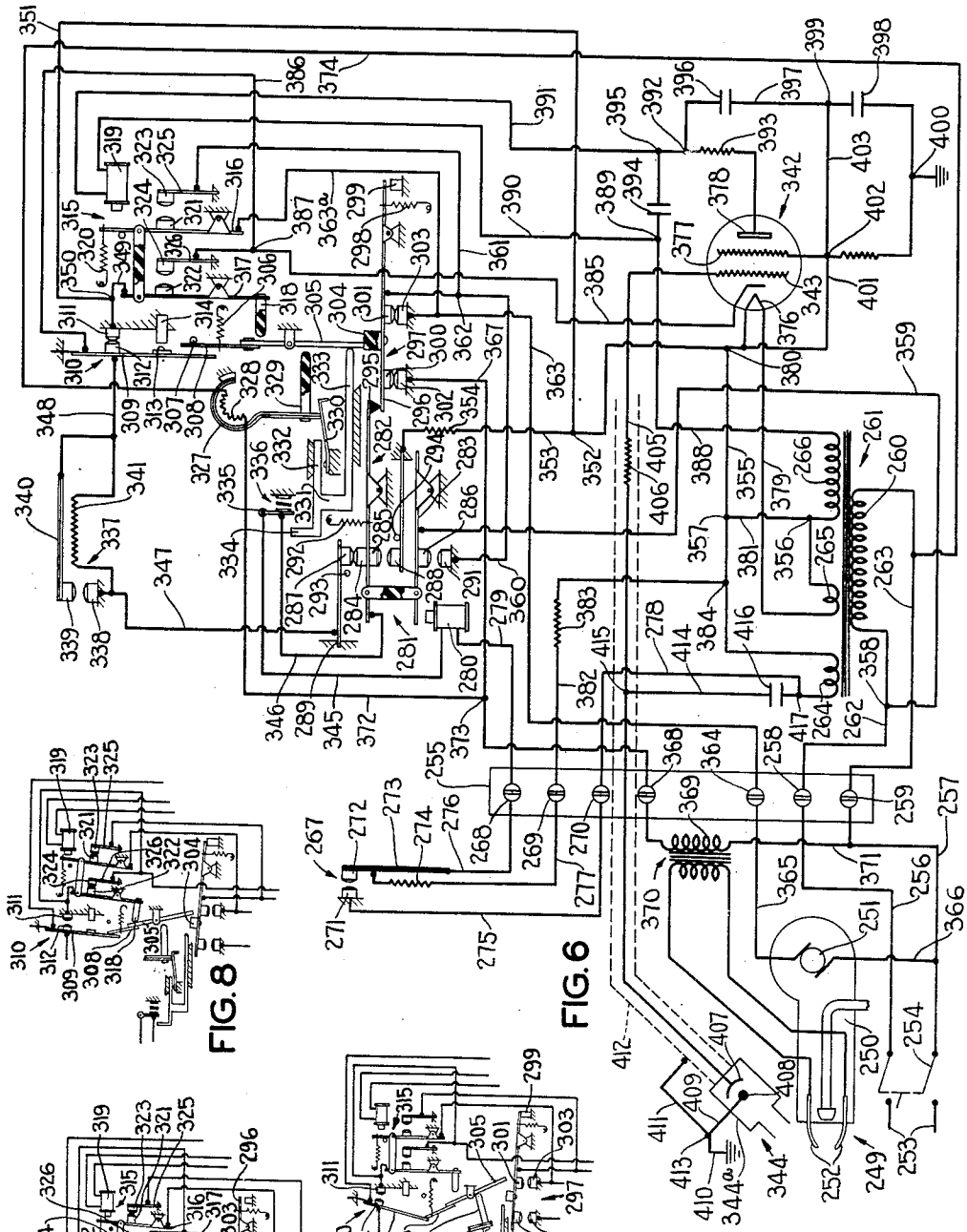


FIG. 6

FIG. 8

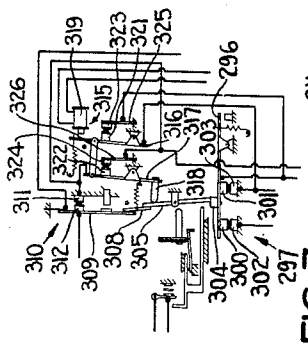


FIG. 7

FIG. 9

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ELECTRICAL FUEL BURNER CONTROL SYSTEM AND APPARATUS THEREFOR

Fred B. Aubert, Detroit, Mich.

Application July 11, 1947, Serial No. 760,205

17 Claims. (Cl. 158—28)

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This invention relates to new and useful improvements in electrical fuel burner control systems and apparatus therefor.

An object of this invention is to provide a control system for fluid fuel burners having electrically operable fuel supply means and electrically controllable ignition means.

Another object of this invention is to provide a control system having a means responsive to the occurrence of flame in the burner whereby the ignition means may be de-energized and energization of the fuel supply means continued.

Another object of this invention is to provide a safety means for a control system to de-energize the fuel supply means and ignition means upon failure of flame to occur in the burner within a predetermined time after initial energization of the system.

Another object is to provide a control device for automatically supervising the operation of a fluid fuel burner.

Other objects of this invention will become apparent from time to time through the specification and claims as hereinafter stated.

This invention consists in the new and improved combination of parts and in their operative relationship to each other and in certain control devices therefor, all to be more fully described hereinafter and the novelty of which will be particularly pointed out and distinctly claimed.

In the accompanying drawings to be taken as part of the specification there are clearly and fully illustrated several preferred embodiments of this invention in which drawings:

Figure 1 is a diagrammatic representation of a fuel burner control system utilizing a thermostatic stack switch responsive to the occurrence of flame in the burner and operable to control operation of the fuel supply means and the ignition means,

Fig. 2 is a diagrammatic view of another form of burner control system in which a photo-electric cell is positioned to be responsive to the occurrence of flame in the burner and is operable to control the activation of an electron tube in the system for controlling the fuel supply means and ignition means for the burner and having electric timing means to delay functioning of the photo-electric cell until the electron tube has had time to become adequately heated,

Fig. 3 is a detail view of the electric timing means portion of Fig. 2 in a partially operated position,

Fig. 4 is a detail view of the electric timing means portion of Fig. 2 when the control system is in a fully operated position,

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Fig. 5 is a detail view of the electric timing means portion of Fig. 2 in safety operation,

Fig. 6 is a diagrammatic view of another form of a burner control system having a photo-electric cell and electron tube for controlling the operation of a fuel supply means and ignition means for the burner, having electric timing means to prevent functioning of the system until the electron tube has had time to become adequately heated, and having safety means to de-energize the system and prevent further operation upon failure of flame to occur in the burner within a pre-determined time after initial energization of the system and having a safety stop member to prevent the safety means from returning to its initial position after operation,

Fig. 7 is a detail view of a section of the system shown in Fig. 6 including the safety means and is shown in an intermediate position of operation,

Fig. 8 is a detail view similar to Fig. 7 but shows the control system in fully operated position, and

Fig. 9 is another detail view similar to Figs. 7 and 8 showing the safety means in safety operated position.

Referring to the drawings by characters of reference, in the system shown in Fig. 1 there is a burner 1 having a fan or blower 2 and a fuel supply line 2^a terminating in a nozzle. In the line 2^a there is a pump 1^a which is driven by a motor 3 which also drives the blower 2. Adjacent the nozzle there are ignition electrodes 4.

Electrical power from a main power source is supplied to electrical conductors 5 and 6 for energization of the system. The electrical conductors 5 and 6 are shown as leading to a connection or terminal board or panel 7 and connected thereto by screws 8 and 9. The parts of the system are shown as being interconnected through the connection panel 7. The elements of the control system to the right of the panel 7 in the drawing are so interconnected and interrelated in their operation that in commercial construction they would probably be housed within a casing as an individual control device, the connections to the control device being made through the connection panel 7 as shown. From the connection points 8 and 9 on the panel 7, two electrical conductors 10 and 11 run to the primary 12 of a transformer 13 and form a complete circuit therewith. From the secondary 14 of the transformer 13 a conductor 15 runs to a connection point 16 on the panel 7 from which another conductor 17 leads to the fixed contact 18 of a room thermostat or other control

switch 19. The thermostat 19 has a movable contact 20 carried by a thermo-sensitive bimetal strip or blade 21 which is connected by a conductor 22 to a connection point 23 on the panel 7. The thermostat 19 has a compensating heater coil 24 which is connected by a conductor 25 from the blade 21 to a connection point 26 on the connection panel 7. A conductor 27 leads from the connection point 23 to the coil 28 of a relay switch 29. The relay switch 29 has two fixed contacts 30 and 31 and two movable contacts 32 and 33 cooperable respectively therewith and carried by pivoted contact arms 34 and 35 respectively, the switch contacts being held in open position initially by a spring 36. In the initial open position of the relay switch 29, the end portion 37 of the contact arm 35 engages and holds closed through an insulating abutment the pivoted contact-carrying arm 38 of a control switch 39. The control switch 39 has two fixed contacts 40 and 41 and has two movable contacts 42 and 43 cooperable respectively therewith and carried by the arm 38. A spring 44 is connected to the contact arm 38 urging it towards contact open position, the opening movement of the switch 39 being limited by the engagement of the arm 38 with a stop 45. The contact arm 38 has an electric insulating abutment 46 thereon which is engaged by a pivoted member 47 which is operable to continue to hold the switch 39 closed after releasing movement of the relay switch 29. The pivoted member 47 is urged towards its initial position in engagement with the abutment 46 by a spring 48 and is limited in its movement in this direction by a stop member 49. The upper portion 50 of the pivoted member 47 is engageable with the contact-carrying arm 51 of a switch 52, the contact-carrying arm 51 being of cantilever spring construction and tensioned toward contact closed position. The contact-carrying arm 51 carries the movable contact 53 which is initially in engagement with a fixed contact 54 of the switch 52. The arm 51 also carries a magnet armature 55 which is attracted by a permanent magnet 56 adjacent the fixed contact 54 which is operable to hold the contacts 53 and 54 tensioned against each other so that movement of the switch 52 will be with a snap action. A second relay switch 57 has a coil 58, a fixed contact 59 and a movable contact 60. The movable contact 60 of the relay switch 57 is carried by a contact-carrying arm 61 and is urged towards open position by a spring 62. The contact-carrying arm 61 has an electric insulating abutment member 63 thereon which is engageable with the pivoted member 47 and operable to move the same out of holding engagement with abutment 46 upon closing movement of the relay switch 57. A bimetal element 64 having an abutment member 65 of electric insulating material is engageable with and operable to move the pivoted member 47 off the abutment 46, the bimetal element 64 being energized for movement by an electric heating coil 66. The bimetal element 64 is also engageable with a flexible stop member 67 which is operable after heating and movement of the bimetal element 64 to prevent the same from returning to its initial position upon cooling. A reset member 68 having movement substantially longitudinal of the stop member 67 has a portion 69 operable upon movement to engage the stop member 67 to move or depress the same to permit the bimetal element 64 to return to its initial position. The reset member 68 also has a projecting portion 70 which is operable upon movement to engage and move the

pivoted member 47 off the abutment 46 and open switch 52. A conductor 71 connects the coil 28 of the relay switch 29 with the contact arm 34 from which a conductor 72 runs to the fixed contact 54 of the switch 52. A conductor 73 leads from the movable contact 53 of the switch 52 to the connection point 74 on a conductor 75 completing a circuit to the secondary 14 of the transformer 13. A resistor 76 connects the connection point 26 on the panel 7 with a connection point 77 on the conductor 73. A resistor 78 and conductor 79 interconnect the fixed contact 30 of the relay switch 29 and a connection point 80 on the conductor 73 and function to complete a holding circuit for the relay switch 29 when the contacts 30 and 32 are closed. From the other fixed contact 31 of the relay switch 29 a conductor 81 leads to a contact point 82 on the conductor 11. A conductor 83 leads from the relay contact arm 35 to the fixed contact 59 of the second relay switch 57. Another conductor 84 interconnects a connection point 85 on the conductor 83 and the contact arm 38 of the control switch 39. A conductor 86 leads from the fixed contact 41 of the switch 39 to a connection point 87 on the panel 7, the circuit being completed by conductors 88 and 89 through the motor 3 to the "ground" conductor 5. The pivoted arm 61 of the second relay switch 57 is connected by a conductor 90 to the connection point 91 on the conductor 86. A conductor 92 runs from the fixed contact 40 of the switch 39 to a connection point 93 on the panel 7, the circuit being completed by conductors 94 and 95 through the primary 96 of an ignition coil 97 to the "ground" conductor 5. A conductor 98 leads from a connection point 99 at the fixed contact 40 to the heater coil 66 of the bimetal element 64 which is in turn connected by a conductor 100 to a connection point 101 on the "ground" conductor 10 from the transformer 12. A conductor 102 leads from the coil 58 of the relay switch 57 to a connection point 103 on the panel 7. Another conductor 104 runs from the panel point 103 to the fixed contact 105 of a thermostatic stack switch 106. The thermostatic stack switch 106 has a movable contact 107 cooperable with contact 105, the movable contact 107 being actuated by a thermostatic bimetal element 108 responsive to stack temperature. The circuit through the stack switch 106 is completed by a conductor 109 running from the movable contact 107 to a connection point 110 on the conductor 17 to the thermostat 19. It should be noted that in this form of the invention as illustrated in the drawing in Fig. 1 the system is shown in its normal starting position prior to energization.

In operation, this form of the invention functions as follows:

When electric current is supplied through the conductors 5, 6, 10 and 11 to the primary 12 of the transformer 13 the system is energized subject to control of the various switches and control mechanisms therein. The initial circuit for the thermostat 19 runs from the transformer secondary 14 through the conductors 15 and 17 to the fixed contact of the thermostat. Assuming that when this system is initially energized the space to be heated will be cold, the contact points 18 and 20 of the thermostat 19 will be closed completing the circuit through the conductors 22 and 27 to the relay coil 28 and thence by conductors 71 and 72 to the closed contacts 53 and 54 of the switch 52, returning by the conductors 73 and 75 to the transformer secondary 14. With this cir-

cuit closed through the thermostat 19, the coil 28 of the relay 29 is energized and will cause the contacts 32 and 33 to close against the fixed contacts 30 and 31. The closing of the contact 32 against the contact 30 completes a circuit from the relay coil 28 through the closed contacts 32 and 30, the resistor 78, conductor 79 and conductors 73 and 75 to the transformer secondary 14. This last-named circuit is a holding circuit for the relay switch 29 and will hold the same closed so long as the transformer 13 remains energized and the thermostat remains closed. The resistor 78 functions as a "drop out" resistor so that if the voltage supplied to the coil 28 should drop below a predetermined minimum value the voltage drop through the resistor 78 would be so great that there would not be sufficient current through the coil 28 to hold the switch 29 closed. The conductor 81 leads from the connection point 82 on the "hot" conductor 11 to the contact 31 of the relay switch 29 and when the relay switch 29 is closed a circuit is completed through the contact arm 35 and the conductors 83 and 84 to the control switch 39. The control switch 39 functions to control the energization of the circuits through the motor 3 and the ignition coil 96 respectively by control of the contact points 43 and 42 respectively. It is seen then that when the system is initially energized the thermostat 19 closes causing the relay switch 29 to close establishing a holding circuit therethrough and energizing a circuit through the motor 3 through the switch contacts 41 and 43 and the conductors 86, 88 and 89, and a circuit through the ignition coil through the contacts 42 and 40 and conductors 92, 94 and 95. At the same time that the circuit through the ignition coil 96 is energized a branch circuit is completed through the conductor 98 to the heater coil 66 for the bimetal 64 and a conductor 100 leading to "ground." If the system is functioning properly when the motor and ignition are energized there will be combustion and immediate occurrence of flame in the burner 1. The occurrence of flame in the burner 1 will cause the thermostatic switch 106 to be heated thereby closing the contacts 105 and 107 and completing a circuit from the transformer secondary 14 through the conductors 15, 17, 109, 104, and 102 to the coil 58 of the second relay switch 57, which circuit is completed back to the transformer secondary by the conductor 75. The energization of the last-named circuit through the relay coil 58 will cause the switch contact 60 to close and by movement of the contact arm 61 and abutment 63 will move the pivoted member 47 clear of the abutment 46 thereby permitting the switch 39 to open, because the contact arm 35 of the relay switch 29 in closing moved free of engagement with the contact arm 38 of the switch 39 thus leaving the pivoted member 47 in primary control of the switch 39. The opening of the switch 39, by opening the contacts 42 and 43, causes the circuit through the motor 3 and the ignition coil 96 to be de-energized, but the closing of the contacts 60 and 59 of the second relay switch 57 establishes substantially simultaneously a second motor circuit (this second motor circuit running by conductor 81 to the closed contacts 31 and 33 of the relay switch 29, by the contact arm 35, the conductor 83, closed contacts 59 and 60 of the second relay switch 57, and the conductors 90, 86, 88 and 89 through the motor 3 to the ground wire 5, this second motor circuit by-passing the open switch 39). It should be noted that the movement of the pivoted member 47 which

permits switch 39 to open also opens switch 52. However, the opening of switch 52 at this point of operation does not affect the operation of the relay coil 28 which remains energized through the previously described holding circuit which includes relay switch contacts 30 and 32.

It is seen that in normal operation of this system the motor and ignition are initially energized but upon recognition of flame by the stack switch 106, the relay switch 57 closes causing the switch 39 to open thereby de-energizing the motor and ignition circuits and energizing a second motor circuit for the maintenance of fuel for the operation of the burner.

If the contacts 105 and 107 of the stack switch 106 fail to close for any reason (e. g., a failure of flame in the burner) or if the second relay switch 57 should fail to function for any reason, the heating of the bimetal element 64 by the heating coil 66 will cause the abutment 65 to engage and move the pivoted member 47 off the abutment 46 and thus permit the switch 39 to open to de-energize the motor and ignition circuits, the switch 52 being opened simultaneously by movement of the pivoted member 47. This action of the bimetal element 64 is a safety feature of this system to prevent the supplying of fuel to the burner 1 if there is a failure of ignition in the burner or a failure of the flame recognition circuit. When the bimetal element 64 moves to its safety operated position it moves past the end of the flexible stop member 67 which slips into position behind the bimetal element 64 thereby preventing the same from returning to its initial position upon cooling. This last-named safety action causes the pivoted member 47 to hold open the switch 52 and thus functions to prevent immediate re-energization of the circuit by opening and subsequently closing the thermostat 19 until investigation has been made to attempt to determine why there has been a failure of the system to function. (Without this last-named safety feature, if the flame recognition circuit failed to function for any reason and the system was moved to safety position as heretofore described, the circuit could be re-established by opening and closing of the thermostat 19 whereupon the system would again begin its cycle of operation as heretofore described, continued cycling of fuel in this manner without ignition thereof would cause a dangerous flooding of the burner.) To reestablish the system after safety operation of the bimetal element 64, the thermostat 19 should be opened to de-energize the holding circuit through the coil 28 of the relay switch 29 to permit the same to open. This opening of the relay switch 29 will cause the pivot arm portion 37 to engage the contact arm 38 and close the control switch 39. The reset member 68 should then be pushed in so that the arm 69 will engage the flexible stop member 67 to move the same downward to permit the bimetal element 64 to return to its initial position and upon release of the reset member 68 the pivoted member 47 can return to its initial position, permitting the switch 52 to close. The arm 70 of the reset member 68 is operable upon movement to engage and move the pivoted member 47, this last-named action being an additional safety feature of the system so that the reset member 68 may not be held in actuated position so that the re-starting of the system after safety operation can be controlled from the thermostat alone. If the arm 70 was not employed and the reset member 68 were permanently in actuated position, the flexible stop member 67 would never

function and the bimetal element 64 would always return to its initial position upon cooling and the system could be re-started by opening and closing of the thermostat 19. The arm 70 of the reset member 68 by its engagement and movement of the pivoted member 47 is operable to hold open the switch 52 and thus break the initial circuit for the relay coil 28 of the first relay switch 29.

In the form of the invention illustrated in Fig. 2 there is a burner 111 having an air and fuel supply means 112 driven by an electric motor 113 and having an electric spark ignition 114. There is a main electric power source 115 leading to a main line switch 116 from which conductors 117 and 118 lead to connection points 119 and 120 respectively on a connection panel 121. As in the previous form of the invention described the various electric circuits are shown connected through the connection panel 121 and in commercial construction the connection panel and all elements of the system to the right thereof on the drawing would be enclosed in a casing or housing as a control device for the system.

From the control panel 121 two conductors 122 and 123 lead to the primary 124 of a transformer 125. There are three secondary portions, 126, 127 and 128, for the transformer 125 from which run the various controlling circuits for the system. There is a thermostat 129 which is responsive to the heat output of the burner 111 and is operable to control energization of the system. The thermostat 129 has a fixed contact 130 and a movable contact 131 which is carried by a bimetal element 132. The thermostat 129 has a compensating resistor 133 connected in a shunt circuit from the bimetal element 132 which is operable to reduce "hunting" by the thermostat 129. There is a relay switch 134 having a coil 135 which is controlled by the thermostat 129 for controlling the system. The relay switch 134 has three pairs of contacts carried by two contact-carrying arms 136 and 137 and is held by a spring 139 so that two pairs of its contacts 139, 140 and 141, 142 are initially open and one pair of its contacts 143 and 144 are initially closed. An end portion 145 of the contact arm 136 having an insulating abutment engages and holds closed the contact arm 146 of a control switch 147 which is urged towards open position by a spring 148 and has its opening movement limited by a stop member 149. The contact arm 146 has a non-metallic abutment portion 150 thereon against which is positioned a pivoted member 151 which is operable to control the operation of the switch 147 after the contact arm portion 145 of the relay switch 134 has moved away from engagement with the contact arm 146. The pivoted member 151 is urged towards its position of engagement with the abutment 150 by a spring 152 and is limited in its direction of movement by a stop member 153. The upper portion 154 of the pivoted member 151 is operable upon movement to engage and move the contact carrying arm 155 of a single pole double throw type switch 156 which has one pair of contacts 157 and 158 initially closed, and a second pair of contacts 159 and 160 initially open. The contact-carrying arm 155 of the switch 156 has positioned thereon a magnetic armature 161 which is cooperable with a permanent magnet 162 adjacent the contact 158 and which is operable to cause the switch 156 to move with a snap action. The contact-carrying arm 155 is of a cantilever construction, the contact 157 and 158 being urged by the spring force of the arm 155 towards an initially closed position. There is a second relay switch 163 having a coil 164 and a fixed contact 165 and movable contact 166. The movable contact 166 is carried by the pivoted contact-carrrying arm 167 and is urged towards open position by a spring 168. The contact-carrying arm 167 of the relay switch 163 has an insulating material abutment portion 169 thereon which is cooperable with the pivoted member 151 to cause movement thereof upon closing movement of the relay switch 163. A bimetal element 170 having an insulating material abutment portion 171 and heating coil 172 therefor is cooperable with the pivoted member 151 upon heating and is operable to cause movement thereof. An electron tube 173 is connected in circuit with the relay switch 163 and is operable to control the same. The electron tube 173 is of a type having a control grid 174 which is controlled by a photo-electric cell 175 in circuit therewith. From the secondary portion 126 of the transformer 125 there is a conductor 176 leading to a reset switch 177 which is held by a spring 178 in a normally closed position. A conductor 179 leads from the reset switch 177 to a connection point 180 on the panel 121 from which another conductor 181 leads to the fixed contact 130 of the thermostat 129. A conductor 182 connects the bimetal element 132 of the thermostat 129 with the connection point 183 on the panel 121 which is connected by a conductor 184 to the coil 135 of the relay switch 134. The coil 135 of the relay 134 is connected to a conductor 185 which interconnects the fixed contact 142 of the relay switch 134 and the fixed contact 158 of the switch 156, there being a resistor 186 in series with the conductor 187 runs from the contact arm 155 of with the coil 135 and the fixed contact 142. The conductor 187 runs from the contact arm 155 of the switch 156 to a connection point 188 on a conductor 189 which interconnects the contact arm 137 of the relay switch 134 and the connection point 190 on the secondary portion 126 of the transformer 125. The compensating resistor 133 on the thermostat 129 is connected by a conductor 191 to a connection point 192 on the panel 121 which is in turn connected by a resistor 193 to a connection point 194 on the conductor 187. The electron tube 173 has a cathode 195 which is heated by a cathode heater element 196. The cathode heater element 196 is energized by a circuit from the secondary portion 127 of the transformer 125 through conductors 197, 198 and 199. The secondary portions 127 and 126 are connected at a connection point 200 to which is connected the conductor 198. From a connection point 201 on the conductor 198 a conductor 202 connects with the connection point 190 on the secondary portion 126 thus providing an operative interconnection of the three transformer secondary portions. The electron tube 173 has a shield grid 203 which is connected by conductors 204 and 205 and by a resistor 206 and capacitance 207 to ground at 208. The cathode heater coil 196 is connected to the shield grid 203 by conductors 199, 209, 205 and 204. The control grid 174 of the electron tube is connected by conductor 210 and a resistor 211 to the cathode 212 of the photo-electric cell 175. The photo-electric cell 175 has an anode 213 which is connected to ground at 214 by a conductor 215. The photo-electric cell 175 is housed in and surrounded by a casing or shield 175a which admits light only from the burner flame so that the cell 175 is solely responsive thereto. The conductor 210

which connects the photo-electric cell 175 to the control grid 174 has a shield 216 therearround to prevent capacitance between the conductor 210 and the system. The conductor 217 connects the shield 216 to ground to prevent capacitance between the shield 216 and the system. A capacitance 218 is positioned between the conductor 210 and the secondary portion 126 so that the current on the control grid 174 will be out of phase with the current on the plate or anode 219 of the electron tube 174 to such an extent that a very slight change of current upon the control grid 174 will render the electron tube 173 conductive, the capacitance 218 also functions to determine the charge or negative bias on the control grid 174. There is a resistor 220 and conductor 221 running from the anode 219 of the electron tube 173 to the coil 164 of the relay switch 163 and another conductor 222 leading from the coil 164 to the secondary portion 128 of the transformer 125. A capacitance 223 is positioned between connection point 224 on the conductor 222 and the conductor 221. Another capacitance 225 is positioned between the conductor 204 and the conductor 221. The capacitors and resistors positioned in the circuit around the electron tube function to reduce capacitance within the tube and to prevent radio interference. A conductor 225a runs from the cathode 195 of the electron tube 173 to the contact 144 of the relay switch 134 from whence another conductor 226 runs to the fixed contact 160 of the switch 156. A conductor 227 runs from the "hot" conductor 123 to the fixed contact 149 of the relay switch 134. The contact arm 136 of the relay switch 134 is connected by a conductor 227a to the fixed contact 165 of the relay switch 163 and is connected at a connection point 228 to the contact arm 146 of the control switch 147. The control switch 147 has two fixed contacts 229 and 230 and two movable contacts 231 and 232 respectively cooperable therewith which are carried by the contact arm 145. A conductor 233 runs from the fixed contact 229 of the switch 147 to a conductor 234 which connects through a connection point 235 on the connection panel 121 to the primary coil 236 of the ignition transformer 237 and thence by a conductor 238 to the "ground" conductor 117. From the junction point 239 of the conductors 233 and 234 a conductors 249 runs to the heater coil 172 for the bimetal element 170, another conductor 241 completing the circuit from the heater coil 172 to the "ground" conductor 122. From the fixed contact 230 of the switch 147 a conductor 242 connects with a conductor 243 leading to the connection point 244 on the connection panel 121 from whence a conductor 245 leads to the motor 113 and a conductor 246 completes the circuit to the ground conductor 117. From the junction point 247 of the conductors 242 and 243 a conductor 248 connects with the contact arm 167 of the relay switch 163.

In this system the position and operative relationship of parts are as shown in Fig. 2 before the system is energized. When the main switch 116 is closed the circuit through the conductors 117, 118, 122 and 123 is completed through the transformer primary 124 thus preparing the system for operation. With the transformer 125 energized, a circuit is energized for the heater coil 196 of the electron tube 173 and the tube 173 begins to heat in preparation for controlling the system. When the thermostat 129 closes calling for heat, a circuit is completed from the transformer secondary portion 126 through the conductor 176, the reset switch 177, the conductors 179 and 181, the closed contacts 130 and 131 of the theromstat 129, the conductors 182 and 184, the relay coil 135, the conductor 185, the closed contacts 157 and 158 of the switch 156, the conductor 187, and the conductor 189 leading to the transformer secondary portion 126 at the connection point 190. This last-named circuit energizes the coil 135 of the relay switch 134 causing the contacts 139 and 141 to close against the fixed contacts 140 and 142 respectively and the contacts 143 and 144 to open. When the contacts 141 and 142 of the relay switch 134 are closed, the circuit through the coil 135 is then completed through the resistor 186 and the closed contacts 141, 142 to the conductor 189 leading to the transformer secondary portion 126. This last-named circuit is a holding circuit for the relay coil 135 which will be energized at all times that the main switch 116 is closed and the thermostat 129 is closed. Before the relay switch 134 closes there is a circuit running from the cathode 195 of the electron tube 173 through the conductor 225a, the closed contacts 143 and 144 of the relay switch 134, the conductors 189 and 202, the secondary portion 128, the conductor 222, the relay coil 164, the conductor 221 and the resistor 220, the circuit being completed to the anode 219 of the electron tube 173. This last-named circuit is operative as a safety means, the operation of which will be described at a later time. With the contacts 139 and 140 of the relay switch 134 closed, there is a circuit established from the "hot" conductor 123 through the conductor 226, the closed contacts 139 and 140 and the contact arm 136, and the conductor 227a to the contact arm 146 of the control switch 147. At the control switch 147 the aforementioned circuit divides and a portion of the same is completed through the conductors 242, 243 and 245 to the motor 113, the circuit being completed to the "ground" conductor 117 by conductor 246. This last-named circuit functions to energize the motor 113. Another portion of the circuit from the switch 147 runs from the contacts 229 and 231 through a conductor 233 to the connection point 239 where the circuit divides, a portion of the circuit being completed through conductors 234 and 238 through the ignition coil 236 to the "ground" conductor 117, and another portion of the circuit runs through the conductor 240 to the heater coil 172 for the bimetal element 170 and is completed through the conductor 241 to the "ground" conductor 122. These last-mentioned circuits energize the ignition electrodes 114 for the burner 111 and the heater coil 172 for the bimetal element 170 respectively. When the relay switch 134 is closed and the contacts 143 and 144 are open the aforementioned circuit from the cathode 195 of the electron tube 173 through the coil 164 of the relay switch 163 is broken. As the heater coil 172 heats the bimetal element 170 this element moves the abutment 171 against the pivoted member 151 causing the same to move. After a predetermined period of heating by the heater coil 172 the bimetal element 170 will cause the abutment 171 to move the pivoted member 151 until the upper portion 154 engages and moves the contact arm 155 of the switch 156. This movement of the pivoted member 151 will cause the contact arm 155 of the switch 156 to move, opening the contacts 157 and 158 and closing the contacts 159 and 160. The amount of movement by the

pivoted member 151 required to close the contact 159 and 160 of the switch 156 is so determined that the pivoted member 151 will not have moved clear of the abutment 150 of the switch 147 at this time. This position of movement of the bimetal element 170, the pivoted member 151 and the contact arm 155 is illustrated in Fig. 3 wherein the bimetal element 170 has moved the aforementioned parts to the position described thus closing the contacts 159 and 160 and thereby establishing a second circuit from the cathode of the electron tube 173. This second cathode circuit is operative through the conductors 225a and 226, the closed contacts 159 and 160 of the switch 156, the conductors 187, 189 and 202, the secondary portion 128, the conductor 222, the relay coil 164, the conductor 221 and the resistor 220, the circuit terminating at the anode 219.

At this point in the operation of the system, with the thermostat 129 closed and the circuits to the ignition and to the motor through the switch 147 energized, the closing of the contacts 159 and 160 of the switch 156 establishes a second cathode circuit rendering the system responsive to the occurrence of flame at the burner 111. With the motor and ignition circuits energized, the next step in the normal sequence of operation of the system would be for the fuel to be ignited at the burner 111. If the system functions normally, the fuel is ignited at the burner 111 and the occurrence of flame will cause the photo-electric cell 175 to become energized and drain a negative potential from the control grid 174 of the electron tube 173 thus rendering the electron tube 173 conductive. When the electron tube 173 is thus rendered conductive by the occurrence of flame at the burner 111 current will be able to flow through the electron tube thus completing the second cathode circuit and energizing the relay coil 164. This energization of the relay coil 164 will cause the contacts 165 and 166 to close a movement of the contact arm 167; this movement of the contact arm 167 will move the abutment 169 against the pivoted member 151 causing the same to move clear of the abutment 150 and permitting the switch 147 to open, as is shown in Fig. 4. When the switch 147 is opened by the aforementioned movement of the pivoted member 151 the opening of the switch contacts 229 and 231, 230 and 232 will de-energize the circuits to the motor 113, the ignition transformer 236, and the heater coil 172, these elements having been described heretofore as being in circuit with the switch 147. The closing of the relay switch 163 simultaneously with the opening of the switch 147 causes the establishment of a second circuit for the motor from the "hot" conductor 123 through the conductor 226, the closed contacts 139 and 140, the contact arm 136, the conductor 227a, the closed contacts 165 and 166 of the relay switch 163, the contact arm 167, the conductor 248, and the conductors 243, 245 and 246 through the motor 113 to the "ground" conductor 117.

It is seen then that in normal operation when the system is energized and the thermostat 129 calls for heat, the relay switch 134 closes establishing a holding circuit for itself and energizes circuits for the motor 113, the ignition 114 and the heater coil 172 through the switch 147. The heater coil 172 then functions as a timer for moving the contact arm 151 to close the switch contacts 159 and 160 to establish a second circuit from the cathode, the length of time for this

operation being substantially that required for the heating of the electron tube 173. The occurrence of flame then at the burner 111 causes the activation of the electron tube 173 and completes the circuit through the relay switch 163 causing the same to close and thus de-energizing the motor, ignition, and heater coil circuits and substantially simultaneously energizing a second motor circuit. If, for any reason, the relay switch 163 fails to close at the time when the heater coil 172 and the bimetal element 170 have moved the pivoted member 151 and contact arm 155 to establish the aforementioned second circuit from the cathode, the heater element 172 will continue to cause the bimetal element 170 to move the pivoted member 151. If the relay switch 163 then fails to close before the pivoted member 151 moves clear of the abutment 150 the switch 147 will be opened thus de-energizing the motor, ignition, and heater coil circuits. This last-mentioned operation is as shown in Fig. 5 and functions as a "safety" for the system in the event that the relay switch 163 fails to close. (The failure of flame at the burner 111 or the failure of the electron tube 173 to function are the principal causes of such safety operation but the safety operation would function as described should the relay switch 163 fail to close for any reason whatsoever.) When the bimetal element 170 has cooled and returned to its initial position after the safety operation, the pivoted member 151 will not be able to return to its initial position because of its engagement with the edge of the abutment 150 of the switch 147. After such safety operation the system will not be able to function again until the relay switch 134 is permitted to open (the relay switch 134 being held closed by its holding circuit during safety operation). If the circuit through the coil 135 of the relay switch 134 is opened, either by opening the thermostat 129 or by opening the reset switch 177, the holding circuit for the coil 135 will be broken thus permitting the spring 138 to move the switch 134 to its initial open position. This opening movement of the relay switch 134 will cause the end portion 145 of the contact arm 136 to engage the contact arm 146 of the switch 147 causing the same to be closed since the spring 138 is stronger than the spring 148. Upon this closing of the switch 147 by the relay switch 134 the spring 152 will then be able to move the pivoted member 151 back into engagement with the abutment 150. This last sequence of operation places the system in its initial operating condition and renders the same operative upon closing of the thermostat 129 and the operation of the other units of the system as heretofore described. If, while the system is energized and in its initial or "off" position, as shown in Fig. 2, the conductor 210 from the control grid 174 should become shorted giving a continuous and false indication of flame at the burner 111, the first-named circuit from the cathode 195 through the closed contacts 143 and 144 of the relay switch 134 will function as a safety means to protect the system. If the described condition occurs, the electron tube 173 will become conductive permitting a completed circuit through the relay coil 164 and causing the relay switch 163 to close. The closing of the relay switch 163 will cause the pivoted member 151 to be moved, as previously described, thus opening the switch 147 and the switch contacts 157 and 158 of the switch 156. The opening of the switch 147 will protect the system in that

the motor and ignition circuits cannot then be energized and the opening of the switch contacts 157 and 158 will prevent energization of the relay switch 134 whenever the thermostat 129 should close.

In the system shown in Fig. 6 there is a modification of the form shown and described in Fig. 2 with certain safety features added and modification of the circuits for the adaptation of these safety features.

There is a burner 249 having a fuel and air supply blower 250 driven by a motor 251 and having an electric spark ignition 252. Electric power for the system is supplied from a main power source 253 and is controlled by a switch 254. As was described in the previous forms of this invention the circuits are shown as being connected through a connection panel 255 and in commercial construction all of the elements shown to the right of the connection panel would be assembled within a casing or other enclosure as a unit control device. From the switch 254 two conductors 256 and 257 lead to connection points 258 and 259 respectively. From the connection points 258 and 259 the circuit is completed through the primary 260 of a transformer 261 by conductors 262 and 263. The transformer 261 has three secondary portions 264, 265 and 266 from which run the circuits for the energization of the system. A thermostat 267 is connected to the connection panel 255 at connection points 268, 269 and 270 and is operable to control the operation of the system by its response to the heat output of the burner 249. The thermostat 267 has a fixed contact 271 and a movable contact 272 carried by a bimetal element 273 from which is connected a resistor 274 which is operable to compensate the thermostat for irregular variations in temperature. The contacts 271 and 272 and the compensating resistor 274 are connected to the connection panel 255 by conductors 275, 276 and 277 respectively. The thermostat 267 is energized by a circuit running from the secondary portion 264 of the transformer 261 which is connected by a conductor 278 to a connection point 270 on the connection panel 255. From the connection point 268 on the connection panel 255 a conductor 279 runs to a relay coil 280 of a relay switch 281. The relay switch 281 has two pivoted contact-carrying arms 282 and 283 which carry the movable contacts 284, 285 and 286, the contacts 284 and 285 being carried by the contact arm 282. The contacts 284 and 285 are engageable with the "fixed" contacts 287 and 288 respectively, which are carried by flexible supporting members 289 and 290. The contact 286 carried by the contact arm 283 is engageable with a fixed contact 291. The switch contacts 287 and 284 are initially closed and the contacts 285, 288, 286 and 291 are initially open, the switch being held in this initial position by a spring 292. The flexible contact arm 289 is inherently flexed towards a stop member 293 towards which it will move upon closing movement of the switch 281. The flexible contact arm 290 is likewise tensioned against the stop member 294. When the relay switch 281 is closed, the contact-carrying arms 282 and 283 move downward under the attraction of the relay coil 280 and the flexible arm 289 causes the contact 287 to travel with the contact 284 until its movement is stopped by the stop member 293. The stop member 293 is so positioned that the contact 284 will not break away from the contact 287 until contact has been made between the contacts 285 and 288 which movement continues until the contacts 286 and 291 are closed and the flexible contact arm 290 is tensioned away from the stop member 294. Upon opening movement of the relay switch 281 a similar action takes place in that the contact 286 will not break from the contact 291 until contact has been made between the contacts 284 and 287. The pivoted contact-carrying arm 282 of the relay switch 281 has an electrically insulated end portion 295 which is engageable with the contact carrying arm 296 of a switch 297 when the relay switch 281 is in its initial open position. The contact-carrying arm 296 is urged by a spring 298 towards an open position but is limited in this movement by a stop member 299. The contact arm 296 carries two contacts 300 and 301 thereon which are engageable with fixed contacts 302 and 303 respectively. The contact arm 296 has a non-metallic abutment member 304 thereon which is engageable by a pivoted member 305 which is operable to hold the switch 297 closed when the pivoted arm portion 295 of the relay switch 281 is not in engagement therewith. The pivoted member 305 is held in its position of engagement with the abutment member 304 by a spring 306 and is limited in this direction of movement by a stop member 307. The upper portion 308 of the pivoted member 305 is engageable with the contact carrying arm 309 of a switch 310. The switch 310 has a fixed contact 311 and a movable contact 312 carried by the contact arm 309, the contact arm 309 being of a cantilever construction and urging the contacts 311 and 312 towards engagement. The contact arm 309 carries a magnetic armature 313 which is cooperable with a permanent magnet 314 adjacent the fixed contact 311 and is operable to cause the switch 310 to open and to close with a snap action. A second relay switch 315 has two pivoted contact carrying arms 316 and 317, the pivoted contact arm 317 having an electrically insulated abutment portion 318 thereon which is operable upon movement to engage and move the pivoted member 305. The relay switch 315 has a coil 319 which is operable on energization to move the contact arms 316 and 317, the same being held in an open position by a spring 320. The relay switch 315 has two movable contacts 321 and 322 which are carried by the pivoted contact arms 316 and 317 respectively, and two fixed contacts 323 and 324 which are carried by two flexible supporting members 325 and 326. The relay switch 315 is operable upon closing movement to cause the abutment member 318 to engage and move the pivoted member 305 clear of the abutment 304 thus permitting the switch 297 to open and simultaneously by engagement of the upper portion 308 with the contact arm 309 to cause the switch 310 to open. The "fixed" contacts 323 and 324 of the relay switch 315 are so positioned in relation to the movable contacts 321 and 322 that when the relay switch 315 closes the contacts 322 and 324 will engage prior to the opening of the switch 310 and the relay switch 315 and will have an overtravel movement due to the flexibility of the flexible contact arms 325 and 326 so that said overtravel movement will permit the switch 310 to be opened after engagement of the contacts of the relay switch 315. There is a bimetal element 327 which is heated by an electric heating coil 328 and has an abutment member 329 of electric insulating material and which is operable upon heating to move the pivoted member 305 for safety operation. The

bimetal element 327 has a flexible stop member 330 engageable therewith which is operable to prevent the same from returning to its initial position upon cooling after having performed its safety function. A reset member 331 has an arm portion 332 engageable with the flexible stop member 330 upon movement and is operable to move the same to permit the bimetal element 327 to return to its initial position upon cooling. The reset member 331 also has an arm portion 333 which is operable upon movement to engage and move the pivoted member 305 to open the switch 310 and to hold the same open so long as the reset member 331 is in its operated position. The reset member 331 also has a side arm or projecting portion 334 which is engageable upon movement with the operating arm 335 of a reset switch 336 and is operable to open and to hold open the same while in operated position. In circuit between the switch 310 and the relay switch 281 is an electric timing switch 337 which operates to delay the functioning of the relay switch 281 for a predetermined time. The timing switch 337 has a fixed contact 338 and a movable contact 339, the movable contact 339 being carried by a bimetal element 340. Through the switch 337 runs a resistor 341 which is operable to cause a sufficient voltage drop therethrough to prevent operation of the relay switch 281 so long as the resistor 341 is functioning. The bimetal element 340 of the timing switch 337 is responsive to the heat generated by the resistor 341 and is operable after a predetermined period of heating to warp so that the contacts 338 and 339 will close and establish a shunt circuit through the bimetal element 340 which has a very low resistance compared to the resistor 341. The relay switch 315 has an electron tube 342 in circuit therewith, said electron tube being operable to control energization of the relay coil 319. The electron tube 342 is of the controllable grid type having a control grid 343 which is controlled by a photo-electric cell 344 which is responsive to the occurrence of flame at the burner 249. From the relay coil 280 of the relay switch 281 there is a conductor 345 leading to the reset switch 336 which is in turn connected by a conductor 346 to the pivoted contact arm 282 of the relay switch 281. From the flexible contact arm 289 of the relay switch 281 there is a conductor 347 leading to the timing switch 337 from whence a conductor 348 leads to the contact arm 309 of the switch 310. From the fixed contact 311 of the switch 310 a conductor 349 runs to the contact arm 317 of the relay switch 315. From a connection point 350 on the conductor 349 another conductor 351 leads to a connection point 352 on a conductor 353 which together with a "drop-out" resistor 354 interconnects the flexible contact arm 290 of the relay switch 281 and a conductor 355 leading to the transformer secondary portion 264. The transformer secondary portions 265 and 266 are connected at connection point 356 and are together connected to the conductor 355 at a connection point 357 by which an operative interconnection of the three secondary portions is obtained. From the connection point 358 on the "hot" conductor 262 a conductor 359 runs to the contact arm 283 of the relay switch 281. From the fixed contact 291 of the relay switch 281 a conductor 360 runs to the contact arm 296 of the switch 297, a branch conductor 361 running from a connection point 362 of the conductor 360 to the flexible contact arm 325 of the relay switch 315. From the fixed contact 303 of the switch 297 the conductor 363 runs to the connection point 364 on the connection panel 255, from whence a conductor 365 runs to the motor 251 which is in turn connected by conductor 366 to the "ground" conductor 257. From the fixed contact 302 a conductor 367 runs to the connection point 368 on the connection panel 255 to which is connected the primary 369 of the ignition transformer 370 which is in turn connected to the "ground" conductor 257 by a conductor 371. A branch conductor 372 runs from the connection point 373 on the conductor 367 to the heater coil 328 of the bimetal element 327 from whence a conductor 374 runs to the "ground" conductor 263. The electron tube 342 has a cathode 375 which is heated by a cathode heater coil 376. The electron tube 342 has a screen grid 377 and an anode 378. The cathode heater coil 376 is connected by a conductor 379 to the transformer secondary portion 265 and is connected to the conductor 355 at a connection point 380, the circuit from the conductor 355 being completed back to the transformer secondary portion 265 by a conductor 381 interconnecting the connection points 356 and 357 thus completing the cathode heater circuit. The circuit from the compensating resistor of the thermostat 267 is completed from the connection panel at point 269 by a conductor 382 having a resistor 383 therein to a connection point 384 on the conductor 355. From the cathode 375 of the electron tube 342 a conductor 385 runs to the flexible contact supporting member 326 of the relay switch 315. A conductor 386 runs from a connection point 387 on the conductor 385 to the contact arm 309 of the switch 310. From the transformer secondary portion 266 a conductor 388 runs to a connection point 389 from whence another conductor 390 runs to the coil 319 of the relay switch 315. From the coil 319 of the relay switch 315 the conductor 391 runs to a connection point 392 from whence a resistor 393 completes the connection to the anode 378 of the electron tube 342. A capacitance 394 is positioned between the connection point 395 on the conductor 391 and the connection point 389 at the juncture of the conductors 388 and 390. At the connection point 392 a capacitance 396 is connected which is in turn connected by a conductor 397 to a capacitance 398 at a point 399, the capacitance 398 being grounded as at 400. A conductor 401 runs from the heater filament connection point 380 of the electron tube 342 to a point 402 which joins a lead from the screen grid 377 and a conductor 403 from the connection point 399 of the capacitances 396 and 398, a resistor 404 completing the connection from the point 402 to ground at 400. From the control grid 343 of the electron tube 342 a conductor 405 having a resistor 406 therein leads to the cathode 407 of the photo-electric cell 344. The conductor 405 and resistor 406 are shielded to prevent capacitance between the conductor 405 and the system. The photo-electric cell 344 has an anode 408 from whence a conductor 409 runs to ground as at 410; another conductor 411 runs from the shield 412 and joins the ground conductor 409 at a connection point 413. There is a conductor 414 running from the connection point 415 on the conductor 405 to a capacitance 416 which is connected to the transformer secondary portion 264 at a connection point 417.

The operative relationship of the various parts of the system as is shown in Fig. 6 corresponds to the initial condition of the system prior to energization. When the main power switch 254

is closed the transformer 261 is energized and the system is ready to function subject to the various controls therein. The electron tube cathode heater coil 376 is energized by the transformer secondary portion 265 as soon as current is supplied to the transformer primary 260 and the electron tube 342 then begins to heat in preparation for its functioning later on. When the thermostat 267 closes calling for heat a circuit is completed from the transformer secondary portion 264 through the conductors 278 and 275, the closed contacts 271 and 272 of the thermostat 267, and the conductors 276 and 279 to the relay coil 280. From the relay coil 280 the circuit continues through the conductor 345, the reset switch 336, the conductor 346, the closed contacts 284 and 287, the conductor 347, the resistor 341 of the timer switch 337, the conductor 348, the closed contacts 311 and 312 of the switch 310, the conductors 351 and 353, and the conductor 355 terminating back at the transformer secondary portion 264. This last-named circuit as described is completed through the relay coil 280 but the voltage drop through the resistor 341 is so great that there is not sufficient current through the relay coil 280 to cause the relay switch 281 to close. While this great voltage drop is taking place through the resistor 341, the same is heating and transmitting heat to the bimetal element 340 so that after a predetermined time the bimetal element 340 will warp to such an extent that the contacts 338 and 339 of the timer switch 337 will close thus establishing a shunt circuit of lower resistance through the bimetal element 340 so that the relay coil 280 is able to function and close the relay switch 281. When the relay switch 281 closes, the contacts 284 and 287 are broken apart and the contacts 285, 288, 286 and 291 respectively are closed. The closing of the contacts 285 and 288 establish a holding circuit for the relay coil 280 which is completed through the closed contacts 285 and 288, the resistor 354 and the conductors 353 and 355 terminating at the transformer secondary portion 264. The resistor 354 which is connected in series with the relay coil 280 in the holding circuit for the relay switch 281 is of a sufficient resistance to cause a voltage drop therethrough which will render the relay coil 280 inoperative or cause the relay switch 281 to open should the voltage in the circuit drop below a predetermined minimum value. The closing of the holding circuit for the relay coil 280 and the opening of the contacts 284 and 287 cause the circuit through the timer switch 337 to be broken and the holding circuit to be independent of the circuit through the timer switch 337. At the time the system is first energized and prior to the closing of the thermostat 267 and the relay switch 281 there is a circuit established from the cathode 375 of the electron tube 342 through the conductors 385 and 386, the closed contacts 311 and 312 of the switch 310, the conductors 351, 353, 355 and 381, the transformer secondary portion 266, the conductors 388 and 390 to the relay coil 319 of the relay switch 315, the circuit being completed by the conductors 391 and resistor 393 leading back to the anode 378 of the electron tube 342. Since this circuit operates through the closed contacts of the switch 310 and (as will be explained later) since the switch 310 will be opened upon activation of the electron tube 342, this circuit functions as a "safety" for the system in the event that the control grid of the electron tube 342 should become shorted giving a false indication of flame while the system is in an "off" position. When the contacts 286 and 291 of the relay switch 281 are closed a circuit is completed from the "hot" conductor 262 through the conductor 359, the closed contacts 286 and 291 and the conductor 360 to the switch 297. Through the closed contacts 301 and 303 of the switch 297 a circuit is completed through the motor 251 by the conductors 363, 365 and 366. Through the closed contacts 300 and 302 of the switch 297 the circuit is completed through the ignition coil primary 369 by the conductors 367 and 371, a branch circuit running from connection point 373 on conductor 367 over the conductors 372 and 374 through the heater coil 328 of the bimetal element 327. It is seen then that upon energization of the system the primary of the transformer 261 is energized thus energizing a circuit for the heater coil 376 of the electron tube 342. When the thermostat 267 closes the circuit is completed through the coil 280 of the relay switch 281, but due to the voltage drop through the timer switch 337 the relay switch 281 is not able to function. After a predetermined time the timer switch 337 establishing a shunt circuit around the high resistor therein permitting the relay switch 281 to close, the aforementioned predetermined time for operation of the timer switch 337 being at least that required for the heating of the electron tube 342. When the relay switch 281 is closed a holding circuit is established for the relay coil 280 and circuits are energized through the control switch 297 to the motor, the ignition and the heater element of the bimetal element 327. At this point in the operation the system is ready to function subject to the occurrence of flame at the burner 249. If upon the aforementioned energization of the circuits through the motor and the ignition, the system should function normally and flame occur in the burner 249 the photo-electric cell 344 will function to drain a negative potential from the control grid 343 of the electron tube 342 thus permitting the passage of electric current therethrough. The photo-electric cell 344 is housed in a casing 344a to shield it from response to extraneous light rays not emitted from the burner flame. Upon the electron tube 342 becoming conductive the aforementioned circuit from the cathode of the electron tube through the coil 319 of the relay switch 315 is completed and the relay switch 315 will close. The closing of the relay switch 315 will cause the contact arm 317 to move the abutment member 318 against the pivoted member 305 moving the same free of the abutment 304 permitting the switch 297 to open and simultaneously engage the contact arm 309 of the switch 310 with the upper portion 308 of the pivoted member 305 causing the switch 310 to open. As was described heretofore the "fixed" contacts 323 and 324 of the relay switch 315 are mounted upon flexible supporting members 325 and 326 so that the movable contacts 321 and 322 upon closing movement may contact the "fixed" contacts before the switch 310 is open. (This step in the operation of the system is illustrated in Fig. 7. The contacts of the relay switch 315 are shown closed and the switch 310 has not yet opened.) The flexibility of the "fixed" contacts permits the movable contacts of the relay switch 315 to have a predetermined amount of overtravel during which overtravel the pivoted member 305 is moved clear of the abutment 304 to permit the

switch 297 to open and the switch 310 is opened by engagement of the upper portion 308 of the pivoted member 305 with the contact-carrying arm 309. This step of the operation is shown in Fig. 8 in which the movable contact arms 316 and 317 have moved past their point of engagement with the "fixed" contacts and the switches 297 and 310 are opened.) At this point, with the switch 297 open and the relay switch 315 closed, a second circuit is established for the motor and a second circuit is established for holding closed the relay switch 315. The second motor circuit runs from the "hot" conductor 262 through the conductor 359, the closed contacts 286 and 291 of the relay switch 281, the conductors 360 and 361, the closed contacts 321 and 323 of the relay switch 315, the conductors 363 and 363a to the connection panel 255 and thence by conductors 365 and 366 through the motor 251 to the ground conductor 257. The second cathode circuit for holding the relay switch 315 closed runs from the cathode 375 of the electron tube 342 by conductor 385 to the flexible contact arm 326 of the relay switch 315, through the closed contacts 322 and 324, the conductors 351, 353, 355 and 381, the transformer secondary portion 266, the conductors 388 and 390 to the relay coil 319, the circuit being completed by conductor 391 and resistor 393 to the anode 378 of the electron tube 342. As was pointed out in the mechanical operation of the relay switch 315 against the pivoted member 305, these circuits through the contacts of the relay switch 315 are established before the switches 297 or 310 are opened thus providing a continuous circuit independent of the opening of the switches 310 and 297. The opening of the switch 297 de-energizes the first-named circuit to the motor 251, the re-establishment of which has already been described, and the circuit to the ignition transformer 370 and the heater coil 328 for the bimetal element 327. It is seen then that in the normal sequence of operation of this system upon energization and upon calling for heat by the thermostat 267, the relay switch 281 is closed after a predetermined delay caused by the time switch 337 to permit the electron tube 342 to heat, the closing of the relay switch 281 being operable to energize the circuits to the motor 251, the ignition transformer 370, and the heater coil 328 for the bimetal element 327. The occurrence of flame then at the burner 249 will cause the electron tube 342 to become conductive thus completing the circuit through the relay switch 315 causing the same to close thus opening the circuits for the motor, the ignition, the heater coil and the electron tube, a second circuit for the motor and for the electron tube being established simultaneously with the opening of the aforementioned circuits. When the system is energized, the thermostat 267 is calling for heat and the relay switch 281 is closed. If the relay switch 315 should fail to close for any reason (e. g. failure of flame at the burner, failure of the electron tube 342, or a break in the relay circuit) the heater coil 328 for the bimetal element 327 will continue to heat to operate as a "safety" means for moving the bimetal element 327 into engagement with the pivoted member 305 to move the same clear of the abutment 304 to permit the switch 297 to open and simultaneously to open the switch 310. At this point in the safety operation the system is in substantially the same condition as that shown in the form of the invention of Fig. 2 in that the switches 297 and 310 are open and the relay switch 281 is closed by its holding circuit. The system at this point is in a "lock-out" position from which position the system cannot function until the switches 297 and 310 are closed. In this form of the invention, however, there is a flexible stop member 330 which is engageable with the bimetal element 327 upon operation thereof to prevent the same from returning to its initial position after safety operation so that the system may not be operated again after safety operation until a check has been made to determine the cause of the failure. With the bimetal element 327 locked by the stop member 330 in its operated position the pivoted member 305 cannot return to its initial position and so even though the circuit through the thermostat 267 might be opened permitting the relay switch 281 to return to its initial position and closing the switch 297 by engagement of the pivoted contact arm portion 295 with the contact arm 296 the pivoted member 305 would still hold open the switch 310 thus preventing reenergization of the relay coil 280 until the bimetal element 327 is permitted to return to its initial position. When the reset member 331 is pushed into engagement with the stop member 330, the stop member 330 is moved clear of engagement with the bimetal element 327 and the same is permitted to return to its initial position.

As an additional "safety" feature the reset arm portion 333 is engageable with the pivoted member 305 so that the reset member 331 may not be lodged into operated position and the stop member 330 thereby rendered ineffective. (If the reset member 331 should be held in operated position the reset arm portion 333 acting through the pivoted member 305 will function to hold the switch 310 open thus preventing operation of the system.) The projecting arm portion 334 of the reset member 331 is cooperable upon movement to engage the reset switch 336 to open the same simultaneously with the resetting of the bimetal element 327 thereby breaking the circuit through the relay coil 280 independently of the thermostat 267. The described step in the sequence of operation of the system in which the bimetal element 327 has moved the pivoted member 305 to safety position is clearly illustrated in Fig. 9. In operation if the fuel should fail to ignite in the burner 249 upon initial operation of the system the bimetal element 327 will move to "safety" position thus locking the system as described until the reset member has been operated. If, upon initial operation, the fuel should ignite at the burner 249 and the system function normally as heretofore described, but during the operation the flame, for some reason, should go out the electron tube 342 would then be blocked for passage of current therethrough thus causing the relay switch 315 to open to de-energize the motor circuit to prevent further supply of fuel to the burner 249. At this point in the operation since the bimetal element 327 has not moved to safety position and the switches 297 and 310 are open the thermostat 267 must be opened or the reset member moved to open the reset switch to break the holding circuit through the relay coil 280 to permit the relay switch 281 to return to its initial position to close the switch 297 and permit the pivoted member 305 to return to its initial position and the switch 310 to close. The relay switch 281 is able to close the switch 297 because the spring 232 is stronger than the spring 298. After the circuit has been opened through the thermostat 267 and the re-

lay switch 281 a subsequent closing of the contacts of the thermostat 267 will cause the system to function as though it were being started initially, that is, the system will go through its normal cycle of operation and should the fuel fail to ignite at the burner 249 the bimetal element 327 will move to safety position as described heretofore.

The systems as shown are applicable especially to the control of "gun or rotary types" of liquid fuel burners having a blower and means for supplying fuel in a fine spray to the burner. These systems, however, would also be adaptable to the control of "pot type" liquid fuel burners wherein an electric blower supplies a forced draft of air to the burner or where the supply of fuel to the burner is controlled by an electric valve such as a solenoid valve. It would also be possible to adapt these control systems to the burning of solid fuel in a finely divided state wherein a powdered fuel and air mixture would be supplied to the burner by a blower which could be controlled by the system. It should therefore be evident that although the systems have been described as specifically applicable to "gun type" oil burners, it is not intended that this invention shall be so limited.

Having thus described the invention, what is claimed and is desired to be secured by Letters Patent of the United States is:

1. In a control device, a circuit including a switch, a relay switch operable to control energization of said circuit, a second circuit including a third switch, said third switch being initially closed, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon predetermined movement to permit said first-named switch to open and to open said third switch, electric timing means operable after a predetermined time as safety means to move said pivoted member through said predetermined movement, and means including a second relay switch arm operable to engage said pivoted member and to move the same to open said first-named and said third switches.

2. In a control device, a circuit including a switch, a relay switch operable to control energization of said circuit, a second circuit including a third switch, said third switch being initially closed, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon predetermined movement to permit said first-named switch to open and to open said third switch, a third circuit connected in parallel with said first-named circuit, a second relay switch having contacts in said third circuit, said second relay switch having a contact carrying pivoted member operable upon movement to close said contacts in said third circuit and also to engage and move said first-named pivoted member through said predetermined movement thereby to open said first-named and said third switches.

3. In a control device, a circuit including a switch, a relay switch operable to control energization of said circuit, a second circuit including a third switch, said third switch being initially closed, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon predetermined movement to permit said first-named switch to open and to open said third switch, a bimetal element, an electric heating coil for said bimetal element, said bimetal element being operable upon heating for a predetermined time to move said pivoted member through said predetermined movement thereby to open said first-named and said third switches for safety operations, a second relay switch having a pivoted member operable upon closing movement to engage and move said first-named pivoted member through said predetermined movement thereby to open said first-named and said third switches.

4. In a control device, a first circuit and a second circuit, a switch having two pairs of contacts for controlling said circuits, a relay switch having a pair of contacts in said first and said second circuits and operable to control energization of said circuits, a third circuit, a second relay switch having a pair of contacts in and controlling said third circuit, said second relay switch being normally open, a fourth circuit including a fourth switch, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open and to open said fourth switch, said second relay switch having a pivoted contact-carrying arm engageable with and operable to move said pivoted member, said second relay switch being operable upon closing movement to move said pivoted member so that said first-named switch and said fourth switch may open thus de-energizing said first, said second, and said fourth circuits and energizing said third circuit, and safety means operable to move said pivoted member to open said first-named switch upon failure of said second relay switch to close.

5. In a control device, a first circuit and a second circuit, a switch for controlling said circuits, a relay switch operable to control energization of said circuits, a third circuit connected in parallel with said first circuit, a second relay switch for controlling said third circuit, said second relay switch being normally open, a fourth circuit including a fourth switch, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open and to open said fourth switch, said second relay switch having a pivoted contact-carrying arm engageable with and operable to move said pivoted member, said second relay switch being operable upon closing movement to move said pivoted member so that said first-named switch and said fourth switch may open thus de-energizing said first, said second, and said fourth circuits and energizing said third circuit, a bimetal element, an electric heating coil and circuit for said bimetal element, said bimetal element being operable upon heating to move said pivoted member, and said heating coil and bimetal element being operable as timing means and as safety means by moving said pivoted member and thereby opening said first-named switch upon failure of said second relay switch to function within a predetermined time.

6. In a control device, a first circuit and a second circuit, a switch having two pairs of contacts for controlling said circuits, a relay switch having a pair of contacts in said first and said second circuits and operable to control energization of said circuits, a transformer, a third circuit from said transformer including a third switch and operable to energize said relay switch, a fourth circuit, a second relay switch having a pair of contacts in and controlling said fourth circuit, said second relay switch being normally open, a holding circuit for said first-named relay

switch operable upon closing of said first-named relay switch to hold the same closed independently of said third circuit, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open and to open said third switch, said second relay switch having a pivoted contact-carrying arm engageable with and operable to move said pivoted member, said second relay switch being operable upon closing movement to move said pivoted member so that said first-named switch and said third switch may open thus de-energizing said first, said second, and said third circuits and energizing said fourth circuit, and safety means operable to move said pivoted member to open said first-named switch upon failure of said second relay switch to close.

7. In a control device, a circuit including a control switch, a second circuit in parallel with said first-named circuit and including a second control switch, said second switch including an arm operable upon closing movement to open said first-named switch, means for controlling the energization of said first-named circuit, means for controlling said control means, safety means operable to open said first-named switch upon failure of said second switch to function, stop means operable to prevent said safety means from returning to its initial state after functioning, a reset mechanism operable upon movement to move said stop means to permit said safety means to return to its initial state, and said reset mechanism being further operable to actuate said second-named control means to prevent energization of said first-named circuit.

8. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch operable to control said circuits, a relay switch for controlling energization of said circuits, a third switch for controlling energization of said relay switch, a second motor circuit, a second relay switch for controlling said second motor circuit, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon movement to permit said first-named switch to open and to open said third switch, a holding circuit for said first-named relay switch operable to hold the same closed upon opening of said third switch, said second relay switch being operable upon closing movement to move said pivoted member thereby opening said first-named and said third switches, a bimetal element operable to move against said pivoted member upon heating, an electric heating coil for said bimetal element, said heating coil and said bimetal element being operable as safety means to move said pivoted member to open said first-named and said third switches upon failure of said second relay switch to close within a predetermined time, a flexible stop member operable to prevent said bimetal element from returning to its initial position upon cooling, a reset member operable upon movement to engage and move said stop member thereby to permit said bimetal element to return to its initial position, and said reset member being further operable upon movement to engage and move said pivoted member.

9. In a control device, a circuit including a switch, a relay switch operable to control energization of said circuit, a second circuit including a third switch, said third switch being initially closed, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon predetermined movement to permit said first-named switch to open and to open said third switch, a third circuit connected in parallel with said first-named circuit, a second relay switch having contacts in said third circuit, an electron tube in circuit with and controlling said second relay switch, and said second relay switch having a contact carrying pivoted member operable upon movement to close said contacts in said third circuit and also to engage and move said first-named pivoted member through said predetermined movement thereby to open said first-named and said third switches.

10. In a control device, a circuit including a switch, a relay switch operable to control energization of said circuit, a second circuit including a third switch, said third switch being initially closed, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon predetermined movement to permit said first-named switch to open and to open said third switch, a third circuit connected in parallel with said first-named circuit, a second relay switch having contacts in said third circuit, an electron tube in circuit with and controlling said second relay switch, said second relay switch having a contact carrying pivoted member operable upon movement to close said contacts in said third circuit and also to engage and move said first-named pivoted member through said predetermined movement thereby to open said first-named and said third switches, a bimetal element, an electric heating coil for said bimetal element, and said bimetal element being operable after heating for a predetermined time to move said pivoted member the distance necessary to open said first-named switch.

11. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch operable to control energization of said circuits, a third switch operable to control said relay switch, a second motor circuit in parallel with said first motor circuit, a second relay switch having contacts in and controlling said second motor circuit, said second relay switch being normally open, an electron tube in circuit with the coil of said second relay switch and operable to control its operation, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open, said second relay switch having a pivoted contact-carrying arm which is operable upon closing movement to energize said second motor circuit and to engage and move said pivoted member to open said first-named switch, said second relay switch being operable upon activation of said electron tube to close thus moving said pivoted member to open said first-named switch thereby de-energizing said motor and ignition circuits and energizing said second motor circuit, and safety means for de-energizing said motor and ignition circuits upon failure of said electron tube to function.

12. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch operable to control energization of said circuits, a third switch operable to control said relay switch, a second motor circuit in parallel with said first motor circuit, a

second relay switch having contacts in and controlling said second motor circuit, said second relay switch being normally open, an electron tube in circuit with the coil of said second relay switch and operable to control its operation, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open, said second relay switch having a pivoted contact-carrying arm which is operable upon closing movement to energize said second motor circuit and to engage and move said pivoted member to open said first named switch, said second relay switch being operable upon activation of said electron tube to close thus moving said pivoted member to open said first named switch thereby de-energizing said motor and ignition circuits and energizing said second motor circuit, a bimetal element, an electric heating coil for said bimetal element, and said bimetal element being operable upon predetermined heating as a safety means to move said pivoted member to open said first-named switch to deenergize said motor and ignition circuits upon failure of said electron tube to function within a predetermined time.

13. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch operable to control energization of said circuits, a third switch operable to control said relay switch, a second motor circuit, a second relay switch for controlling said second motor circuit, said second relay switch being normally open, an electron tube in circuit with the coil of said second relay switch and operable to control its operation, timing means operable to prevent energization of said first-named relay switch until sufficient time has passed for said electron tube to become adequately heated, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open, said second relay switch having a pivoted contact-carrying arm which is operable upon movement to engage and move said pivoted member, said second relay switch being operable upon activation of said electron tube to close thus moving said pivoted member so that said first-named switch may open thereby de-energizing said motor and ignition circuits and energizing said second motor circuit, a bimetal element, an electric heating coil for said bimetal element, said bimetal element being operable upon heating to move said pivoted member, and said bimetal element being further operable as a safety means to open said first-named switch to de-energize said motor and ignition circuits upon failure of said electron tube to function within a predetermined time.

14. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch operable to control energization of said circuits, a third switch operable to control said relay switch, a second motor circuit, a second relay switch for controlling said second motor circuit, said second relay switch being normally open, an electron tube in circuit with the coil of said second relay switch and operable to control its operation, timing means operable to prevent energization of said first-named relay switch until sufficient time has passed for said electron tube to become adequately heated, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open, said second relay switch having a pivoted contact-carrying arm which is operable upon movement to engage and move said pivoted member, said second relay switch being operable upon activation of said electron tube to close thus moving said pivoted member so that said first-named switch may open thereby de-energizing said motor and ignition circuits and energizing said second motor circuit, a bimetal element, an electric heating coil for said bimetal element, said bimetal element being operable upon heating to move said pivoted member, said bimetal element being further operable as a safety means to open said first-named switch to de-energize said motor and ignition circuits upon failure of said electron tube to function within a predetermined time, a flexible stop member operable to prevent said bimetal element from returning to its initial position upon cooling, a reset member engageable with said stop member upon movement and operable to move said stop member to permit said bimetal element to return to its initial position, and said reset member being further operable to engage and move said pivoted member to open said third switch thereby to prevent operation of said control device so long as said reset member is in operated position.

15. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch operable to control energization of said circuits, a third switch operable to control said relay switch, a second motor circuit, a second relay switch for controlling said second motor circuit, said second relay switch being normally open, an electron tube in circuit with the coil of said second relay switch and operable to control its operation, an electrical resistor operable to cause a sufficient voltage drop therethrough to prevent functioning of said first-named relay switch, a thermostatic switch responsive to the heat output of said resistor and operable to close a shunt circuit of less resistance than said resistor after a predetermined exposure to the heat of said resistor, said predetermined exposure being of the same duration as the heating time for said electron tube, a pivoted member engaging and holding closed said first-named switch, said pivoted member being operable upon a predetermined movement to permit said first-named switch to open, said second relay switch having a pivoted contact-carrying arm which is operable upon movement to engage and move said pivoted member, said second relay switch being operable upon activation of said electron tube to close thus moving said pivoted member so that said first-named switch may open thereby de-energizing said motor and ignition circuits and energizing said second motor circuit, a bimetal element, an electric heating coil for said bimetal element, said bimetal element being operable upon heating to move said pivoted member, said bimetal element being further operable as a safety means to open said first-named switch to de-energize said motor and ignition

circuits upon failure of said electron tube to function within a predetermined time, a flexible stop member operable to prevent said bimetal element from returning to its initial position upon cooling, a reset member engageable with said stop member upon movement and operable to move said stop member to permit said bimetal element to return to its initial position, and said reset member being further operable to engage and move said pivoted member to open said third switch thereby to prevent operation of said control device so long as said reset member is in operated position

16. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch having a plurality of contacts and operable to control energization of said circuits, a second motor circuit, a second relay switch for controlling said second motor circuit, said second relay switch being initially open, an electron tube in circuit with and controlling said second relay switch; a fourth switch having two pairs of contacts, one pair of which are initially closed and one pair initially open; said last-named closed contacts being in circuit with the coils of said first named and said second relay switches, said last-named open contacts being in circuit with the coil of said second relay switch, a pivoted member engaging and holding closed said first switch, said pivoted member being operable upon partial movement to engage said fourth switch to open the closed contacts and to close the open contacts thereof and upon full movement to permit said first switch to open, said second relay switch being engageable with said pivoted member on closing movement, and said second relay switch being responsive to the activation of said electron tube and upon closing movement being operable to move said pivoted member to open said first switch thereby de-energizing said ignition circuit and said first-named motor circuit and energizing said second motor circuit.

17. In a control device for controlling a burner motor and electric ignition means, a motor circuit and an ignition circuit, a switch having two pairs of contacts and operable to control said circuits, a relay switch having a plurality of contacts and operable to control energization of said circuits, a second motor circuit, a second relay switch for controlling said second motor circuit, said second relay switch being initially open, an electron tube in circuit with and controlling said second relay switch; a fourth switch having two pairs of contacts, one pair of which are initially closed and one pair initially open; said last-named closed contacts being in circuit with the coils of said first-named and said second relay switches, said last-named open contacts being in circuit with the coil of said second relay switch, a pivoted member engaging and holding closed said first switch, said pivoted member being operable upon partial movement to engage said fourth switch to open the closed contacts and to close the open contacts thereof and upon full movement to permit said first switch to open, said second relay switch being engageable with said pivoted member on closing movement, said second relay switch being responsive to the activation of said electron tube and upon closing movement being operable to move said pivoted member to open said first switch thereby de-energizing said ignition circuit and said first-named motor circuit and energizing said second motor circuit, a bimetal element, an electric heating coil for said bimetal element, said bimetal element being operable to move upon heating to engage and move said pivoted member, said bimetal element and heating coil being operable as a timing means for actuating said fourth switch to break and to subsequently re-establish the circuit through said second relay switch thereby delaying the operation of said second relay switch until sufficient time has passed for said electron tube to become adequately heated, and said bimetal element being further operable as a safety means to move said pivoted member to open said first switch and de-energize said motor and ignition circuits upon failure of activation of said electron tube within a predetermined time.

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