Nov. 22, 1938. E. V. FRANCIS 2,137,754

CONTROL SYSTEM FOR PULVERIZED FUEL BURNERS

Filed April 26, 1935 4 Sheets-Sheet 1

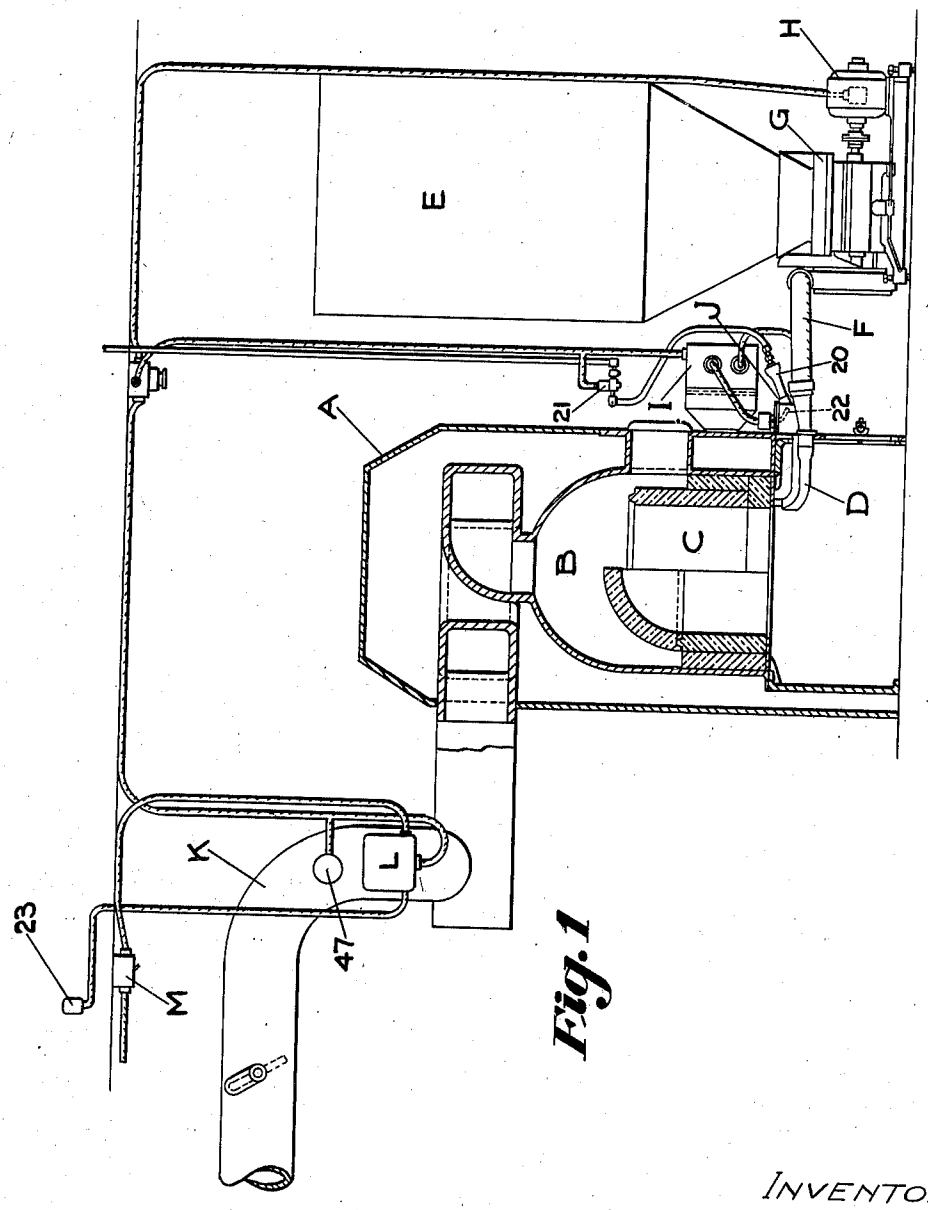


Fig. 1

INVENTOR:
Earle V. Francis,
BY
Chas. M. Nissen,
ATT'Y.

Nov. 22, 1938. E. V. FRANCIS 2,137,754

CONTROL SYSTEM FOR PULVERIZED FUEL BURNERS

Filed April 26, 1935 4 Sheets-Sheet 2

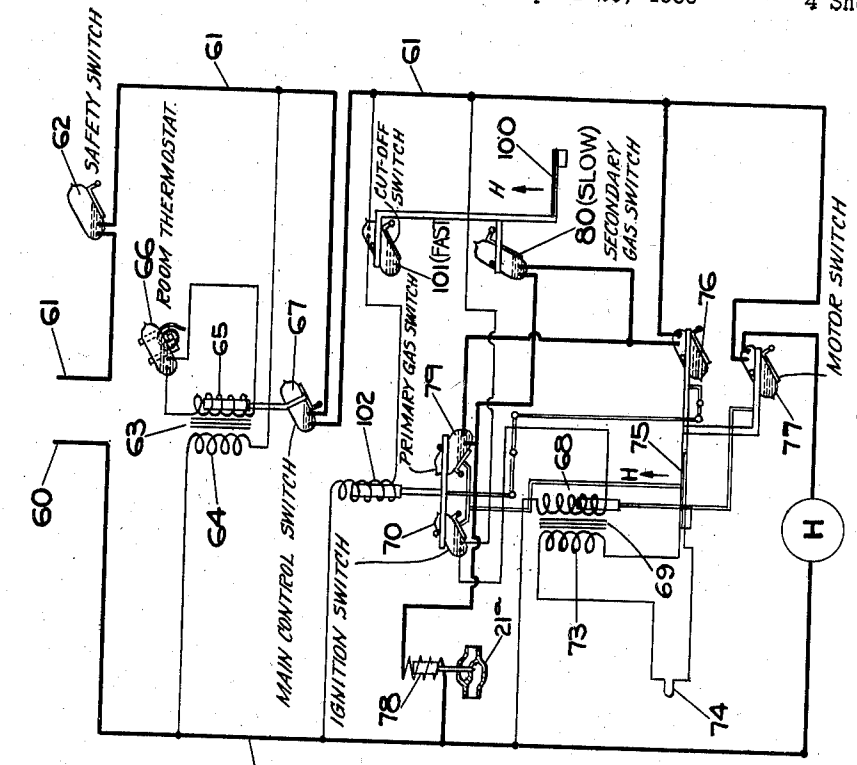


Fig. 3

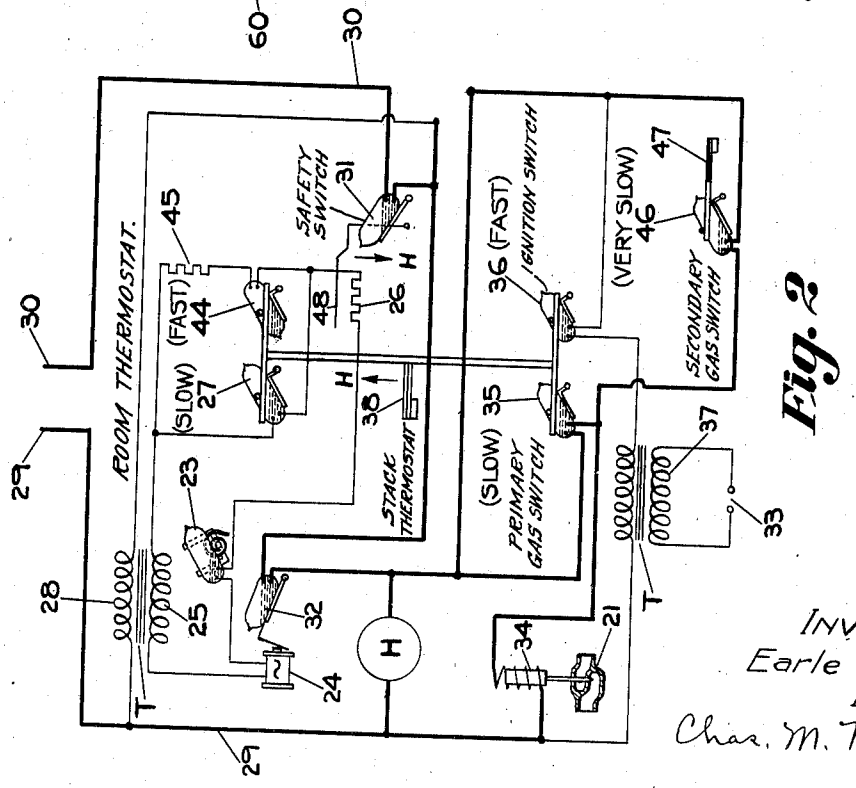


Fig. 2

INVENTOR:
Earle V. Francis,
By
Chas. M. Nissen,
ATT'Y.

Nov. 22, 1938. E. V. FRANCIS 2,137,754

CONTROL SYSTEM FOR PULVERIZED FUEL BURNERS

Filed April 26, 1935 4 Sheets-Sheet 3

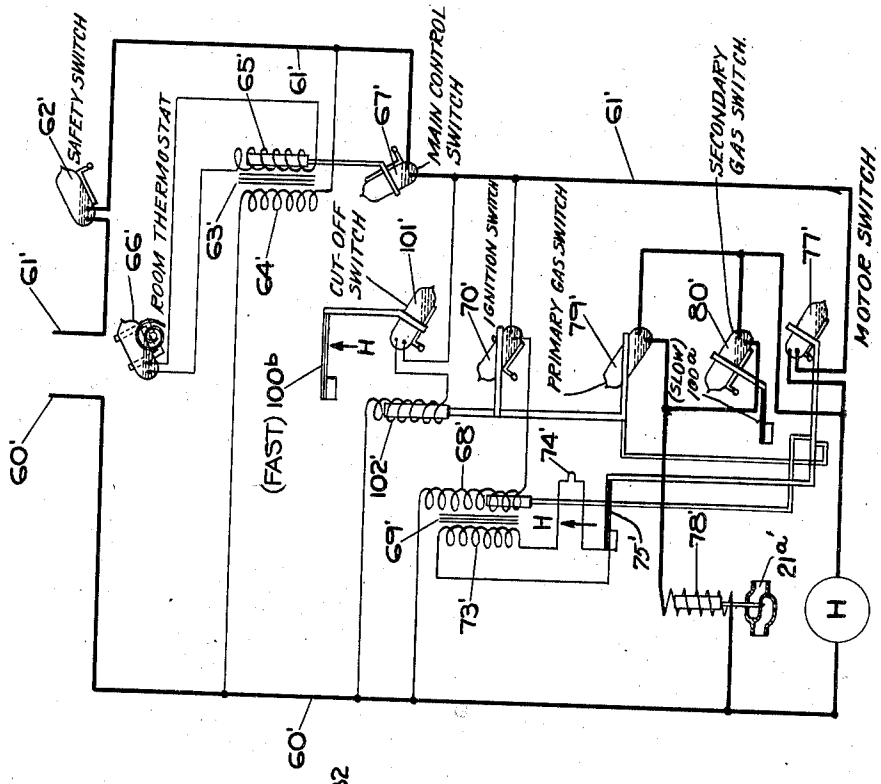


Fig. 4.

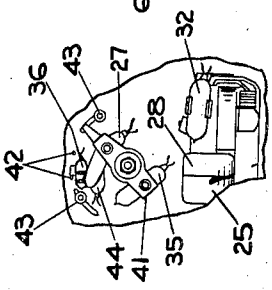


Fig. 6

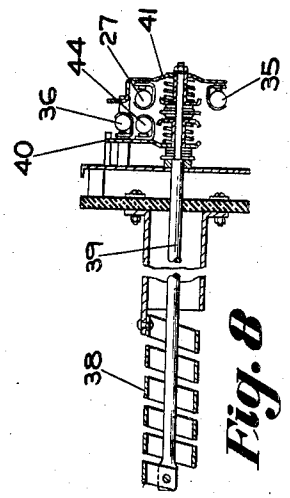


Fig. 8

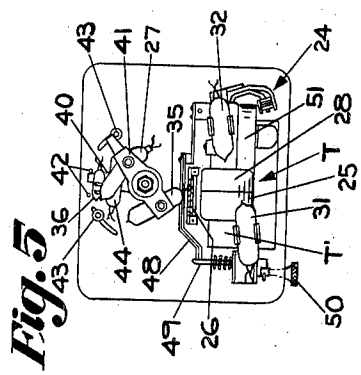


Fig. 5

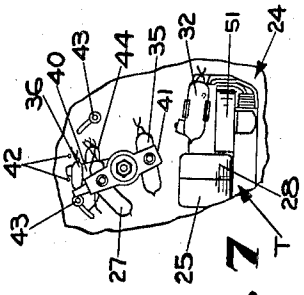


Fig. 7

INVENTOR:
Earle V. Francis,
BY
Chas. M. Nissen,
ATT'Y.

Nov. 22, 1938. E. V. FRANCIS 2,137,754

CONTROL SYSTEM FOR PULVERIZED FUEL BURNERS

Filed April 26, 1935 4 Sheets-Sheet 4

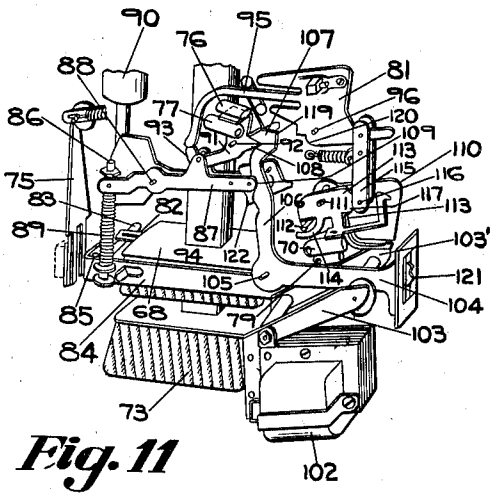
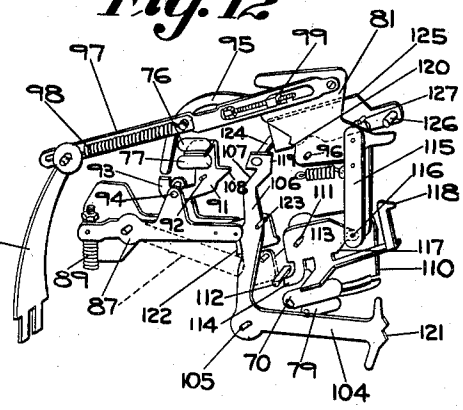


Fig. 11

Fig. 12



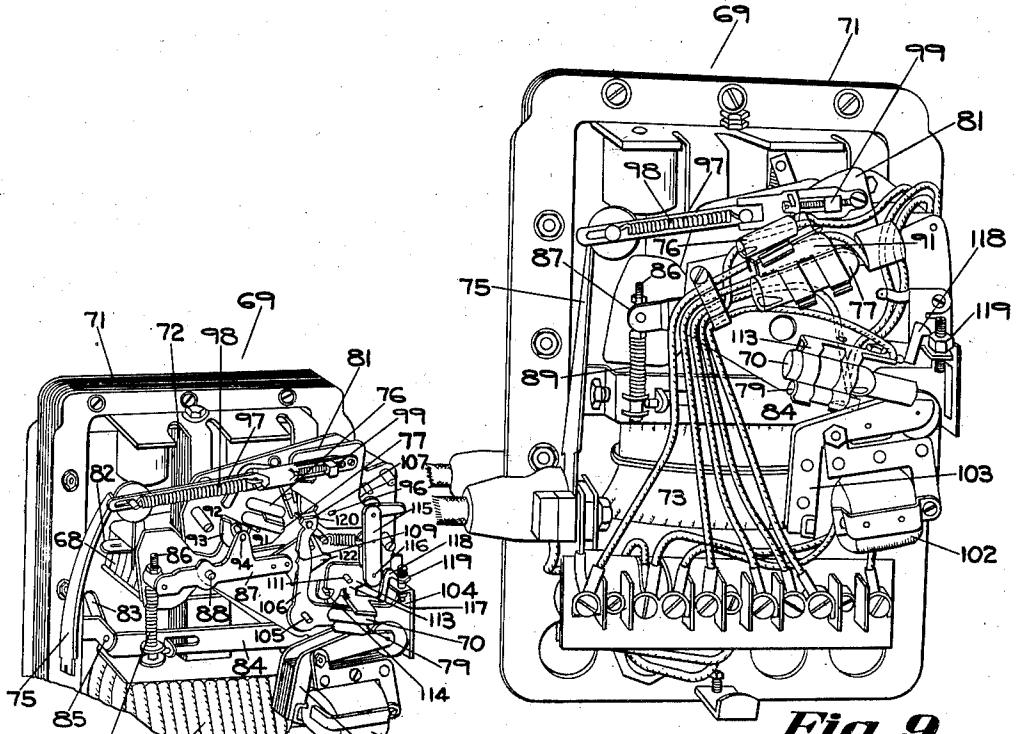


Fig. 9

Fig. 10

INVENTOR:
Earle V. Francis,
BY
Chas. M. Nissen,
ATT'Y

Patented Nov. 22, 1938 2,137,754

UNITED STATES PATENT OFFICE

2,137,754

CONTROL SYSTEM FOR PULVERIZED FUEL BURNERS

Earle V. Francis, Columbus, Ohio, assignor to The Jeffrey Manufacturing Company, a corporation of Ohio

Application April 26, 1935, Serial No. 18,336

4 Claims. (Cl. 110—28)

The invention relates to an electrical control system particularly adapted for pulverized coal burners.

An object of the invention is to provide a completely automatic control system for a pulverized coal burner, particularly of the type designed for domestic use, which is very efficient and economical in operation yet is operative to insure the proper control of the burner.

A specific object of the invention is to provide an improved control system for a pulverized coal burner having a preliminary combustion chamber, which system is fully automatic and which employs a combined gas and electric ignition means, in which the operation of the electric ignition means is discontinued after a short period of fuel combustion, while the gas ignition means is operative for a somewhat longer period and until a pulverized coal combustion supporting temperature is reached within the preliminary combustion chamber, after which said gas ignition means is also rendered inoperative.

Another specific object of the invention is to provide an improved control system for a pulverized fuel burner having a preliminary combustion chamber, which system is fully automatic and which employs a combined gas and electric ignition means, which electric ignition means is energized prior to the energization of the gas ignition means and which electric ignition means is cut off after a short period of fuel combustion while the gas ignition means is operative for a somewhat longer period and until a pulverized coal combustion supporting temperature is reached within the preliminary combustion chamber, after which said gas ignition means is also rendered inoperative.

Other objects of the invention will appear hereinafter, the novel features and combinations being set forth in the appended claims.

Referring to the accompanying drawings:

Fig. 1 is an elevational view of an automatic thermostatically controlled domestic heating system embodying the improvements of the present invention, with the furnace shown in section;

Fig. 2 is a circuit diagram of one circuit of my invention;

Fig. 3 is a circuit diagram of another circuit of my invention;

Fig. 4 is a circuit diagram of a third circuit of my invention;

Fig. 5 is a front elevational view of the combined stack controlled switches and the relays adapted to be used with the circuit of Fig. 2 with the stack controlled switches in the shut-down position;

Fig. 6 is a detailed view of the switches of Fig. 5, when the system has just started operation;

Fig. 7 is a detailed view similar to Fig. 5, when the system is in full operation;

Fig. 8 is a sectional view of the thermostatically controlled stack switches seen in Figs. 5, 6 and 7;

Fig. 9 is a front elevational view of the control mechanism, except for the stack switches, employed with the circuits of Figs. 3 and 4, shown in its normal condition when the system is shut down;

Fig. 10 is a view of the mechanism of Fig. 9, with certain parts removed for clarity, during the starting of the combustion device;

Fig. 11 is a view of the mechanism of Fig. 9, with certain parts removed for clarity, during the running period; and

Fig. 12 is a view of the mechanism of Fig. 9, with numerous parts removed for clarity, when there is a current interruption during the ignition period just before the fuel motor is turned on.

Referring particularly to Fig. 1, there is illustrated an installation comprising a domestic heating unit which is automatically thermostatically controlled by the control system comprising my invention and in which pulverized fuel is employed. The installation comprises a furnace A, which is illustrated as of the hot air type, although it may be of the hot water or steam type, including a fire box or main combustion chamber B, within which is positioned a preliminary combustion chamber C. The preliminary combustion chamber C is an important element of my invention for it has been found after exhaustive tests that a preliminary combustion chamber is necessary for the proper combustion of pulverized fuel, such as pulverized coal. This is due to the fact that the pulverized fuel is not subject to any extensive pre-heating and must be completely ignited within the fire box or main combustion chamber B. The combustion chamber temperature necessary for proper combustion of powdered or pulverized coal is approximately 2000 to 2500 degrees Fahrenheit which is, in general, more than twice the combustion chamber temperature necessary for proper combustion of fuel oil and is many times the combustion chamber temperature necessary for proper combustion of gas. For example, gas will burn in an open room at room temperature but this is not possible with most fuel oils and is entirely impossible with pulverized coal. For fuel oils, the combustion space temperature must be higher than for gas and for

pulverized fuel it must be still higher. The latter is higher than ordinary domestic furnaces, made of iron, can stand.

The preliminary combustion chamber C is made of fire brick or other refractory material and is designed so as to be heated to a very high temperature in a relatively short period of time, whereby it will be effective to maintain combustion of the pulverized coal. That is, the preliminary combustion chamber C is heated by the combined gas and pulverized coal, the former being electrically ignited, during initial combustion and reaches a pulverized coal combustion supporting temperature by forming a hot spot on the interior thereof against which the pulverized fuel is fed. This hot spot is preferably not concentrated, but spreads over a substantial area of the interior of said combustion chamber to prevent rapid deterioration of said preliminary combustion chamber. Due to the presence of this preliminary combustion chamber C, the gas needs to be employed only for a relatively short period and until the mentioned pulverized coal combustion supporting temperature is reached. In practice this may vary from 3 to 12 minutes. The period during which the electrical ignition means is energized may be appreciably less as it need only ignite the gas. After the preliminary combustion chamber C has reached the pulverized coal combustion supporting temperature, the gas may be turned off and the preliminary combustion chamber C will be effective to ignite the pulverized fuel delivered thereto and will maintain combustion thereof. This preliminary combustion chamber C also performs the additional function of protecting the walls of the fire box or main combustion chamber B, which are usually of iron and are incapable of standing the above mentioned high temperatures. Said preliminary combustion chamber C is preferably open at the bottom for it has been found that if the bottom of said chamber C is closed an accumulation of spongy ash will result and clog said preliminary combustion chamber within a short time, thereby rendering the furnace inoperative.

The form of said chamber may be varied somewhat from that illustrated in the drawings and may take the form illustrated in any of the different species disclosed in my application Serial No. 716,119 filed in the U. S. Patent Office on March 17, 1934, of which the instant application constitutes a continuation in part.

In the operation of the system, the pulverized coal is fed through the open bottom of the preliminary combustion chamber C through the nozzle D having a lower pulverized coal conduit and an upper ignition conduit and which may take the form of the nozzles illustrated in any of the figures of my above mentioned application. The pulverized coal is stored in the bin E and fed through the conduit F to the nozzle D by means of a feeding mechanism G driven by an electric motor H. The detailed structure of the feeding mechanism G preferably takes the form disclosed more in detail in my application Serial No. 652,975 filed in the U. S. Patent Office on January 23, 1933.

An ignition means, including a transformer I and an igniter J, is provided which is of the combined gas and electric type. That is, the igniter J comprises a gas jet nozzle **20** which is supplied with gas from the usual commercial source and is controlled by a gas valve **21**. As the gas is admitted from the gas jet nozzle **20** into the upper ignition conduit of burner nozzle D, it is ignited by either a spark or incandescent type electric igniter **22** which may take the form of any of the igniters disclosed more in detail in my above mentioned application, Serial No. 716,119.

The control of the combustion within the furnace A is entirely automatic and responds to the temperature of a control thermostat **23**, such as a room thermostat. Various control relays and switches are provided, as will be hereinafter described more in detail, some of which are responsive to the temperature in the stack K associated with the furnace A and, as illustrated in Fig. 1, these control devices are mounted within a control box L. A line switch M is provided for controlling the energization or de-energization of the entire system.

As will be hereinafter pointed out more specifically in considering the several control circuits, the room thermostat **23** will be effective to start up the feed mechanism G to feed pulverized coal to the furnace A whenever the room temperature reaches a pre-determined low value. The control system will automatically operate to turn on the igniting gas and the electrical ignition means to ignite the pulverized coal during a preliminary period. After a short period of combustion, the electrical ignition means will be turned off as it would be uneconomical to maintain it energized for a long period. The igniting gas, however, will be maintained for a longer period and until the preliminary combustion chamber C has reached such a temperature that the incoming pulverized fuel will be ignited thereby without the aid of the gas. When this temperature of the preliminary combustion chamber is reached, the igniting gas will also be turned off and the control of the feed mechanism G will be directly under the supervision of the room thermostat **23** and will be rendered operative until the room, in which said room thermostat **23** is located, has reached a predetermined temperature. Automatic means is also provided so that the system would be rendered entirely inoperative and will require a manual re-setting should combustion not be properly established.

Attention is directed to Figs. 2, 5, 6, 7 and 8, the first of which is a circuit diagram representing one control circuit comprising my invention and the last four of which illustrate the structure of the mercury switches and the operating means therefor. The condition of the circuit, as illustrated in Fig. 2, is representative of the situation a short interval after the room thermostat **23** has been closed in response to a low room temperature. Upon the closing of the contacts of said mercury switch **23**, relay **24** will be energized through a circuit from the left hand terminal of the secondary **25** of transformer T through said relay **24**, the contacts of mercury switch **23**, the heating resistor **26**, the normally closed contacts of slow mercury switch **27** and the right hand terminal of the secondary **25** of said transformer T. The primary winding **28** of said transformer T is normally energized directly from the line conductors **29** and **30**, which are connected to the usual source of alternating current through the switch M of Fig. 1. It may be noted that a safety switch **31**, comprising a mercury tube, is connected in the line conductor **30** and it is necessary that the contacts of this switch **31** be in a closed position in order that the control system may be operative.

When the above described circuit, including relay **24**, is closed, the normally open contacts of mercury switch **32** are closed and a circuit is provided from the line conductor **29** through the

motor H of the feed mechanism G to the line 30 by way of safety switch 31. Thus the energization of relay 24 is effective to start the operation of feed motor H and is effective to start the delivery of powdered coal from the storage bin E to the furnace A. The switch 32 also causes energization of the gas control valve 21 and the electric spark ignition means 3 simultaneous with the energization of motor H. Said gas control valve 21 is controlled through the solenoid 34, the terminals of which are connected between the lines 29 and 30 through the normally closed contacts of mercury switch 35 and/or parallel mercury switch 46, mercury switch 32 and safety switch 31. The spark ignition means 33 is energized by virtue of the fact that the primary of transformer T is connected between the line conductors 29 and 39 through the normally closed contacts of fast mercury switch 36 and through the contacts of mercury switch 32 and safety switch 31 over an obvious circuit. The spark ignition means 33 is connected to the terminals of the secondary winding 37 of transformer T.

It is thus evident that the closing of mercury switch 32 is effective to cause a simultaneous operation of the pulverized fuel feed mechanism G, the opening of the gas valve 21 and the energization of the spark ignition means 33. Under these conditions, pulverized coal will be fed to the preliminary combustion chamber C through the nozzle D which will be ignited by a flame of burning gas which issues from the top conduit of said burner nozzle D, which flaming gas is ignited by the electrical spark ignition means 33. Combustion is thus initiated in the furnace A.

In response to the combustion in the furnace A, the thermostatic stack controlled mechanism illustrated in detail in Fig. 8 will become operative whereby the bi-metallic helix 38 will start to turn the shaft 39. Upon said shaft 39 there is impositively mounted a pair of levers 40 and 41. There is sufficient frictional engagement between said shaft 39 and the levers 40 and 41, which is provided by appropriate springs, so that the levers 40 and 41 tend to rotate with said shaft 39. The rotary movement of the lever 40 is restricted by a pair of spaced pins 42 and the rotary movement of the lever 41 is restricted by a pair of adjustable spaced pins 43.

The normal non-operating position of the levers 40 and 41 is illustrated in Fig. 5 in which lever 40 is at its extreme right hand position and adjacent the right hand pin 43. As the shaft 39 rotates, under the influence of heat, in a counter-clockwise direction, the lever 40 moves from the right hand pin 42 to the left hand pin 42 in a relatively short period of time or in response to a relatively low combustion temperature. Said arm 40 carries the normally closed mercury switch 36 and the normally open mercury switch 44. Thus, when said lever 40 moves from the right hand pin 42 to the left hand pin 42 in response to initial combustion in the furnace A, it is effective to break the contacts of mercury switch 36 which cuts out the electrical ignition means 33. It also closes the contacts of mercury switch 44. The function of the mercury switch 44 is to insert a resistor 45 in a series circuit including the secondary 25 of transformer T, relay 24, the contacts of switch 23 and safety heating resistor 26, whereby the relay 24 will be maintained energized after mercury switch 27 is open in response to a prolonged or higher combustion temperature and will prevent the energization of a bi-metallic safety device associated with the safety heating resistor 26 for operating the safety switch 31. This will be explained more in detail hereinafter.

After a higher combustion temperature is reached or the combustion has been prolonged for a more extended period within which the preliminary combustion chamber C reaches a pulverized coal combustion supporting temperature, shaft 39 will be operative to move the lever 41 to the left-hand pin 43 and, just before this position is reached, the contacts of the normally closed mercury switches 27 and 35 will be opened. Switch 27 may be adjusted so as to open ahead of switch 35. The opening of contacts of mercury switch 35 will open one circuit to the solenoid 34 of the gas valve 21. However, this solenoid will still be energized by virtue of a normally closed mercury switch 46 which is associated with a very slow stack controlled mechanism 47. That is, the stack controlled mechanism 47 is effective to open the contacts of mercury switch 46 only after a heating period which is in excess of that required to open switches 27 and 35. This stack controlled mechanism may be of the general type illustrated in Fig. 8 except that, of course, there will be only one lever and one mercury switch associated therewith which will be adjusted for very slow operation, or it may take the form of any other well-known temperature responsive control mechanism. The opening of the contacts of the mercury switch 27 is effective to reduce the current in the previously closed circuit, including secondary 25, the relay 24, contacts of switch 23 and the safety heat resistor 26 and to insert effectively in said series circuit the resistor 45 through the contacts of switch 44. This so reduces the current in the resistor 26 that the bi-metallic safety operating device associated therewith will not be operated.

After a prolonged combustion period, which is determined by the adjustment of the stack controlled mechanism 47, the solenoid 34 will be de-energized and the gas shut off. This represents the normal running condition in which the supplying of pulverized coal to the furnace A is directly controlled by the room thermostat 23.

After the room has reached a predetermined temperature, the contacts of mercury switch 23 will be opened whereupon relay 24 will be de-energized, thus opening the circuit to motor H of the feed mechanism G and discontinuing the supplying of pulverized fuel to the furnace. All of the stack controlled or heat responsive mercury switches 27, 35, 36, 44 and 46 thus begin to return to their normal positions as the temperature in the furnace A decreases. Upon the temperature in the room again reaching the minimum temperature to which it is adjusted, the above mentioned cycle of operation will be repeated.

In order to provide a safety device whereby the system will be rendered entirely inoperative, if proper combustion does not take place in the furnace A within a pre-determined time, automatic means are provided for preventing operation of the system under the mentioned conditions. Assuming, for example, that after relay 24 is energized and contacts of switch 32 are closed, combustion does not take place, or does not take place at a sufficiently rapid rate to energize the helix 38 properly, a current will flow through the series circuit comprising transformer secondary 25, relay 24, contacts of switch 23, safety heating resistor 26 and the contacts

of switch 27. Associated with the safety heating resistor 26 is a bi-metallic strip 48. With this resistor 26 heated by the normal current flowing through the above mentioned circuit, it will be effective to deflect the bi-metallic strip 48 so that after a pre-determined period of time said strip 48 will release a latch 49 (Fig. 5) which, when released, will allow the mercury switch 31 to tilt under the influence of gravity and open the contacts thereof. When the contacts of said safety switch 31 are opened, the entire system is disabled and it is necessary to re-set manually the control mechanism to close the contacts of said safety switch 31 by the operation of a re-set knob 50. It is to be noted that in the ordinary operation of the system, the contacts of switch 44 are closed after which the contacts of switch 27 are opened before strip 48 is deflected sufficiently to release latch 49, in which case the current flowing through the mentioned circuit, now including resistor 26, will be reduced to an amount insufficient to operate the safety switch 31 even though it flows indefinitely.

Attention is directed to the fact that the two switches 35 and 46 are effectively in parallel and thus, if either is closed, the gas valve 21 may be operated. This is to provide for the establishing of a circuit for the solenoid 34 of the gas valve 21 in case the system is shut down for a relatively short time during which the very slow switch 46 has not had sufficient time to close. This tends to prevent needless operations of the safety switch 31 which might otherwise take place were switch 35 omitted.

It may be pointed out that in Fig. 2 the transformer T is shown as independent of the relay 24 but this construction is not necessary and they may be combined as a single unit. In Fig. 5 there is illustrated the combined transformer T and relay winding at T'. The field core 51 operates as the field for the transformer and also as a core for the relay 24 which controls the switch 32. The primary of said combined relay and transformer T' is seen at 28.

Referring to Fig. 3 of the drawings, there is illustrated another circuit comprising my invention which has certain features of operation not present in the circuit of Fig. 2 and which is associated with an essentially different switch controlling mechanism which is illustrated in Figs. 9, 10, 11 and 12. One of the features of the invention of the control system of Fig. 3 lies in the fact that an incandescent type of electrical ignition means is provided and this electrical ignition means is heated for a pre-determined period so as to reach incandescence before the gas valve is opened and the motor H of the feed mechanism G is operated. This period may be termed the pre-ignition period.

The condition of the system as illustrated in Fig. 3 is just after the room temperature responsive switch 66 is closed. The control system of said Fig. 3 includes a pair of line conductors 60 and 61 which are connected to the usual source of commercial alternating current—as, for example, through the switch M of the type illustrated in Fig. 1. A mercury safety switch 62 is in the line 61 and may be operated from any safety device such as an over-pressure gauge associated with a steam boiler or an over-temperature thermostat associated with an air or hot water furnace. The transformer 63 has its primary 64 connected directly across the line conductors 60 and 61. The secondary 65 of the transformer 63 has its terminals directly connected to the terminals of the room temperature responsive mercury switch 66. It is thus evident that upon closing of the contacts of the room temperature responsive switch 66, the secondary 65 of the transformer 63 will be energized. Energization of said secondary 65 is effective to close the normally open mercury switch 67 in the line conductor 61. A movable solenoid may be associated with said secondary 65 for operating said mercury switch 67 or said secondary 65 may be of the floating coil type and be effective to close the contacts of said switch 67 when energized. Upon the closing of contacts of mercury switch 67, it is evident that line voltage will be applied to the lines 60 and 61 and any devices which are directly connected between these lines will be energized. The only device, excepting winding 64, which is directly connected across lines 60 and 61 when the terminals of switch 67 are closed, is the floating primary winding 68 of the constant current transformer 69. The circuit to said primary winding 68 is an obvious one and includes the normally closed contacts of mercury switch 70.

Referring more particularly to Figs. 9, 10 and 11, there is illustrated the structural details of the constant current transformer 69 and its association with other control elements of the system. Said constant current transformer 69 comprises a shell type core 71 having a central leg 72 upon which is mounted the floating primary winding 68 and a stationary secondary 73. When the floating primary coil 68 is energized, as aforesaid, it will be lifted upon the leg 72 due to magnetic repulsion between the primary 68 and the secondary 73. As the transformer 69 is of the constant current type, a constant flow of current will be induced in the closed secondary circuit thereof (Fig. 3) which includes stationary winding 73, incandescent ignition means 74 and bimetallic thermal element 75. This flow of constant current in said secondary circuit will heat the incandescent ignition means 74 to a proper temperature within a pre-determined time which will be constant regardless of any voltage fluctuations due to the constant current transformer and will cause the bi-metallic thermal element 75, by reason of the heating thereof by the current flowing therethrough, to deflect to the right as viewed in Figs. 9, 10, 11 and 12.

As the thermal element 75 is deflected, it is effective to close the normally open contacts of gas switch 76, which is of the mercury type, and to close the normally open contacts of motor switch 77, which is also of the mercury type. While both the mercury switches 76 and 77 are operated by the bi-metallic thermal element 75, they are so adjusted that the contacts of switch 76 are closed a short interval of time prior to the closing of the contacts of switch 77. The closing of the gas switch 76 is effective to close a circuit to the operating solenoid 78 of the gas valve 21*a* through the normally closed contacts of switch 79 or the normally closed contacts of switch 80, which switches 79 and 80 are connected in parallel. Thus the closing of switch 76 opens the gas valve 21*a* and supplies gas to the furnace A which will be ignited by the ignition means 74. After a very short interval of time, the closing of motor switch 77 will close the circuit to the motor H and start the feeding of the pulverized coal by the feed mechanism G to the furnace A. Combustion is thus initiated.

Referring particularly to Figs. 9, 10, 11 and

12, attention is directed to the structural details of the control mechanism and its operation in performing the above described functions. The normal non-operating condition of the control mechanism is illustrated in Fig. 9. As illustrated in this figure, the thermal element **75** is undeflected and is in a normal position. When the constant current flows through secondary circuit, including the secondary **73** of transformer **69**, the ignition means **74** and said thermal element **75**, the floating primary winding **68** rises, as illustrated in Fig. 10, and the element **75** starts deflecting to the right. The floating primary winding **68** carries a pair of lateral projections, one of which is seen at **82** in Figs. 10 and 11, which projections are adapted to strike against a pair of pivoted levers, one of which is seen at **83** in Figs. 10 and 11, when said floating coil is in the lowered position and is de-energized. The rising of the floating winding **68** in response to its energization lifts the projections **82** from the levers **83** and allows the bracket **84** to move downwardly. Said bracket **84** is pivoted at each side, one of the pivots being seen at **85** in Figs. 10 and 11. The bracket **84** is connected by a shaft **86** to a lever **87** which is pivoted about a pivot **88**. The downward movement of the bracket **84** is positively transferred to the lever **87** but the upward movement of said bracket **84** is transferred to the lever **87** through a compression spring **89**. Also attached to the lever **87** is a retarding dash pot **90** which dampens the action of the lever **87**.

The gas switch **76** and the motor switch **77** are carried on a carrier plate **91** which is pivoted at **92** and is normally biased by gravity to move in a clockwise direction. Said carrier plate **91** is provided with an arm **93** with which cooperates a pin **94** carried by the lever **87**. When the floating primary winding **68** is in its lowered position, the lever **87** is rotated clockwise and the pin **94** is effective to rotate the carrier plate **91** in a counter-clockwise direction and to maintain the contacts of switches **76** and **77** in an open position. This, of course, is their normal non-operating position. When the floating primary winding **68** is in its raised position, the lever **87** will be pivoted to lift the pin **94** from the arm **93**, thereby allowing the carrier plate **91** to pivot in a clockwise direction and close the contacts of mercury switches **76** and **77**. However, this rotation of the carrier plate **91** is also controlled by the projecting finger **95** carried by the plate **81** which cooperates with arm **93** so that carrier plate **91** cannot rotate to close the contacts of mercury switches **76** and **77** until the plate **81** is rotated in a clockwise direction about its pivot **96** under the influence of the thermal element **75**. The thermal element **75**, upon being heated and deflecting to the right at a uniform rate, rotates the plate **81** about said pivot **96** through the intermediary of the pivoted lever **97**. This motion is positive as the thermal element **75** deflects to the right but is impositive through a lost motion tension spring connecting means **98** when the thermal element **75** restores to normal. The effective length of the lever **97** may be adjusted by an adjusting mechanism **99** whereby the time intervals between the first energization of the thermal element **75** and the closing of the mercury switches **76** and **77** may be adjusted. This provides for a variable determination of the period during which the ignition means **74** is energized prior to the time that the gas is turned on and the period during which the gas is turned on prior to the time the motor H is operated.

After the thermal element **75** has been deflected a pre-determined amount and the plate **81** thereby pivoted in a clockwise direction a pre-determined amount, the finger **95** will allow pivotal movement of the carrier plate **91** to a position first to close the gas switch **76** and after a short interval to close the motor switch **77**. When these events have taken place, the mechanism will be in full operation with the ignition means **74** energized, the gas valve **21***a* open and gas being delivered to the furnace, and the motor H operating and delivering powdered coal to the furnace. Combustion of the powdered coal will thereby be initiated, assuming that everything operates properly.

When the system of Fig. 3 and the control mechanism of Figs. 9, 10, 11 and 12 is employed, said control mechanism will preferably not be associated with the stack K as is generally illustrated for the control box L in Fig. 1, but will be positioned at a remote point—for example, on an appropriate panel on a wall in the building, or it may be positioned adjacent the transformer T. However, there will be associated with the stack K a combustion responsive stack switch carrying two mercury switches, one of which operates in a short interval of time and the other of which operates in a relatively long interval of time. These stack switches may be operated by a mechanism similar to that illustrated in Fig. 8 except that only two stitches will be employed instead of the four illustrated. One of the switches would be a fast switch and might correspond to the switch **36** of Fig. 8 and the other switch would be a slow switch and might correspond to the switch **35**.

With conditions as above described and with combustion initiated in the furnace A, the thermostatic stack control mechanism **100** (Fig. 3) will be operated and will first close the normally open contacts of the fast mercury switch **101**. The closing of the contacts for this switch **101** will energize the relay coil **102** which will operate to open the normally closed contacts of mercury switches **70** and **79**. The opening of the contacts of mercury switch **70** will de-energize the circuit to the floating primary winding **68**. The opening of the contacts of the mercury switch **79** will be without effect at this time due to the closed condition of the normally closed contacts of mercury switch **80**, which is connected in parallel therewith.

As a result of the de-energization of the floating winding **68**, this winding will drop to its lowered position, the circuit, including the stationary secondary **73**, ignition means **74** and thermal element **75**, will be de-energized and the thermal element **75** will start to cool and to assume a normal position. A pre-determined time interval after the mercury switch **101** closes its contacts and within a time limit sufficient to heat the preliminary combustion chamber to a pulverized coal combustion supporting temperature, which will ordinarily be from 2 to 10 minutes, the contacts of mercury switch **80** will be open and the gas valve solenoid **78** de-energized, thereby closing the gas valve **21***a* and shutting off the supply of gas. This presents the normal running condition of the system in which the motor H is operating the feed mechanism G to supply fuel to the furnace A under the direct control of the room thermostat **66** and when the room temperature becomes sufficiently high to

open the contacts of the switch 66 and thereby open the circuit of switch 67, the entire mechanism will be disabled, the motor H shut down and the mechanism will restore to its normal non-operating condition.

Referring particularly to Figs. 9, 10, 11 and 12, attention is now directed to the operation of the control mechanism in response to combustion conditions which are effective to close mercury switches 101 and 80, as above described. The condition of the control mechanism before the stack controlled mechanism was effective to close the contacts of switches 101 and 80, is illustrated in Fig. 10. When mercury switch 101 closes and relay coil 102 is energized, the armature 103 of the relay associated with said coil 102, is attracted and is effective to move the lever 104, best seen in Figs. 10 and 11, about its pivot 105. Lever 104 carries an arm 106 which is moved in a counter-clockwise direction under the influence of armature 103, as illustrated in Fig. 11. Said arm 106 carries a latch 107 which cooperates with a tongue 108 extending from the carrier plate 91 to latch said carrier plate 91 in a position where switches 76 and 77 will be closed regardless of the position of lever 87 or plate 81. In addition, the arm 106 has a notch 109, best seen in Fig. 10, which cooperates with lever 87 to maintain said lever in a position illustrated in Fig. 11 without regard to the position of the floating primary winding 68. The armature 103, through its back lever 103', (Fig. 11), cooperates with a plate 110 which is loosely pivoted on a pivot 111 to rotate said plate about said pivot in a counter-clockwise direction. Said plate 110 carries a pin 112 adapted to move the plate 113 in a counter-clockwise direction upon striking an arm 114 thereof. The plate 113 is also pivoted on pivot 111. Plate 113 carries the two mercury switches 70 and 79. Thus the energization of the coil 102 is effective to pivot the plate 113 and to move the switches 70 and 79 from a closed position to an open position.

This results in the turning off of the ignition means 74 and the locking of the motor switch 77 and the gas switch 76 in a closed position. The gas switch 76 is effective to keep the gas valve 21*a* open because both of the contacts of mercury switch 80 are still closed. After the pre-determined combustion temperature is reached, as above mentioned, the contacts of mercury switch 80 are opened and the gas valve 21*a* will close and shut off the gas. This presents the normal running condition of the system and, as was above set forth, is illustrated in Fig. 11 of the drawings.

It may be pointed out that due to the de-energization of the floating primary winding 68 in response to the opening of the contacts of switch 70, said floating primary winding will drop and the thermal element 75 will restore to normal. The dropping of the floating primary winding 68, of course, again brings the lateral projections 82 into contact with the levers 83 and tends to rotate the lever 87 in a clockwise direction. This rotation of the lever 87 is prevented, however, as it is locked in position by the notch 109 of arm 106, as was above described, and the floating primary winding 68 cannot move to its lowermost position. Any tendency for the bracket 84 to pivot the lever 87 results in a compression of the spring 89. In addition, the plate 81 is prevented from being pivoted in a counter-clockwise direction to its normal position under the influence of the thermal element 75 due to the contact between projecting finger 95 and arm 93 of the carrier plate 91, which carrier plate 91 is latched in the position illustrated in Fig. 11 by the latch 107. Thermal element 75, therefore, upon restoring to its normal position, merely tensions the spring of the spring connecting means 98 and does not rotate the plate 81 to its non-operating position.

After the room temperature responsive switch 66 opens its contacts in response to a pre-determined room temperature, the motor H is shut down due to the opening of the contacts of switch 67 and combustion is terminated. This, of course, results in the thermal stack controlled mechanism returning the stack switches 101 and 80 to their normal positions, as illustrated in Fig. 3, under which conditions the relay coil 102 is de-energized and the armature 103 is released. This releases the lever 87 and the carrier plate 91 whereupon the floating primary winding 68 is allowed to drop to its lowermost position. The carrier plate 91 then pivots under the influence of pin 94 carried on lever 87 to open the contacts of gas switch 76 and motor switch 77 and plate 81 rotates in a counter-clockwise direction to its normal non-operating position. Upon the room temperature dropping to a pre-determined minimum, the above mentioned cycle of operation is repeated.

The control system of Fig. 3 and the control mechanism of Figs. 9, 10, 11 and 12 is provided with a number of safety features which will now be described. As was above mentioned, the stack controlled mechanism is so adjusted that in normal operation the ignition means 74 will be disabled in response to a relatively short period of furnace combustion while the gas will be supplied to said furnace for a period sufficient to raise the temperature of the primary combustion chamber C sufficiently high that it will maintain combustion of the pulverized coal without the aid of the gas. Should there be no response by the thermostatic stack controlled mechanism 100 to the starting of the motor H—as, for example, when there was a failure of combustion in the furnace or an improper combustion in the furnace—it is evident that the switch 101 would never be closed and thus relay coil 102 would not be energized to perform the above described functions. Under these circumstances, the contacts of mercury switch 70 would not be opened and the heating of the bi-metallic thermal element 75 would not be discontinued in the manner above described. Said thermal element 75 would, therefore, continue its deflection with a consequent clockwise rotation of the plate 81 about its pivot 96 until the snap mechanism comprising the downwardly extending arm 115, comprising a pair of spaced plates connected at their lower ends by a roller mounted on a pin 116, was operated to such a position that said roller passed over the center of the cam 117 on plate 113 and rotated said plate 113 in a counter-clockwise direction about its pivot 111. Under these conditions, the switches 70 and 79 carried on the plate 113 would be moved to open circuit position. The condition of said plate 113 when thus moved is generally as illustrated in Fig. 12 though other parts thereof are different as said Fig. 12 illustrates another condition. It may be pointed out that said plate 113 carries a latch 118 which cooperates with an adjustable stop 119 whereby the time interval within which said plate 113 will be pivoted as above described in the absence of the operation of the coil 102 may be adjustably determined.

With mercury switch 70 thus moved to an open position, the current which is supplied to the thermal element 75 will be cut off and said element will tend to restore to its normal position. However, as the lever 104 is in its lowered position, the point 119 of the arm 106 thereof will drop into the notch 120 of plate 81 and prevent said plate 81 from rotating in a counter-clockwise direction to its normal position. (See Fig. 10.) Under these conditions, the gas switch 76 and the motor switch 77 will be locked with their contacts in an open position, the switches 70 and 79 will be locked with their contacts open and it will be impossible for the mechanism to return to the normal position until it is manually re-set. Manual re-setting of the mechanism is provided by thumb tab 121 on the lever 104 which may be reached from the outside of the covering for the control mechanism. By pushing upwardly on said thumb tab 121, arm 106 will release the plate 81 and allow it to return to normal, whereupon the snap action mechanism, including arm 115, will return the plate 113 to its normal position and close the contacts of switches 70 and 79. This safety device therefore requires a manual resetting of the mechanism where improper combustion takes place and serves as a warning to the operator that inspection of the system is desirable.

Another feature of the control mechanism resides in the provision for re-cycling thereof should there be a current interruption during the ignition period—that is, where there is a current interruption when the igniter 74 is energized and the thermal element 75 is deflecting and just before the gas switch 76 and the motor switch 77 are moved to a closed position. When the current in the floating primary winding 68 thus ceases to flow, the said winding 68 will drop and pivot the lever 87 to move the pin 94 in a clockwise direction. Pin 94 will engage the arm 93 and will maintain the switches 76 and 77 in an open circuit position. As the lever 87 pivots, its carries with it the pivoted plate 122 which carries a pin 123 which, as best seen in Fig. 12, rides on a cam surface of the arm 106 to move said arm 106 in a counter-clockwise direction. Arm 106 carries at its top a pin 124 which, in normal operation, supports a plate 125 pivoted about a pivot 126. When the arm 106 is moved in a counter-clockwise direction as aforesaid, the pivoted plate 125 drops down behind the pin 124 to prevent rotation of the arm 106 in a clockwise direction and thereby prevents the point 119 of the arm 106 from dropping into the notch 120 which, if allowed to take place, would require a manual resetting of the control device. This condition is illustrated in Fig. 12 of the drawings. Further movement of the lever 87 under the influence of the downwardly moving floating primary winding 68, to the dotted line position, illustrated in Fig. 12, carries the plate 122 until the bottom thereof contacts with the pin 112. This rotates the plate 113 upon which are mounted the switches 79 and 80 to open the contacts thereof. The cam 117 of said plate 113 rides over the roller carried on pin 116 and is therefore held in position with said plate 113 latched up as illustrated in Fig. 12. The circuit to the thermal element 75 is thus maintained open for the switch 70 is in open circuit position, and the thermal element 75 restores to normal. As said thermal element 75 restores to normal, the plate 81 is rotated counter-clockwise and the arm 115 strikes a pin 127 carried on the plate 125 lifting said plate 125 about its pivot 126 and allowing the pin 124 to move beneath said plate 125, whereupon the arm 106 will assume its normal non-operative position. In addition, the roller carried on pin 116 will snap over the cam 117 of plate 113 and thereby move the switches 70 and 79 to their normally closed position as the thermal element 75 reaches its normal position. The control mechanism is therefore completely re-set by automatic operation and is ready to start another cycle of operation without requiring any manual re-setting thereof. It is, of course, desirable that said control mechanism be required to re-cycle upon a current interruption for otherwise a short current interruption might be sufficient to cool the incandescent ignition means 74 so that, were the gas and pulverized fuel fed to the furnace, there would be a failure of combustion due to the lack of proper incandescence of said ignition means 74.

Means are also provided for completely shutting down the system and automatically starting it up again in a normal manner should there be a current interruption during the running condition of the system; that is, when the motor H was operating to deliver pulverized coal to the furnace under the control of the room thermostat 66, as was above mentioned. Should the current fail during a running condition, it is extremely desirable that the apparatus automatically shut down and then start again for otherwise upon a short interruption of current the primary combustion chamber might become so cool that it would not support combustion, yet the stack operated switches 80 and 101 might still be closed due to the stack temperature. Unless properly cared for, such a condition might be very dangerous.

The normal running condition of the control apparatus is illustrated in Fig. 11. Upon a current interruption, the dropping of the floating primary winding 68 would cause the pin 94, carried on lever 87, to lock the gas switch 76 and the motor switch 77 in an open position. Armature 103 will be released and switches 70 and 79 will be moved to their normally closed position. Let us assume that the stack temperature has fallen insufficiently to open the contacts of switch 101 and the contacts of room temperature responsive switch 66 are closed when the current is restored. Under these conditions, relay coil 102 will be energized the moment the current is restored. This will move the armature 103 which will, in turn, rotate the arm 106 in a counter-clockwise direction so that the top of said arm 106 will engage beneath the tongue of the carrier plate 91. This will effectively lock the carrier plate 91 in a position with the contacts of the gas switch 76 and the motor switch 77 open. Under these conditions, neither gas nor pulverized coal can be supplied to the furnace and the condition will persist until the stack switch 101 has opened, whereupon relay coil 102 will be de-energized and the entire mechanism restored to its normal non-operating position. Thereupon, the said control mechanism will be in a condition to start a new period of operation, if room temperature responsive switch 66 is still closed.

It is thus evident that with the control circuit of Fig. 3 and with the control mechanism of Figs. 9, 10, 11 and 12 a very flexible and very efficient system of automatic control is provided. The incandescent ignition means 74 is energized for a predetermined period as a first incident to starting up of the furnace. After it is heated to incandescence, gas and pulverized fuel are supplied to the furnace to initiate combustion,

the gas being turned on for a very short interval prior to the time the pulverized coal is fed to said furnace. Thereafter, in response to normal combustion conditions, the ignition means 74 is disabled while the gas is supplied for an additional period. The system is so adjusted that the gas supply is continued until the temperature in the preliminary combustion chamber C is sufficient to maintain the combustion of the pulverized coal without the aid of gas. This period is generally sufficient to heat the walls of said preliminary combustion chamber C to approximately 2000 to 2500 degrees Fahrenheit. After this preliminary combustion chamber temperature is reached, the gas is automatically shut off and the pulverized fuel is supplied under the direct control of room temperature responsive thermostat 66. Thus the temperature in the room in which thermostat 66 is placed may be automatically controlled. It is evident that the switch 66 may be controlled by either room air temperature or by water temperature where a hot water system is used or by a combination of the two where said hot water system is employed.

Referring particularly to Fig. 4 of the drawings, there is illustrated another embodiment of my invention which employs the control apparatus of Figs. 9, 10, 11 and 12. This circuit is in general very similar to the circuit of Fig. 3 and attention will be first directed to the features in which they differ. In Fig. 3, there is an individual gas switch 76 and an individual motor switch 77, both of which are mounted on the carrier plate 91. In the system of Fig. 4, a combined gas and motor switch 77' is employed instead of the two switches 76 and 77. This will, of course, mean that the gas valve 21*a*' and the motor H in the system of Fig. 4 will be turned on together in the normal operation of the device. In addition, in the system of Fig. 3 a single stack temperature responsive device was employed to operate switches 101 and 80 though they were operated at different speeds. Such an arrangement may also be employed to operate the switches 101' and 80' in the system of Fig. 4, but I prefer to employ separate thermostatic stack controlled mechanisms 100*a* and 100*b* in the system of said Fig. 4. That is, a relatively fast stack controlled mechanism 100*b* will be employed for operating the switch 101' and a relatively slow stack controlled mechanism 100*a* will be employed for operating the switch 80'. With these differences in mind, the operation of the system of Fig. 4 will be obvious.

Briefly described by using primed reference characters to denote elements in Fig. 4 similar to the same elements in Fig. 3, the normal operation thereof will be as follows:

Upon the closing of the room temperature responsive switch 66' in response to a pre-determined low room temperature, the circuit to the secondary 65' of the transformer 63' will be closed and the normally open contacts of mercury switch 67' will be closed. It is evident, of course, that the primary winding 64' of the transformer 63' is supplied with current from the line conductors 60' and 61' in the latter of which there may be provided a safety switch 62' operated by an excessive pressure or excessive temperature controlling device. Upon the closing of the contacts of said switch 67', the floating primary 68' of constant current transformer 69' will be energized through the normally closed contacts of the mercury switch 70'. Current will therefore flow in the series circuit including the secondary 73' of the transformer 69', the incandescent ignition means 74' and the bi-metallic terminal element 75'. This will result in the lifting of the floating primary winding 68' and the deflection of the thermal element 75', as was above described in connection with the system of Fig. 3. Thermal element 75' upon deflecting a pre-determined amount will close the normally open terminals of the combined gas and motor switch 77' after a pre-determined adjustable time interval during which the ignition means 74' has reached incandescence. On the closing of the contacts of switch 77', the gas valve solenoid 78' will be energized through the contacts of normally closed switches 79' or 80' in parallel, and the motor H which operates the feed mechanism G will start into operation to feed pulverized coal to the furnace. Solenoid 78' will, of course, operate the gas valve 21*a*' to supply gas to the furnace which will be ignited by the ignition means 74' and which ignited gas will ignite the pulverized coal. Combustion will therefore be initiated.

In the system of Fig. 4, it is thus to be noted that the gas valve 21*a*' and the motor H are first energized simultaneously while in the system of Fig. 3 the gas valve 21*a* is open a very short interval before the motor H is started. The system of Fig. 3 therefore has an advantage over that of Fig. 4 in that ignition of the gas ordinarily takes place before the pulverized fuel is supplied to the furnace. However, the system of Fig. 4 is more simple in that a single mercury switch 77' performs the function performed by the two mercury switches 76 and 77 in the system of Fig. 3.

After combustion is initiated, the fast operating stack controlled mechanism 100*b* will close the contacts of the normally open mercury switch 101' in response to combustion temperature for a short period. This opens the contacts of normally closed mercury switches 70' and 79'. The former de-energizes the floating primary winding 68' and allows it to drop with the consequent de-energization of the ignition means 74' and the thermal element 75'. Thermal element 75' therefore starts returning to its normal de-energized position. The gas valve 21*a*' is maintained open for a longer period for, though the contacts of mercury switch 79' are open, the circuit to the solenoid 78' is maintained closed through the closed contacts of mercury switches 80' and 77'. Thus the gas is maintained on with the pulverized coal after the ignition means 74' is shut off and until the preliminary combustion chamber C has had an opportunity to reach a sufficiently high temperature to maintain the combustion of the pulverized coal without the aid of the gas.

After a pre-determined period of combustion, which may be adjusted by operation of the stack temperature responsive device 100*a*, the contacts of mercury switch 80' are moved to an open position whereupon solenoid 78' is de-energized and the gas valve 21*a*' is closed, resulting in the shutting down of the gas supply. The operation of the motor H is thereafter under the direct control of the room temperature responsive switch 66'.

All of the safety features which were described in connection with the system of Fig. 3 fully apply to the system of Fig. 4 and thus need not be repeated. It is thus evident that the control system of Fig. 4 has substantially all the capabilities

of operation of the control system of Fig. 3 which were above set forth except for such distinctions as were specifically mentioned. It is therefore to be understood that the description of the system of Fig. 3 applies with equal force to the system of Fig. 4 except for such differences as are specifically pointed out above.

Obviously those skilled in the art may make various changes in the details and arrangement of parts without departing from the spirit and scope of the invention as defined by the claims hereto appended, and I wish therefore not to be restricted to the precise construction herein disclosed.

Having thus described and shown an embodiment of my invention, what I desire to secure by Letters Patent of the United States is:

1. In a system for burning fluent fuel, the combination with a furnace including a main combustion chamber, of a preliminary combustion chamber within said main combustion chamber, a fluent fuel delivering means including a motor, an electro-magnetic gas valve, ignition means, parallel circuits for said motor, valve and ignition means, a thermostatically controlled switch for closing and opening all of said circuits, a switch individual to said electro-magnetic gas valve, a switch individual to said ignition means, a shunt circuit for said gas valve switch including a combustion temperature controlled switch, and initial temperature responsive means adapted to open the switches individual to said gas valve and ignition means responsive to initial combustion, said shunt circuit combustion temperature controlled switch being effective to maintain said gas valve open for a period after said initial temperature responsive means opens said individual switches and until said preliminary combustion chamber reaches a fluent fuel combustion supporting temperature.

2. In a system for burning a fluent fuel, the combination with a fuel motor and a motor circuit, ignition means and an ignition circuit, and a gas valve and a gas valve circuit, of a thermally controlled switch for energizing all of said circuits in response to a predetermined low temperature, combustion responsive switches for disabling said gas valve and said ignition circuits respectively, said switches being adapted to open said circuits in response to initial combustion, and a shunt circuit for said gas valve switch including a second combustion temperature responsive switch, said second combustion responsive switch opening after said first mentioned combustion temperature responsive switches are operated whereby said gas valve will be operated for a prolonged period beyond the period of energization of said ignition means.

3. In a system for burning a fluent fuel, the combination with a fuel motor, an electro-magnetic gas valve, and ignition means, of parallel circuits for said motor, valve and ignition means, a thermostatically controlled switch for closing and opening all of said circuits, a switch individual to said electro-magnetic gas valve and a switch individual to said ignition means, a shunt circuit for said gas valve switch including a combustion temperature controlled switch, initial combustion responsive means adapted to open the switches individual to said gas valve and ignition means responsive to initial combustion, said shunt circuit combustion temperature controlled switch being effective to maintain said gas valve open for a prolonged period and after said ignition means is rendered inoperative until a high combustion temperature is reached.

4. In a system for burning a fluent fuel, the combination with a fuel motor, an electro-magnetic gas valve, ignition means, of branch circuits individual to each of said elements, a line common to all of said branch circuits, a thermostatically controlled switch in said line, a first switch in the branch circuit including said gas valve, a second switch in the branch circuit including said ignition means, initial combustion responsive means for operating said first and second switches, a shunt circuit for said first switch including a third switch, prolonged combustion responsive means for operating said third switch whereby said gas valve will be maintained open for a prolonged period, and means for discontinuing operation of said system to require manual re-setting thereof when combustion does not begin within a predetermined time after said thermostatically controlled switch is operated.

EARLE V. FRANCIS.