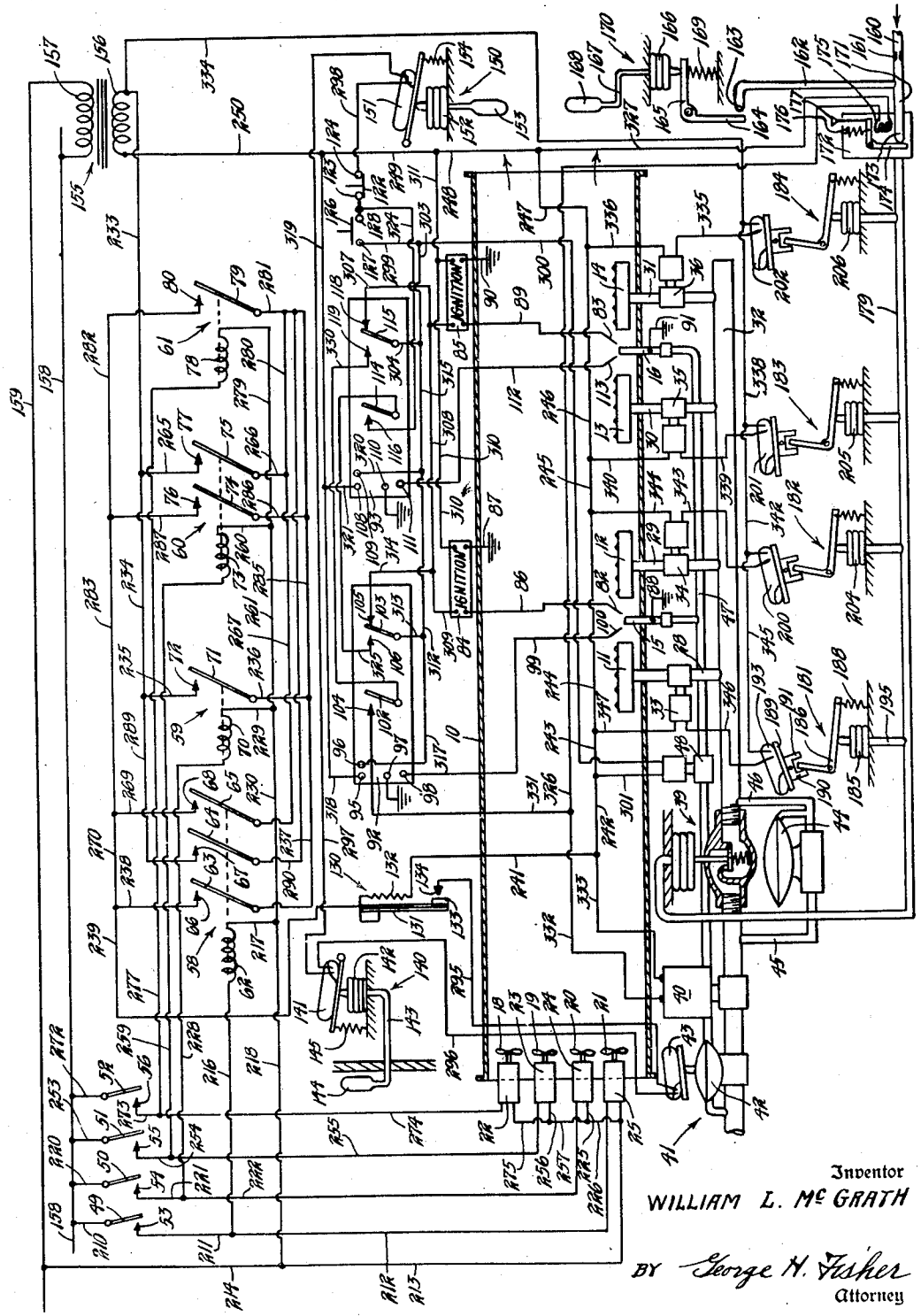
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BURNER CONTROL SYSTEM

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BURNER CONTROL SYSTEM

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The present invention is concerned with a burner control system and more particularly one of the type in which the burners are placed directly in an air stream of a ventilating duct.

An object of the present invention is to provide a burner control system in which a plurality of fluid circulating means are provided for circulating heating fluid in heat transfer relation with a burner and in which means are provided for supplying fuel to the burner only when more than a predetermined number of such fluid circulating means are in operation.

A further object of the present invention is to provide a burner control system employing a plurality of burners in which means is provided for varying the fuel flow to all of said burners, and in which an individual valve is provided for each burner, with means for closing all of the individual valves when the common fuel flow adjusting means assumes a predetermined minimum position.

A still further object of the present invention is to provide an arrangement such as set forth in the last object in which individual valves are sequentially closed upon the main flow controlling means moving towards closed position and in which the individual valves are sequentially opened upon the minimum flow controlling means moving towards open position.

A still further object of the present invention is to provide a burner control system of the type discussed in the last two objects in which the means for controlling the individual valves is characterized by a relatively wide differential so that the valves are sequentially opened when the minimum flow controlling means is nearer open position than when the individual valves are sequentially closed.

A still further object of the invention is to provide a burner control system in which burners are located directly in an air stream being circulating to a space to be conditioned and in which provision is made for interrupting the flow of fuel to the burners when the temperature outside of the space rises above a predetermined value.

A still further object of the invention is to provide a system of the type discussed in the above objects in which provision is made for safeguarding against operation of the burners when the ignition means is not operating properly.

A still further object of the present invention is to provide a system of the type considered which is extremely simple by reason of the combined use of electric and pneumatic controls.

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Other objects of the invention will be apparent from a consideration of the specification, claims and drawing in which the single figure is a schematic representation of my improved burner control system.

Referring to the drawing for a more detailed understanding of the invention, the reference numeral 10 is employed to indicate a ventilating duct. As indicated by the arrows adjacent the inlet and outlet of the duct 10, the air is drawn in at the left-hand end of the duct 10 and is forced out at the right-hand end thereof. The air is circulated through the duct by a plurality of propeller fans 18 to 21, these fans being driven by motors 22 to 25. While the fans have been shown for convenience in illustration as disposed one above the other, it is to be understood that these fans will normally be arranged symmetrically of the duct. Located within the duct are a plurality of gas burners 11, 12, 13 and 14. The burners 11 and 12 constitute one bank of burners and the burners 13 and 14 a second bank of burners. While only two burners have been shown in each bank, it is to be understood that each bank may consist of any desired number of burners. Associated with the bank of burners comprising burners 11 and 12 is a pilot burner 15. A similar pilot burner 16 is associated with the other bank of burners consisting of burners 13 and 14.

The burners 11, 12, 13 and 14 are connected by pipes 28, 29, 30 and 31 to a main gas supply pipe 32. Interposed in the pipes 28, 29, 30 and 31 are electrically operated valves 33, 34, 35, and 36. The valves 33 to 36 are of any suitable type which assume a closed position upon the operators being deenergized and which move to an open position upon their operators being energized and remain in such position as long as such energization continues. The valves 33 to 36 serve individually to control the flow of gas to the burners 11 to 14. The flow of gas through main gas conduit 32 is controlled by a pneumatic valve 39. This valve is of the type in which an increase in the pressure of the pneumatic fluid moves the valve towards open position. Since the construction of the valve is entirely conventional, a detailed description thereof is deemed unnecessary.

The flow of fuel through conduit 32 is further controlled by an electrically operated valve 40. The valve 40 may be of any type in which the valve is maintained open only during the energization of the operator and moves to closed position as soon as the operator is deenergized. Associated with the gas conduit 32 on the inlet

side of the valve 40 is a low pressure cut-off switch 41. This comprises a pressure chamber 42 operatively connected to a mercury switch 43. The pressure chamber is so related to the mercury switch 43 that as long as the pressure within conduit 32 is above a predetermined value, switch 43 will remain in closed position. Upon the pressure dropping below the predetermined value, however, the mercury switch 43 will move to open position. The low pressure cut-off switch 41, as will be explained later, is employed to interrupt operation of the system when the gas pressure drops to an undesirably low value.

Connected in parallel with the pneumatic valve 39 by pipes 45 and 46 is a conventional pressure regulating valve 44. This pressure regulating valve 44 serves to maintain a predetermined minimum pressure in pipe 32 regardless of the position of the pneumatic valve 39 to insure safe operation of any of burners 11—14 whenever its respective solenoid valve is opened. It will be obvious that even when valve 39 is completely closed, it is possible for fuel to be supplied to the downstream portion of pipe 32 through valve 44, this fuel being at the pressure for which pressure regulator 44 is set, said pressure being the minimum at which the burners will properly operate.

The pilot burners 15 and 16 are connected to a pipe 47 which is connected to the main gas supply pipe 32 on the upstream side of the low pressure cut-off 41. The flow of gas through pipe 47 and hence to the pilot burners 15 and 16 is controlled by a valve 48 which may be of the solenoid type.

The operation of the fan motors 22 to 25 is controlled by a plurality of fan switches comprising switch blades 49, 50, 51 and 52. These switch blades 49 to 52 are adapted to be moved into or out of engagement with the associated fixed contacts 53, 54, 55 and 56. The switch blades 49 to 52 may be actuated by any suitable means.

Switch blades 49 to 52 also control the energization of a plurality of relays 58, 59, 60 and 61. The relay 58 comprises a relay coil 62 and a plurality of switch blades 63, 64, and 65. The switch blades 63, 64 and 65 are adapted to engage contacts 66, 67 and 68, respectively. The switch blades 63 to 65 are normally biased out of engagement with contacts 66 to 68 by any suitable means (not shown). Upon energization of the relay coil 62, the switch blades 63 to 65 are moved into engagement with contacts 66 to 68.

The relay 59 comprises a relay coil 70 and a single switch blade 71 which cooperates with a fixed contact 72. As with relay 58, the switch blade 71 is biased out of engagement with contact 72 and is adapted to be moved into engagement therewith upon the energization of relay coil 70.

The relay 60 comprises a relay coil 73 and a pair of switch blades 74 and 75 which are adapted to cooperate with contacts 76 and 77, respectively. Switch blades 74 and 75 are similarly biased out of engagement with contacts 76 and 77 and are moved into engagement therewith upon energization of coil 73.

Relay 61 comprises a relay coil 78 and a single switch blade 79 adapted to be moved into engagement with fixed contact 80 upon energization of relay coil 78.

Associated with the pilot burners 15 and 16 are ignition electrodes 82 and 83. The ignition

electrodes 82 and 83 are connected to ignition transformers 84 and 85. The ignition electrode 82 is connected to one secondary terminal of transformer 84 by a conductor 86. The other secondary terminal of the ignition transformer is connected to ground at 87. The pilot burner 16 is also connected to ground as indicated by the numeral 88. Similarly, the ignition electrode 83 is connected to one secondary terminal of ignition transformer by conductor 89. The other secondary terminal of transformer 85 is connected to ground at 90 and the burner 16 is connected to ground at 91.

A flame detecting apparatus 92 is associated with pilot burner 15 and a similar flame detecting apparatus 93 is associated with burner 16. These flame detecting apparatuses 92 and 93 are of the electronic type in which the presence or absence of a flame is determined by the conductivity of a gap normally bridged by the pilot burner flame. The details of the apparatus have not been shown inasmuch as this type of flame detecting apparatus is well known in the art. A typical apparatus of this type is that shown in the Harrison Patent No. 2,224,119 granted December 3, 1940. The flame detecting apparatus 92 is provided with a pair of power supply terminals 95 and 96, a ground terminal 97, and a flame electrode terminal 98. The flame electrode terminal 98 is connected by a conductor 99 to a flame electrode 100 disposed adjacent the pilot burner 15. Associated with the apparatus 92 are a pair of relay switch blades 102 and 103. Switch blade 102 is adapted to be moved into engagement with a contact 104. The relay switch blade 103 is normally in engagement with a contact 105 and is adapted to be moved into engagement with a contact 106 upon the gap between flame electrode 100 and pilot burner 15 being bridged by a burner flame such as happens when pilot burner 15 is properly ignited. The mechanism for operating switch blades 102 and 103 is not shown, since this mechanism is conventional, as previously explained.

The flame detecting apparatus 93 comprises a pair of power supply terminals 108 and 109, a ground terminal 110 and a flame electrode terminal 111. The flame electrode terminal is connected by means of a conductor 112 to a flame electrode 113 disposed adjacent the burner 16. Also associated with apparatus 93 are a pair of switch blades 114 and 115. The switch blade 114 is adapted to be moved into engagement with a fixed contact 116. The switch blade 115 is normally biased into engagement with a fixed contact 118 and is adapted to be moved into engagement with a contact 119 upon the gap between flame electrode 113 and burner 16 being bridged by a burner flame.

A pair of push button switches are provided for starting and stopping the system. One of these switches is a normally closed switch and comprises a switch blade 122 biased into engagement with a pair of contacts 123 and 124. Upon the push button being held inwardly, the blade 122 is held out of engagement with contacts 123 and 124. The other push button switch is a normally open switch and comprises a switch blade 126 adapted to be moved into engagement with contacts 127 and 128 upon the push button being moved inwardly.

A thermal timer 130 is provided for delaying the supply of fuel to the pilot burner until the fans 18 to 21 have been in operation for a predetermined period of time. This timer com-

prises a bimetallic element 131 with which is associated an electric heater element 132. The bimetallic element is adapted to warp to the right upon being heated by heater 132. The bimetallic element 131 carries a contact 133 which is adapted to be engaged with a fixed contact 134 upon the bimetallic element being warped to the right. Such engagement of contacts 133 and 134 occurs a predetermined period of time after the initial energization of heater element 132.

A plurality of switches responsive to limiting conditions are provided for preventing a supply of fuel to the burners when the various limiting conditions assume undesired values. The low pressure cut-out switch 41, previously referred to, is one of these switches. Another such switch is designated by the reference numeral 140. This switch comprises a mercury switch 141 which is positioned by a bellows 142 connected by capillary tubing 143 to a bulb 144 located outside of the space being conditioned. The switch 141 is biased by a spring 145 to switch open position. As long as the temperature outside the space, to which bulb 144 is subjected, is above a predetermined value, the bellows 142 is effective to hold switch 141 in closed position, as shown in the drawing. Upon the outside temperature dropping below this predetermined value, however, the biasing spring 145 is effective to move switch 141 to open position. While the value of this predetermined temperature will vary in accordance with the particular application of the burner control system, I have found it desirable in certain types of applications to have the switch set for a temperature of approximately 65°.

A further limiting switch is designated by the reference numeral 150. This switch is a high limit switch and comprises a switch 151 positioned by a bellows 152 to which is connected a fluid filled bulb 153. The bulb 153 is located in the path of the air leaving duct 10 and responds to the temperature of this discharge air. The switch 151 is biased to closed position by a spring 154. Upon the temperature of the discharge air rising above a predetermined high limit value, the switch 151 is moved to open position against the biasing action of spring 154.

A transformer 155 is employed to supply low voltage power for controlling the electrical portion of the system. This transformer comprises a low voltage secondary 156 and a line voltage primary 157. The line voltage primary is connected to line wires 158 and 159 leading to any suitable source of power (not shown).

As previously indicated, the valve 39 is controlled pneumatically. Pneumatic means is also provided for controlling the energization of valves 33 to 36. The pneumatic portion of the system will now be described.

Air or other pneumatic fluid at a desired pressure such as 15 pounds is supplied to pipe 160 from any desired source. A suitable restricting means 161 is located in the pipe. Connected to the pipe 160 is a branch pipe 162 terminating in a nozzle 163 of a conventional pneumatic thermostat 170. Since this thermostat is entirely conventional and forms no part of the present invention, it has been shown schematically. In this schematic showing, a flapper valve 164 cooperates with the nozzle 163. The flapper valve 164 forms an element of a bell-crank lever 165. Cooperating with the other arm of the bell-crank lever 165 is a bellows 166 which is connected by capillary tubing 167 to a volatile fluid-filled bulb 168 located in the path of the air discharging from duct 10.

A spring 169 bears against the same arm of lever 165 as does bellows 166. The position of the lever 165 is determined by the relative forces exerted by bellows 166 and spring 169. As the discharge temperature decreases, the temperature of bulb 168 decreases to permit bellows 166 to contract and allow the spring 169 to rotate the lever 165 counter-clockwise. Such rotation moves the flapper valve 164 closer to the orifice 163 so as to decrease the escape of fluid through the orifice 163 and hence to increase the pressure within the conduit beyond the restriction 161.

A pipe 171 connects with pipe 162. This pipe is in turn connected to an electro-pneumatic relay 172. This relay comprises a nozzle 173 and a flapper valve 174 and bleed valve 177 positioned by an electromagnet 175. The flapper valve 174 is biased toward nozzle 173 and bleed valve 177 is urged open by a spring 176. When the electromagnet 175 is energized, the flapper valve 174 is moved away from nozzle 173 and bleed valve 177 is closed to permit a flow of pressure fluid through the relay 172. Connected with the outlet side of the relay 172 is a conduit 179 which leads to the pneumatic valve 39. The position assumed by pneumatic valve 39 varies with the pressure maintained in conduit 179 which, as previously explained, depends upon the temperature to which bulb 168 is responsive. When the temperature adjacent bulb 168 falls, the pressure within conduit 179 will increase to increase the pressure applied to the expansible chamber of valve 39 so as to move the valve towards open position.

A plurality of pneumatic electric relays 181, 182, 183 and 184 are provided for controlling the energization of solenoid valves 33 to 36. The relay 181 comprises a bellows element 185 which is associated with a bell-crank lever 186. The right-hand end of the horizontal arm of the bell-crank lever is biased downwardly by a spring 188. The other arm of the bell-crank lever is associated with a switch carrier 189 having a pair of spaced arms 190 and 191. The carrier 180 carries a mercury switch 193. The cooperating arm of the bell-crank lever 186 is adapted upon rotation of lever 186 to move the switch 193 between circuit-open and circuit-closed positions. The bellows 185 is connected by a conduit 195 to the conduit 179 so that the pressure within the bellows 185 corresponds to the pressure within conduit 179. It will be obvious that as this pressure rises, the bell-crank lever 186 will be rotated in a counter-clockwise direction and as the pressure falls, the spring 188 will be effective to rotate lever 186 in a clockwise direction. Upon the lever 186 being rotated in a counter-clockwise direction, the upstanding arm of lever 186 will engage the finger 190 to rotate switch 193 in a clockwise direction to circuit closed position. When, on the other hand, the lever 186 is rotated in a clockwise direction, the upstanding arm will engage finger 191 to rotate switch carrier 189 in a counter-clockwise direction to move switch 189 to circuit open position. It will be apparent that after switch 193 has been once closed, it will not be moved to open position until the upstanding arm of bell-crank lever 186 has moved through a distance determined by the spacing of fingers 190 and 191. The spacing of fingers 190 and 191 thus determines the differential of the switch or the difference between the pressure at which the switch is closed and the pressure at which the switch is opened.

A detailed description of relays 182, 183 and

184 is not believed necessary in view of their similarity to relay 181. These relays comprise mercury switches 200, 201 and 202 which are actuated by bellows 204, 205 and 206 in the same manner as described in connection with relay 181. As with the case of relay 181, there is a predetermined differential between the pressure at which the switch is closed and the pressure at which it is reopened. The four relays 181 to 184 are adjusted so that they are operated at different values. This is indicated in the drawing by showing these switches tilted to different degrees. Thus, as the pressure rises due to an increase in temperature, switch 202 will first be closed due to the fact that it is initially tilted less from the horizontal. Upon a further drop in pressure in conduit 179, switch 201 will be closed. As the pressure rises, switches 200 and 193 will be successively closed. As the temperature adjacent bulb 168 again drops, the switches will sequentially open. Upon such a drop in temperature, switches 193, 200, 201 and 202 will be successively opened.

The fingers of the relays 181 to 184 are so adjusted with respect to the mechanism of the relays and the pneumatic valve 39 that the switches 193, 200, 201 and 202 are not opened until the valve 39 is nearly in full open position. As the temperature drops, however, the switches 193, 200, 201 and 202 are not reopened until the valve is in a predetermined minimum open position.

Operation

The various elements of the system are shown in the position they assume when the system is completely shut down. Before any of the elements of the system can be placed into operation, it is necessary to close the circuits to at least two of the fan motors 22 to 25. Let it be assumed that switch blades 49 and 50 are engaged with contacts 53 and 54. The engagement of switch blade 49 with contact 53 establishes a circuit to fan motor 25 as follows: from the line wire 158 through conductor 210, switch blade 49, contact 53, conductors 211 and 212, fan motor 25, and conductors 213 and 214 to the other line wire 159. At the same time, an energizing circuit is established to the relay coil 62 as follows: from line wire 158 through conductor 210, switch blade 49, contact 53, conductors 211 and 216, relay coil 62, and conductors 217, 218, and 214 to the other line wire 159. The establishment of the circuit just traced to fan motor 25 causes fan 21 to be placed into operation. The energization of relay coil 62 by reason of the circuit just traced causes switch blades 63, 64, and 65 to be moved into engagement with contacts 66 to 68. The engagement of these contacts alone does not result in the establishment of any energizing circuit, however.

Engagement of switch blade 50 with contact 54 establishes the following energizing circuit to fan motor 24 to cause operation of fan 20: from line wire 158 through conductor 220, switch blade 50, contact 54, conductors 221 and 222, fan motor 24, and conductors 225, 226, 213 and 214 to the other line wire 159. At the same time, an energizing circuit is established to relay coil 70 as follows: from line wire 158 through conductor 20, switch blade 50, contact 54, conductors 221 and 228, relay coil 70, and conductors 229, 230, 218 and 214 to the other line wire 159. The establishment of the circuit just traced to relay coil 70 causes contact blade 71 to be moved into engagement with contact 72.

It will be noted that two of the relays 58 to 61 have now been energized. Upon any two of these relays being energized, it is possible to establish a circuit to the electrical heating element 132 of timer 130. The following circuit is established upon the energization of relay coils 62 and 70, as has just been described. From the right-hand terminal of secondary 156 through conductors 233, 234 and 235, contact 72, contact blade 71, conductors 236 and 237, contact blade 63, contact 66, conductors 238 and 239, heating element 132 and conductors 241, 242, 243, 244, 245, 246, 247, 248, 249, and 250 to the other terminal of secondary 156. It will be noted that the circuit just traced to heating element 132 depended upon the establishment of a conductive path between conductors 233 and 239. The various relay switches of relays 58 to 61 are so arranged that it is necessary to have two relays energized before a circuit can be established between conductors 233 and 239. Before proceeding with the further description of the operation of the system, various possible circuits between the conductors 233 and 239 and the conditions under which they are established will be considered in more detail.

Let it be assumed that instead of switches 49 and 50 being engaged with contacts 53 and 54, switches 49 and 51 will engage with their associated contacts. The engagement of switch 49 with contact 53, of course, causes energization of the fan motor 25 and the relay coil 62 in the manner previously described. Engagement of switch blade 51 with contact 55 results in the following circuit being established to fan motor 23: from line wire 158 through conductors 253, switch blade 51, contact 55, conductors 254 and 255, fan motor 23, and conductors 256, 257, 226, 213 and 214 to the other line wire 159. The engagement of switch blade 51 with contact 55 also results in the energization of relay coil 73 through the following circuit: from line wire 158 through conductor 253, switch blade 51, contact 55, conductors 254 and 259, relay coil 73, and conductors 260, 261, 230, 218 and 214 back to the other line wire 159.

The energization of relay coil 73 results in switch blades 74 and 75 being moved into engagement with contacts 76 and 77. Relay coils 62 and 73 are now energized. Under these conditions, it is possible to trace a circuit between conductors 233 and 239 as follows: from conductor 233 through conductor 265, contact 77, switch blade 75, conductors 266 and 267, switch blade 65, contact 68, and conductors 269 and 270 to conductor 239. The establishment of this connection again makes possible the establishment of a circuit to heater coil 132.

If, on the other hand, switch blades 51 and 52 are closed, it is also possible to establish a circuit between conductors 233 and 239. The effect of the closure of switch blade 51 with its contact 55 has been discussed. When switch blade 52 is engaged with contact 56, the fan motor 22 is energized through the following circuit: from line wire 158, through conductor 272, switch blade 52, contact 56, conductors 273 and 274, fan motor 22, and conductors 275, 257, 226, 213, and 214 to the other line wire 159. At the same time, a circuit is established to relay coil 78 as follows: from line wire 158 through conductor 272, switch blade 52, contact 56, conductors 273 and 277, relay coil 78, and conductors 279, 261, 230, 218 and 214 back to the other line wire 159. Fans 18 and 19 will now be in operation and relay coils 73 and 78 will be energized. Under these condi-

tions, it is possible for a circuit to be established between conductors 233 and 239 as follows: from conductor 233 through conductor 265, contact 77, switch blade 75, and conductors 266, 280 and 281, switch blade 79, contact 80, and conductors 282, 283 and 270 to conductor 239. Again, the connection of conductors 233 and 239 will result in the establishment of an energizing circuit through heater 132.

The operation has been considered when fans 20 and 21 are in operation, when fans 21 and 19 are in operation, and when fans 18 and 19 are in operation. If fans 19 and 20 are in operation, the relay coils 70 and 73 will be energized and a circuit will be established between conductors 233 and 239 as follows: from conductor 233 through conductors 234 and 235, contact 72, switch blade 71, conductors 236, 285 and 286, switch blade 74, contact 76, and conductors 287, 283 and 270 to conductor 239. Again, a circuit is established to heater 132. If fans 18 and 21 are the ones that are operated, relay coils 78 and 62 will be energized and a circuit will be established between conductors 233 and 239 as follows: from conductor 233 through conductors 234 and 289, contact 67, switch blade 64, conductors 290 and 281, switch blade 71, and conductors 282, 283 and 270 to conductor 239. Again, a circuit is established to heater 132.

It will be seen from the foregoing paragraphs that regardless of which two fans are energized a circuit is established between conductors 233 and 239 so as to cause a circuit to be established through heater 132, the remainder of this circuit being identical to that first traced. It is to be furthermore noted that this circuit through heater element 132 can only be established upon the closure of at least two fan switches. Each one of the circuits which was traced above included the relay contacts of two separate relays.

Upon heater 132 being energized as a result of the establishment of any of the above circuits, the bimetallic element 131 is heated so as to warp to the right. After a predetermined period of time this warping results in the engagement of contacts 133 and 134. The engagement of contacts 133 and 134 results in the establishment of the following circuit upon the engagement of push button switch blade 126 with contacts 127 and 128: from the right-hand terminal of secondary 156 through conductor 233, through any of the combinations of relay circuits previously traced to conductor 239, bimetallic element 131, contact 133, contact 134, conductor 295, low pressure cut-out switch 43, conductor 296, outdoor temperature responsive switch 141, conductor 297, high limit switch 151, conductor 298, contact 124, switch blade, 122, contact 123, contact 128, switch blade 126, contact 127, conductors 299 and 300, solenoid valve 48, and conductors 301, 243, 244, 245, 246, 247, 248, 249, and 250 back to the other terminal of secondary 156. The energization of solenoid valve 48 as a result of the establishment of this circuit, causes gas to flow to the pilot burners 15 and 16. At the same time, a circuit is established to the primary of ignition transformer 84 as follows: from the right-hand terminal of secondary 156 through conductor 233, through the relay circuits previously traced to conductor 239, bimetallic element 131, contacts 133 and 134, conductor 295, switch 43, conductor 296, switch 141, conductor 297, switch 151, conductor 298, contact 124, switch blade 122, contact 123, contact 128, switch blade 126, contact 127, conductors 299, 303, 304, switch blade 115, contact 118, conductors 307, 308 and 309, the primary of ignition transformer 84, conductors 310, 311, 249 and 250 back to the other terminal of secondary 156. It is also possible to establish a similar circuit through switch blade 103 and contact 105. This circuit will be traced only from switch contact 127. Proceeding from this contact, current may flow through conductors 299, 303, 315, 312, and 313, switch blade 103, contact 105, conductors 314 and 309, the primary of ignition transformer 84, and conductors 310, 311, 249 and 250 back to left-hand terminal of secondary 156. It will be obvious that the primary of ignition transformer 85 is connected in parallel with the primary of ignition transformer 84. Thus the two ignition transformers are energized simultaneously so that an ignition spark is produced between ignition electrode 82 and pilot burner 15 and also between ignition electrode 83 and pilot burner 16.

As a result of the establishment of the circuits traced, gas is supplied to the pilot burners 15 and 16 and an ignition spark is produced for igniting these pilot burners. Under normal conditions, the pilot burners 15 and 16 will be quickly ignited. The flame detecting apparatus 92 is designed to detect the establishment of a flame at the pilot burner 15 and the flame detecting apparatus 93 is designed to detect the establishment of a flame at pilot burner 16. The movement of push button switch blade 126 into engagement with contacts 127 and 128 also caused energizing circuits to be established to the power supply terminals of the two flame detecting apparatuses. Tracing the circuits only from contact 123 of the normally closed push button switch, a circuit is established through the power supply terminals 95 and 96 of apparatus 92 as follows: from contact 123 through contact 128, switch blade 126, contact 127, conductors 299, 303, 315, 312 and 317, input terminals 96 and 95, and conductors 318, 319 and 250 back to the left-hand terminal of secondary 156. The following circuit is also established from terminal 123 through power supply terminals 108 and 109 of flame detecting apparatus 93, from contact 123 to contact 128, switch blade 126, contact 127, conductors 299, 303, 315, and 320, power supply terminals 109 and 108, and conductors 321, 319 and 250 to the left-hand terminal of secondary 156.

The operator will maintain switch blade 126 engaged with contacts 127 and 128 until the apparatuses 92 and 93 have indicated the establishment of a flame by the movement of switch blades 102, 103, 114 and 115 from the position shown to their other circuit making positions. Usually such an apparatus is provided with a signal light to indicate when this has happened. As soon as switch blades 102, 103, 114 and 115 have moved to their opposite circuit making positions, it is possible for the operator to release switch blade 126 and the solenoid valve 48 will remain energized through the following circuit traced only from contact 123 of the normally closed switch: from contact 123 through conductor 324, contact 116, switch blade 114, conductor 325, contact 106, switch blade 103, conductors 313, 312, 315, 303, and 300, solenoid valve 48, and conductors 301, 243, 244, 245, 246, 247, 248, 249, and 250 to the left-hand terminal of secondary 156. The establishment of this circuit insures the continued energization of solenoid valve 48 despite the release of switch blade 126 from contacts 127 and 128. The ignition circuits previously traced

are terminated, however, as soon as switch blades 103 and 115 move out of engagement with contacts 105 and 118. It will be noted that the ignition circuits proceed through the contacts 105 and 118 in parallel so that as soon as both switch blades 103 and 115 have separated from these contacts, the ignition circuit is completely interrupted regardless of whether push button switch blade 126 is in engagement with the contacts 127 and 128 or not.

A permanent circuit is also now established to the power supply terminals of the flame detecting apparatuses 92 and 93. The circuit to terminals 96 and 95 from contact 123 is as follows: from contact 123, through conductor 324, contact 116, switch blade 114, conductor 325, contact 106, switch blade 103, conductors 313 and 317, power supply terminals 96 and 95, and conductors 318, 319 and 250 to the left-hand terminal of secondary 156. The circuit to terminals 108 and 109 is as follows: from contact 123 through conductor 324, contact 116, switch blade 114, conductor 325, contact 106, switch blade 103, conductors 313, 312 and 320, power supply terminals 109 and 108, and conductors 321, 319 and 250 to the other terminal of secondary 156. The result of the establishment of this circuit is to insure the continued operation of flame detecting apparatuses 92 and 93 despite the movement of the normally open push button switch blade 126 to circuit open position.

A circuit is now established to the electro-pneumatic relay 172. This circuit will be traced from the contact 123 of the normally closed push button switch and is as follows: from contact 123, through conductor 324, contact 116, switch blade 114, conductor 325, contact 106, switch blade 103, conductors 313, 312, 315 and 304, switch blade 115, contact 119, conductor 330, switch blade 102, contact 104, conductors 331, and 326, coil 175 and conductors 327, 248, 249 and 250 back to the left-hand terminal of secondary 156. The establishment of the above traced circuit results in the electro-pneumatic relay being moved to open position so that the pressure existing in the line 171 is caused to exist in line 179. Thus, the pressure in line 179 assumes a value determined by the discharge temperature responsive thermostat 170. Under normal conditions, this discharge temperature following a shut down will be sufficiently low that valve 39 will move to a partially open position, at least.

A circuit is now also established to the main shut-off valve 40. Again, this circuit will be traced only from the contact 123 of the normally closed push button switch. This circuit is as follows: from contact 123, through conductor 324, contact 116, switch blade 114, conductor 325, contact 106, switch blade 103, conductors 313, 312, 315, and 304, switch blade 115, contact 119, conductor 330, switch blade 102, contact 104, conductors 331 and 332, shut-off valve 40, conductors 333, 242, 243, 244, 245, 246, 247, 248, 249 and 250 back to the left-hand terminal of secondary 156.

The establishment of the above circuit causes shut-off valve 40 to be opened so that gas is supplied to the inlet side of pneumatic valve 39. Since the rise in pneumatic pressure following the energization of the relay 172 takes much longer than the opening of valve 40, pneumatic valve 39, initially closed, will gradually open. This prevents a sudden increase in the gas flow to the burners. Even with pneumatic valve 39 completely closed, a certain minimum flow of gas will be established through pipe 45, pressure regulator 44, and pipe 46 to the gas supply pipe 32. With the various elements of the pneumatic system in the position shown in the drawing, however, all of the solenoid valves 33 to 36 will be closed so that no gas may flow through the individual burners. Let it be assumed now that the temperature adjacent bulb 168 drops so as to increase the pressure continually in pipe 179. As this pressure continues to increase, valve 39 will move to open position. As it approaches open position, switches 202, 201, 200 and 193 will be successively moved to closed position, as previously described. The movement of switch 202 to closed position will cause an energizing circuit to be established to solenoid valve 36 as follows: from the right-hand terminal of secondary 156 through conductor 334, switch 202, conductor 335, solenoid valve 36, and conductors 336, 247, 248, 249 and 250 to the left-hand terminal of secondary 156. The energization of solenoid valve 36 permits gas to flow through conduit 31 to burner 14, this gas being ignited by the pilot burner 16.

The closure of switch 201 causes the following circuit to be established to solenoid valve 35: from the right-hand terminal of secondary 156 through conductors 334 and 338, switch 201, conductor 339, solenoid valve 35, and conductors 340, 246, 247, 248, 249, and 250 back to the left-hand terminal of secondary 156. The energization of solenoid 35 results in burner 13 being placed in operation.

A closure of switch 200 causes the following circuit to be established to solenoid valve 34: from the right-hand terminal of secondary 156 through conductors 334, 338, 342, switch 200, conductor 343, solenoid valve 34, and conductors 344 and 245 to 250 back to the left-hand terminal of secondary 156. The energization of solenoid valve 34 results in burner 12 being placed in operation.

The closure of switch 193 results in the establishment of the following energizing circuit to solenoid valve 33; from the right-hand terminal of secondary 156 through conductors 334, 338, 342, and 345, switch 193, conductor 346, solenoid valve 33, conductor 347, and conductors 244 to 250 back to the left-hand terminal of secondary 156. The establishment of the traced circuit causes energization of solenoid valve 33 so that burner 11 is placed in operation.

In the above paragraphs, it has been assumed that all of the burners were brought into operation sequentially. It is of course entirely possible for the temperature to assume an intermediate valve at which only burners 13 and 14, for example, are placed into operation. In any event, the burners will raise the temperature of the air being circulated through the duct 10 by those of the fans 18 to 21 in operation. This will cause a rise in the discharge temperature to which bulb 168 is subjected so as to cause the pressure within conduit 179 to decrease. A decrease in pressure will result in pneumatic valve 39 being moved towards closed position so as to reduce the flow of gas to the burners. Any tendency of this to decrease the discharge temperature will cause a rise of the pressure in tube 179 so as to cause pneumatic valve 39 to move back towards open position. It can be readily seen that under normal circumstances, the flow of gas to the burners will be modulated so as to maintain a substantially constant discharge temperature. The number of burners in opera-

tion will depend to a large extent upon the heating load.

Under normal conditions, the burners will continue to remain in operation as long as it is desired to have the system operating. The flow of gas will be modulated to the burners in the manner described. If the temperature of the discharge duct rises sufficiently high as to cause the pneumatic valve **39** to approach its minimum position, however, the valves **33** to **36** will be successively closed. Thus, as this discharge temperature rises, the pressure within pipe **179** will decrease to decrease the pressure within bellows **185**, **204**, **205**, and **206**. This will successively cause reopening of switches **193**, **200**, **201**, and **202** and closure of valves **33** to **36**. This will, as indicated above, not occur during normal circumstances and will occur only when there is a major change in load as indicated in a rise or fall of outside temperature or by a variation in the amount of air handled by the system.

When any one burner is placed out of operation due to a rise in discharge temperature, there will be a consequent reduction in discharge temperature which will cause the pneumatic valve **39** to open slightly again and increase the flow of gas to the burners remaining in operation so that the system will balance off again but with fewer burners in operation. The fact that the pneumatic electric switches **181** to **184** are set with a relatively wide differential is very important in preventing short cycling of the system. If this differential were too narrow, the solenoid valves **33** to **36** would be continually opening and closing. The result is that the discharge temperature would be continually varying. By providing these valves with a wide differential, the control of the discharge temperature is, under normal circumstances, taken care of solely by adjustment of the pneumatic valve **39**.

If during the operation of the burners, any of the various limiting conditions occur, the system will be immediately shut down. For example, if the gas pressure falls below a predetermined minimum value, the switch **43** will be opened. The opening of this switch will interrupt all of the circuits traced through push button switch **122**, which circuits include all of the switches to the various valves and to the flame detecting apparatus. The result is that the entire system will be shut down until the gas pressure is restored to the desired value.

Again, if the outdoor temperature rises to a value such that operation of the system is no longer needed, switch **141** will move to an open position. This again will interrupt the various circuits traced so as to cause termination of the operation of the system. Again, if the discharge temperature rises to an unduly high value, switch **151** will open to interrupt the circuits to the solenoid valves **40** and **49** and to terminate operation of the system.

If, at any time, either of the pilot burners **15** and **16** is extinguished, the switch blades of the particular flame detecting apparatus will move to their deenergized position. It will be noted that all of the circuits traced through the flame detecting apparatus involve the in contacts of both flame detecting apparatuses. As an added precaution, the circuit traced to the main shut-off valve **40** includes both sets of in contacts of both of the flame detecting apparatuses. It will be obvious that as soon as either pilot burner is extinguished, the solenoid valves **40** and **48** will be closed to interrupt flow of gas to both the main and pilot burners.

Under all conditions, when the system has once been shut down, it is necessary to reclose switch **126** manually before the system can be again placed into operation.

It will be seen that I have provided a burner control apparatus in which provision is made for initially preventing the operation of the system unless at least two of a plurality of circulating fans are placed into operation. Furthermore, it will be seen that the apparatus provides for a delay after the fans have been placed into operation before the burners can be placed in operation. The system, furthermore, provides for modulation of the flow of gas to the burners with means for sequentially closing individual valves to individual burners as the main modulating valve is modulated below a minimum position. It will also be seen that provision is made for maintaining these individual valves closed until the main modulating valve reaches a position close to wide open position. This insures that gas will initially be supplied at substantially full pressure to the burners so that there will be no danger of the gas "popping back" in the mixer.

It will, furthermore, be seen that I have provided a system employing a combination of electric and pneumatic controls in such a manner as to reduce the apparatus to a minimum for the functions performed.

While I have shown a detailed embodiment of my invention, it is to be understood that this is for purposes of illustration and that my invention is to be limited only by the scope of the appended claims.

I claim as my invention:

1. In a fluid fuel burner control system, a burner, an electrically operated shut-off valve for controlling the flow of fuel to said burner, a pneumatically operated valve for also controlling the flow of fuel to said burner, means responsive to a controlling condition indicative of the demand for burner operation for gradually controlling the pressure of the pneumatic fluid associated with said pneumatically operated valve so as to cause said valve to be modulated between maximum and minimum open position, an electro-pneumatic relay for causing said pneumatically operated valve to move to minimum open position independently of said condition responsive means when deenergized, energizing means for both said electrically operated valve and said electro-pneumatic relay, and means including a main controlling switch effective when moved to one position to cause simultaneous deenergization of said electrically operated valve and said electro-pneumatic relay.

2. In a fluid fuel burner control system, a plurality of burners, an electrically operated shut-off valve for controlling the flow of fuel to all of said burners, a pneumatically operated valve for also controlling the flow of fuel to all of said burners, means responsive to a controlling condition indicative of the demand for burner operation for gradually controlling the pressure of the pneumatic fluid associated with said pneumatically operated valve so as to cause said valve to be modulated between maximum and minimum open positions, further electrically operated valves individually controlling the flow of fuel to said burners, pneumatically operated switches controlling said further valves to cause them to open sequentially as the pneumatic pressure changes, an electro-pneumatic relay for

causing said further valves to close and said pneumatically operated valve to move to minimum position independently of said condition responsive means when said relay is deenergized, energizing means for both said electrically operated valve and said electro-pneumatic relay, and means including a main controlling switch effective when moved to one position to cause simultaneous deenergization of said electrically operated valve and said electro-pneumatic relay.

3. In a fluid fuel burner control system, a burner, a conduit leading to said burner, a main controller for varying the flow of fuel to said conduit, and a pressure regulating valve connected in parallel with said main controller to maintain a minimum pressure of fluid in said conduit, said pressure being the minimum required for safe operation of said burner.

4. In a fluid fuel burner control system, a plurality of burners, a main conduit leading to all of said burners, means individual to each burner for individually controlling the flow of fuel from said conduit to said burners so as to vary the number of burners in operation, a main controller for varying the flow of fuel to said main conduit and hence to all of said burners, and a pressure regulating valve connected in parallel with said main controller to maintain a predetermined minimum pressure of fluid in said conduit sufficient to insure safe operation of said burner.

5. In a temperature control system, a duct leading from the outside to a space to be heated, controllable means circulating air from the outside to said space through said duct, a plurality of burners in said duct, an electrically operated shut-off valve for controlling the flow of fuel to all of said burners, a pneumatically operated valve for also controlling the flow of fuel to all of said burners, means responsive to a controlling condition indicative of the demand for burner operation for gradually controlling the pressure of the pneumatic fluid associated with said pneumatically operated valve so as to cause said valve to be modulated between maximum and minimum open positions, further electrically operated valves individually controlling the flow of fuel to said burners, pneumatically operated switches controlling said further valves to cause them to open sequentially as the pneumatic pressure changes, an electro-pneumatic relay for causing said further valves to close and said pneumatically operated valves to move to minimum position independently of said condition responsive means, energizing means for both said electrically operated valve and said electro-pneumatic relay, means preventing energization of said valve and relay until means for causing a predetermined circulation of air in said duct has been energized, and means including a main controlling switch effective when moved to one position to cause simultaneous deenergization of said electrically operated valve and said electro-pneumatic relay.

6. In a temperature control system, a duct leading from the outside to a space to be heated, controllable means circulating air from the outside to said space through said duct, a plurality of burners in said duct, means responsive to the temperature of the outside air, further means responsive to the temperature of the air leaving said duct, an electrically operated shut-off valve for controlling the flow of fuel to all of said burners, a pneumatically operated valve for also controlling the flow of fuel to all of said burners, means responsive to a controlling condition indicative of the demand for burner operation for gradually controlling the pressure of the pneumatic fluid associated with said pneumatically operated valve so as to cause said valve to be modulated between maximum and minimum open positions, further electrically operated valves individually controlling the flow of fuel to said burners, pneumatically operated switches controlling said further valves to cause them to open sequentially as the pneumatic pressure changes, an electro-pneumatic relay for causing said further valves to close and said pneumatically operated valve to move to minimum position independently of said condition responsive means, energizing means for both said electrically operated valve and said electro-pneumatic relay, means including said outdoor temperature responsive means and said further means permitting said energization only when said outlet air temperature is below a predetermined value and the temperature of the air leaving said duct is below a second predetermined value, additional means preventing said energization until means for causing a predetermined circulation of air in said duct has been energized, and means including a main controlling switch effective when moved to one position to cause simultaneous deenergization of said electrically operated valve and said electro-pneumatic relay.

7. In a temperature control system for a space, an air passage to said space, controllable means circulating air through said passage to said space, a plurality of temperature changing units disposed in said passage, means supplying fuel to said units, flow control means controlling said fuel supply, means causing said flow control means to open only after sufficient operation of said controllable means to establish a predetermined circulation of air, modulating valve means in series with said flow control means also controlling said fuel supply, an "on" and "off" control for each of said temperature changing units, temperature responsive means within said space, said temperature responsive means controlling said modulating valve means, and means for sequentially controlling said "on" and "off" controls in such a manner that said temperature changing units are sequentially placed into operation as said modulating valve means approaches one of its extreme positions and are sequentially placed out of operation as said modulating valve approaches the other of its extreme positions.

8. In a temperature control system for a space, air passage means to said space, controllable means circulating air through said passage to said space, a plurality of main burners in said passage, means for supplying fluid fuel to said burners, a main electrically operated valve for controlling the flow of fuel to all of said burners, means opening said valve only after a sufficient operation of said controllable means to establish a predetermined air circulation, a proportioning valve in series with said electrically operated valve for controlling said fuel flow, temperature responsive means for controlling said proportioning valve, a pilot burner associated with each of said main burners, ignition means for said pilot burner, apparatus associated with each pilot burner for detecting whether said pilot burner is ignited, said apparatus comprising a relay having in contacts and out contacts and being operable upon the associated pilot burner being ignited to cause said relay to open said out contacts and close said in contacts, an energizing circuit for each

of said ignition means controlled by out contacts of all of said relays in parallel, and an energizing circuit for said valve controlled by in contacts of all of said relays in series.

9. In a ventilating system in which a stream of air is caused to flow through a conduit, a burner of sectional structure adapted to heat the air as it flows in such conduit, a gas supply pipe, leads from the gas supply pipe to the several sections of the burner, a pneumatically operated control valve arranged in the supply pipe, controlling gas flow to all of the sections of the burner, cut-off valves in the leads to the several sections of the burner, means for operating the cut-off valves severally, each such means including a pneumatically driven element, and the pneumatically driven elements being severally responsive to different degrees of pressure, a source of pneumatic pressure effective upon the control valve and upon the pneumatic elements of the cut-off valves, and means for varying the degree of pneumatic pressure so effective, in response to variation in temperature of the heated stream of air.

10. In a ventilating system in which a stream of air is caused to flow through a conduit, a burner of sectional structure adapted to heat the air as it flows in such conduit, a gas supply pipe, leads from the gas supply pipe to the several sections of the burner, a pneumatically operated valve arranged in the supply pipe and controlling the flow of gas to all of the sections of the burner, and solenoid valves arranged in the leads to the sections of the burner, the valves opening in response to the energizing and closing upon the deenergizing of the solenoids, a pneumatic-electric switch associated with each solenoid valve and adapted to close the solenoid-energizing circuit in response to pneumatic pressure, the switches severally being so responsive to different degrees of pressure, a pneumatic pressure line leading to said pneumatically operated valve and to the said switches, a control member responsive to the temperature of the stream of heated air arranged in the pneumatic pressure line and establishing the effective value of the pressure in accordance with such temperature.

11. In a ventilating system in which a stream of air is caused to flow through a conduit, a burner of sectional structure adapted to heat the air as it flows in such conduit, a gas supply pipe, leads from the gas supply pipe to the several sections of the burner, a control valve arranged in the supply pipe, controlling gas flow to all of the sections of the burner, cut-off valves in the leads to the several sections of the burner, means for operating the cut-off valves severally, each such means including a pneumatically driven element, and the pneumatically driven elements being severally responsive to different degrees of pressure, a source of pneumatic pressure effective upon the control valve and upon the pneumatic elements of the cut-off valves, and means for varying the degree of pneumatic pressure so effective, in response to variation in temperature of the heated stream of air.

12. In a temperature control system, temperature changing apparatus, at least three fluid circulating means for circulating fluid through said temperature changing apparatus, means for controlling said circulating means, a relay associated with each fluid circulating means and operable by said controlling means, each of said relays including electrical contacts positioned thereby, electrically operated means for controlling the operation of said temperature changing means, and a plurality of energizing circuits for said electrically operated means, each of said energizing circuits including in series the contacts of two of said relays.

13. In heating apparatus, a plurality of burners, a fuel supply pipe, a main solenoid valve in said pipe, a proportioning valve in said pipe downstream from said solenoid valve, conduits individually connecting said burners to said pipe, a solenoid valve in at least one of said conduits, means for insuring a predetermined minimum pressure in said pipe downstream from said proportioning valve whenever said main solenoid valve is open, and a pair of thermostatically controlled devices connected in controlling relation to said solenoid valves and proportioning valve for operation thereof in a sequence wherein said main solenoid is opened and said proportioning valve partly opened before the solenoid valve in said conduit is opened.

14. In a temperature control system, temperature changing apparatus, a solenoid valve and a proportioning valve serially arranged for controlling said temperature changing apparatus, at least three fluid circulating means for circulating fluid through said apparatus, means for controlling said circulating means, a relay associated with each fluid circulating means, each of said relays including electric switch contacts positioned thereby, temperature responsive means for controlling said proportioning valve, and a plurality of energizing circuits for said solenoid valve, each of said energizing circuits including in series the contacts of two of said relays.

15. In a condition changing apparatus, a plurality of devices for changing said condition, a fluid supply pipe, a shutoff valve in said pipe, conduits individually connecting said devices to said pipe, a proportioning valve downstream from and in series with said shutoff valve and arranged to control flow through said supply pipe and thus control flow to said devices, a pressure regulating valve in by-pass relation to said proportioning valve for maintaining a predetermined pressure in said pipe and said conduits whenever said shutoff valve is open, a valve in at least one of said conduits, and control means responsive to said condition connected to control said shutoff valve, proportioning valve and the valve in said conduit in a predetermined sequence.

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