Sept. 27, 1932. A. F. KRAUSE 1,880,178

HEATING APPARATUS

Filed Oct. 27, 1928 6 Sheets-Sheet 1

Fig. 1.

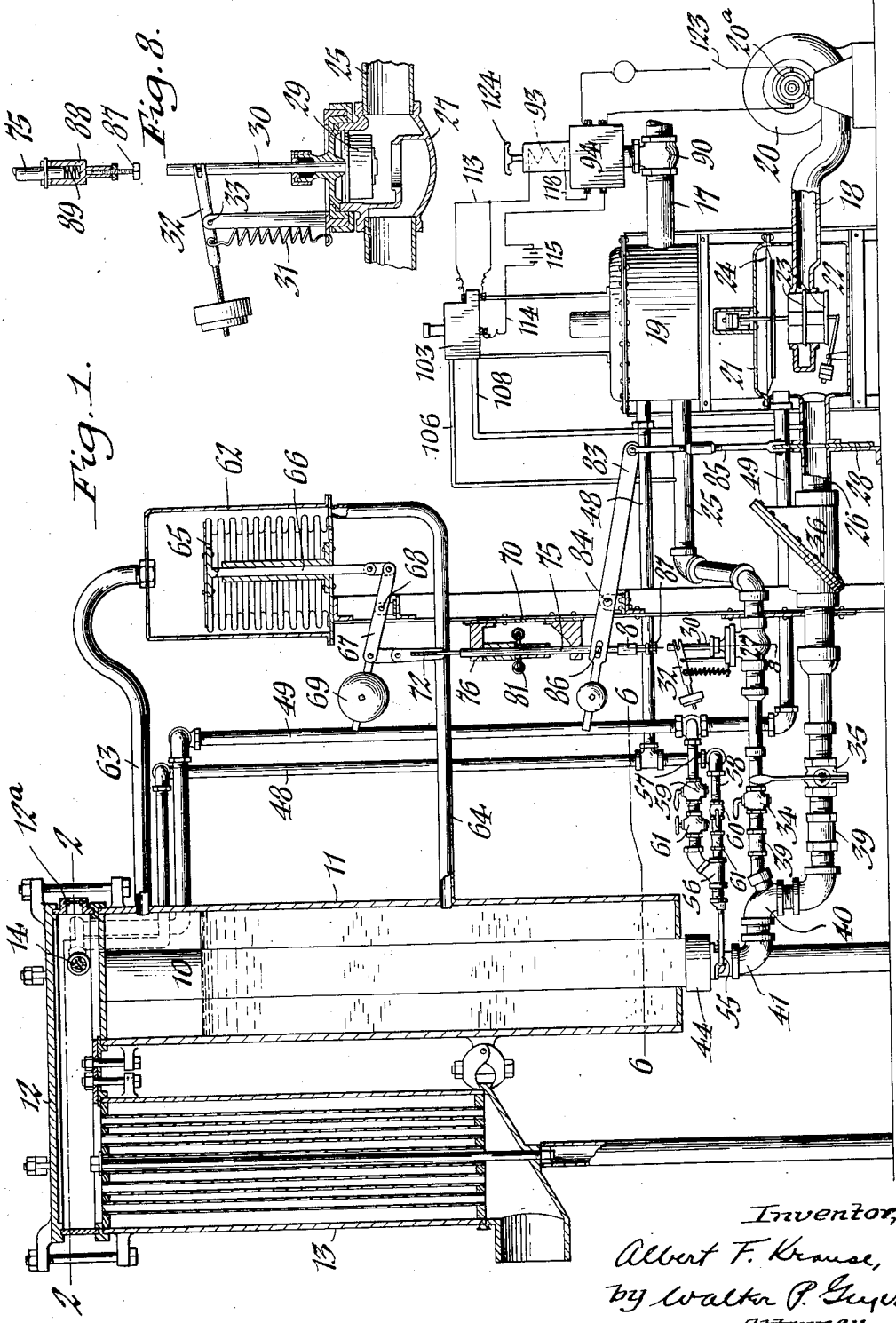


Fig. 8.

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Sept. 27, 1932. A. F. KRAUSE 1,880,178

HEATING APPARATUS

Filed Oct. 27, 1928 6 Sheets-Sheet 2

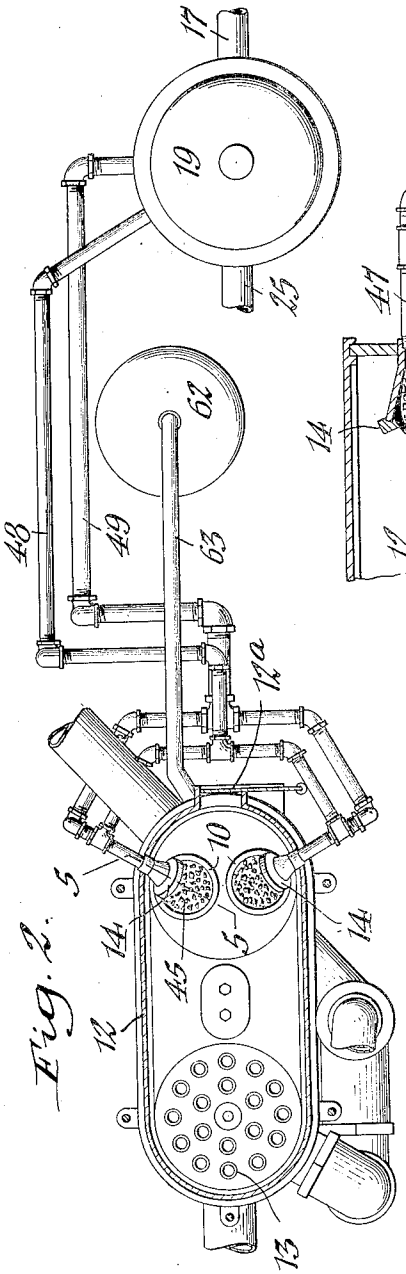


Fig. 2.

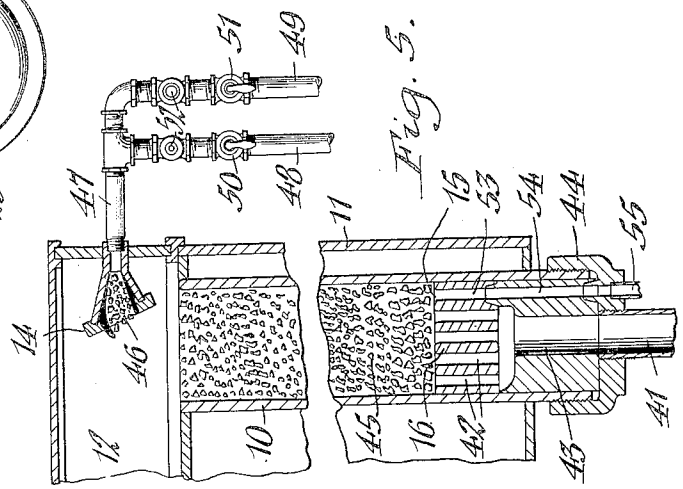


Fig. 5.

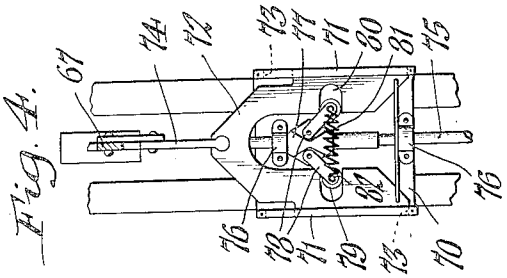


Fig. 4.

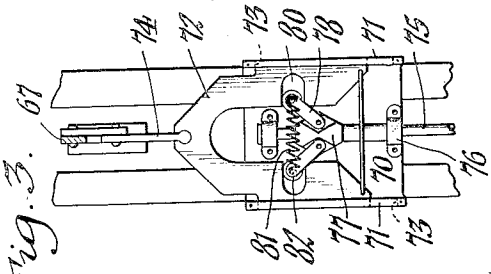


Fig. 3.

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Sept. 27, 1932. A. F. KRAUSE 1,880,178

HEATING APPARATUS

Filed Oct. 27, 1928 6 Sheets-Sheet 3

Fig. 6.

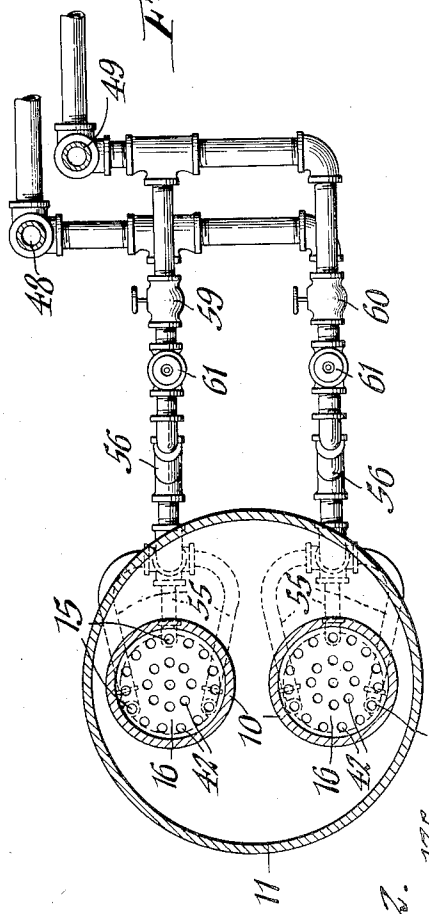


Fig. 7.

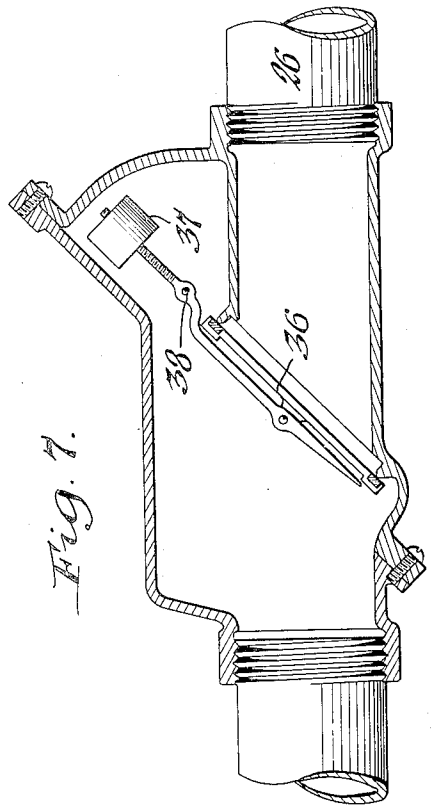
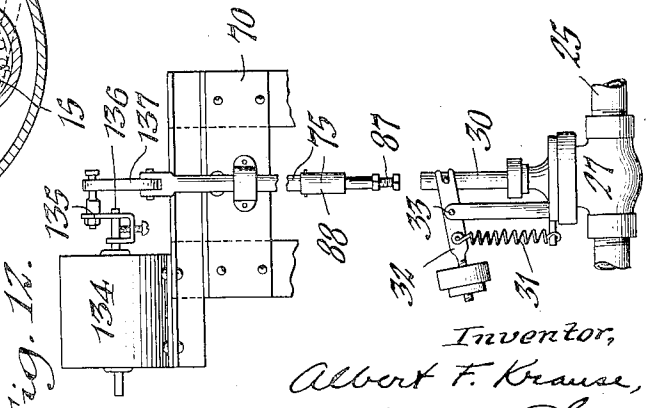


Fig. 12.



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Sept. 27, 1932. A. F. KRAUSE 1,880,178

HEATING APPARATUS

Filed Oct. 27, 1928 6 Sheets-Sheet 4

Fig. 10.

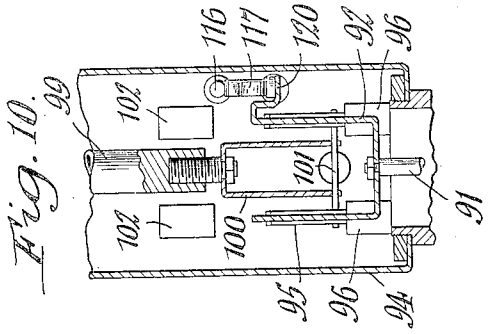
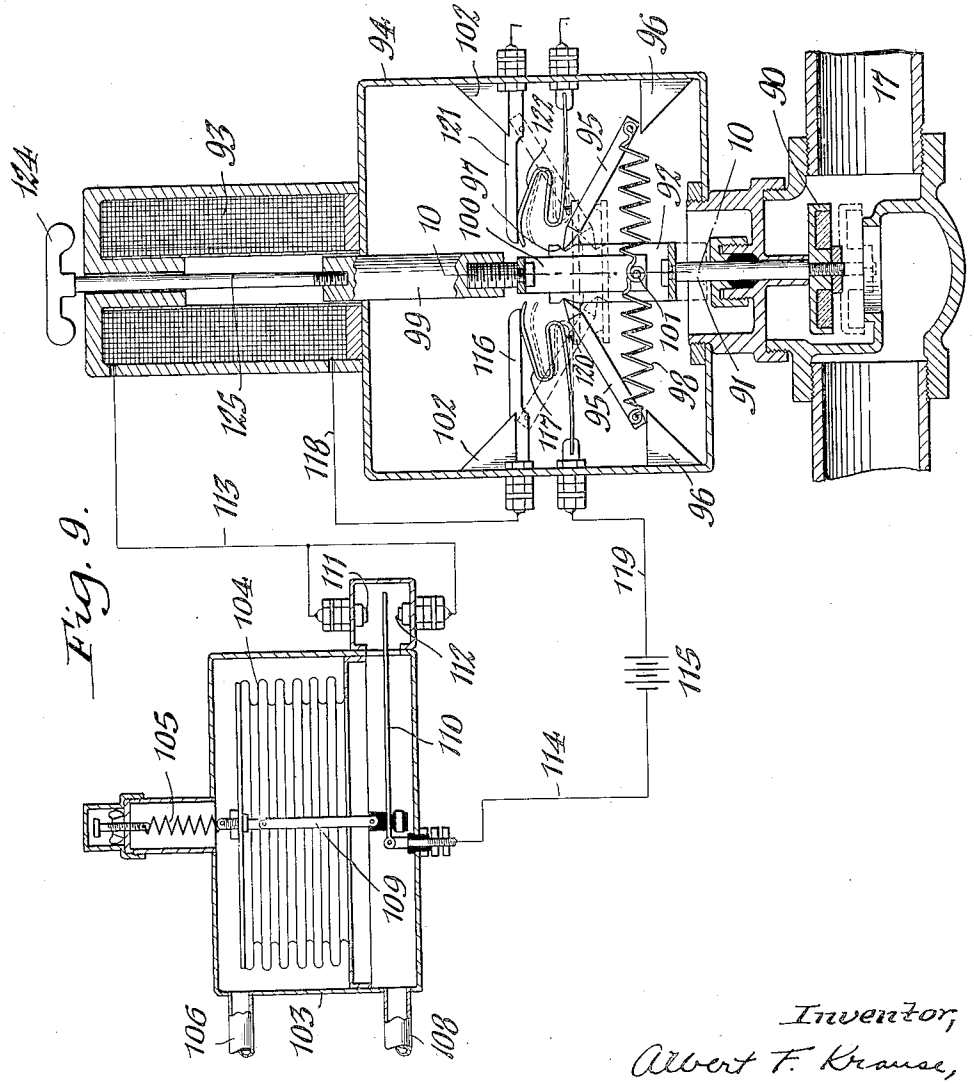


Fig. 9.



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Sept. 27, 1932. A. F. KRAUSE 1,880,178

HEATING APPARATUS

Filed Oct. 27, 1928 6 Sheets-Sheet 5

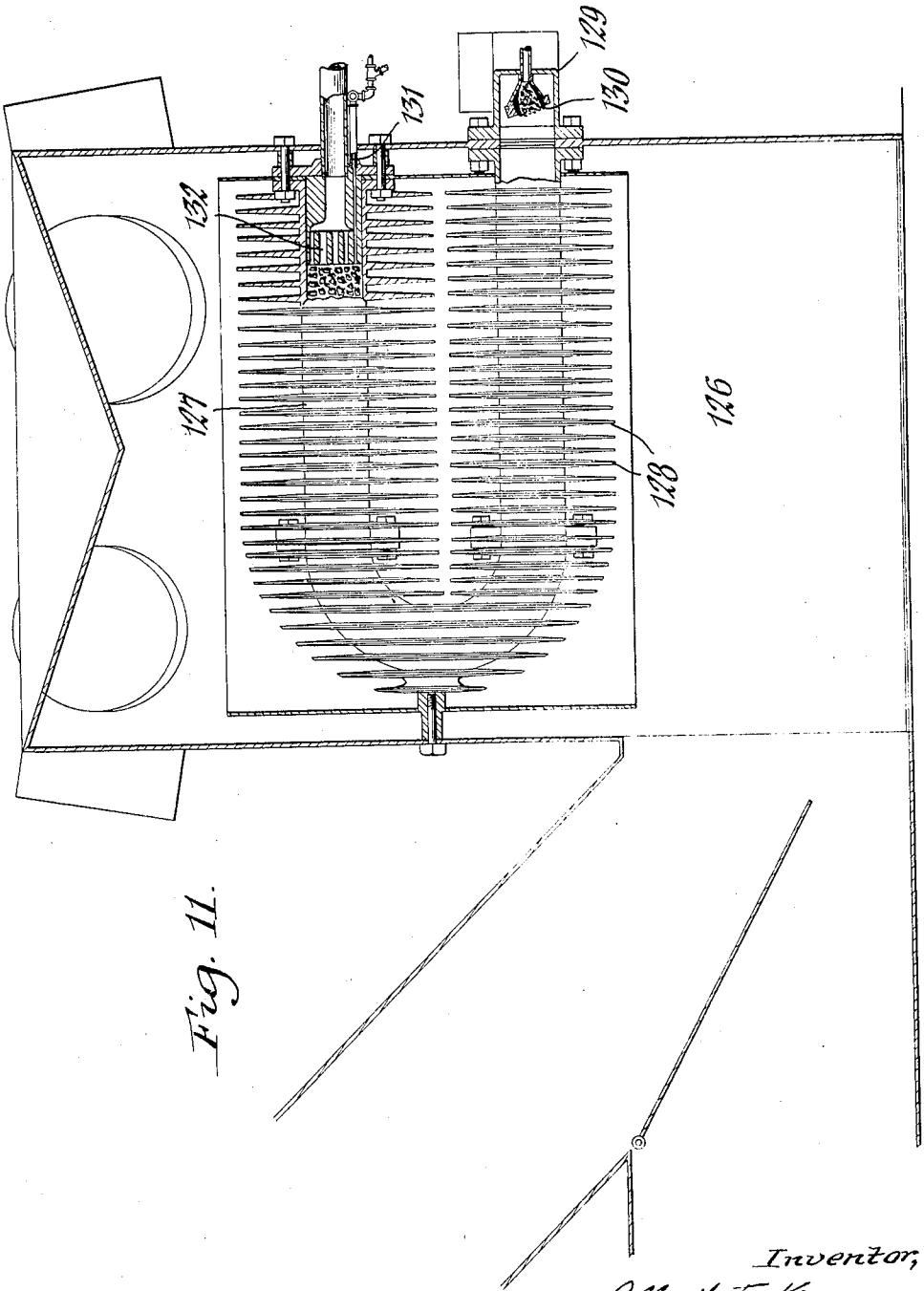


Fig. 11.

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Sept. 27, 1932. A. F. KRAUSE 1,880,178

HEATING APPARATUS

Filed Oct. 27, 1928 6 Sheets-Sheet 6

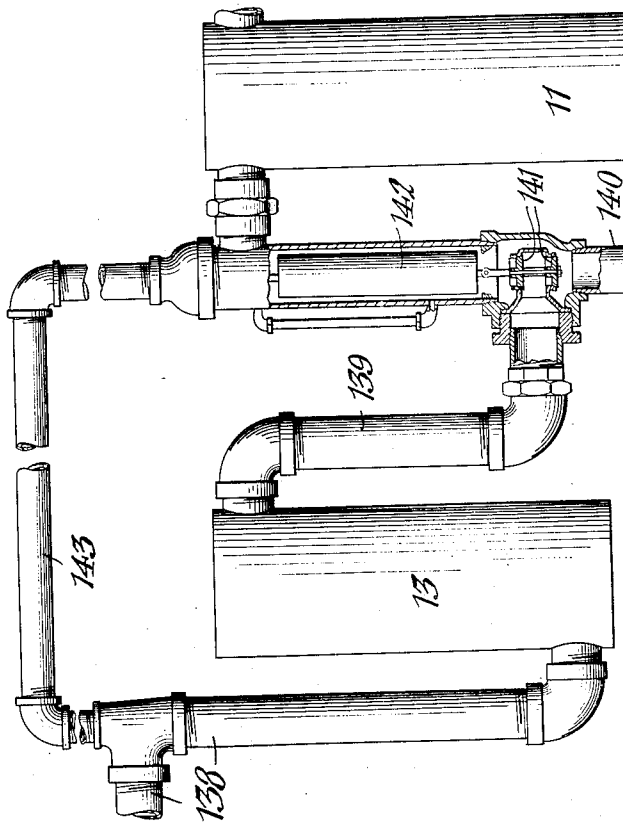


Fig. 14.

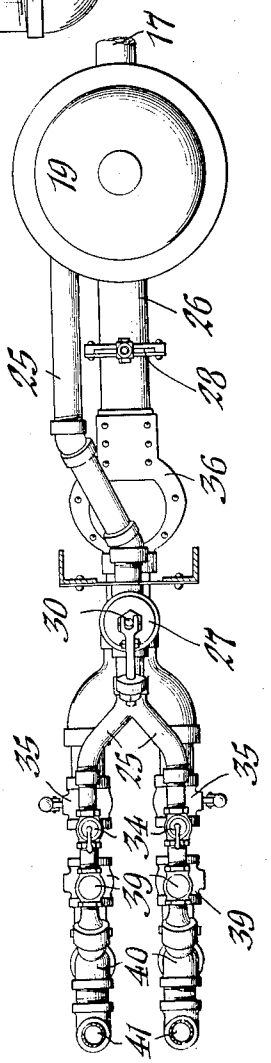


Fig. 13.

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Patented Sept. 27, 1932

1,880,178

UNITED STATES PATENT OFFICE

ALBERT F. KRAUSE, OF BUFFALO, NEW YORK

HEATING APPARATUS

Application filed October 27, 1928. Serial No. 315,525.

This invention relates generally to improvements in heating apparatus, but more particularly to an apparatus employing gas as the heating medium.

It is well known that in all practical methods of combustion a certain amount of excess air above that theoretically required for the complete combustion of the fuel must always be supplied. This excess of air has the effect of decreasing the efficiency of the combustion process by reducing the temperature of the flame and increasing the stack and radiation losses. Also, where convection is depended upon in transmitting the heat of combustion to the furnace or boiler walls, excessively large heat-absorbing surfaces are required, thus increasing the size and weight of the heating plant.

The main object of my invention is the provision of a heating apparatus which is economical and efficient in operation, which requires a minimum of excess air to produce the combustible mixture, and which transmits the heat of combustion to the furnace or boiler walls mostly by conduction and radiation, rather than by convection.

A further object is to so construct the heating apparatus that a much greater rate of heat transfer per unit of area is obtained and whereby a material saving in weight, construction and installation cost is afforded.

A still further object of the invention is the provision of simple and reliable means for effectually controlling the apparatus.

Other objects of the invention reside in certain novel features of construction and arrangement of parts hereafter described and particularly pointed out in the appended claims.

In the accompanying drawings:—

Figure 1 is a sectional side elevation, partly diagrammatic, of a heating apparatus embodying my invention. Figure 2 is a horizontal section taken in the plane of line 2—2, Figure 1. Figures 3 and 4 are detailed views of one form of controlling device for automatically governing the flow of the combustible mixture to the heating elements of the apparatus. Figure 5 is an enlarged fragmentary vertical section taken in the plane of line 5—5, Figure 2. Figure 6 is an enlarged horizontal section on line 6—6, Figure 1. Figure 7 is an enlarged longitudinal section of the check valve disposed in the air line. Figure 8 is an enlarged vertical section of the main gas controlling valve and its associated parts. Figure 9 is a vertical section of the mechanism employed for cutting off the gas supply in the event the air supply should fail or drop below a predetermined pressure. Figure 10 is a transverse vertical section on line 10—10, Figure 9. Figure 11 is a modification showing the invention as applied to a hot air furnace. Figure 12 is a front elevation of a mechanism employed for operating the main gas and air valves when the output of the boiler is controlled by a thermostat. Figure 13 is a top plan view showing the main gas and air line connections to the heating elements. Figure 14 is a side elevation, partly in section showing the water connections between the boiler and preheater together with the valve structure for maintaining the water in the boiler at a suitable level.

Similar characters of reference indicate corresponding parts throughout the several views.

Referring to Figures 1 to 5 inclusive my invention has been shown in connection with a heating apparatus embodying a steam heating boiler designed to maintain a constant steam pressure. In its general organization the apparatus comprises means for maintaining both gas and air supplies at a substantially constant predetermined pressure; a heating chamber immersed in a tank containing the water which it is desired to convert into steam and in communication with the gas and air supplies, said chamber being closed to the atmosphere and having an outlet at its top for the products of combustion and containing granular refractory material which absorbs most of the heat of combustion and transmits it to the water in the tank mostly by conduction and radiation; primary and secondary pilot burners located at the opposite ends of the heating chamber for controlling the ignition of the combustible mixture; and controlling devices for govern-

ing the flow of gas and air to the heating chamber.

The heating chamber, which is indicated generally at 10, is disposed in an upright position in a water tank or boiler 11 depending from the bottom side of a header 12 and into which the open upper end of the heating chamber discharges for conveying the products of combustion to the chimney (not shown). Also depending from this header and communicating therewith is a water heater 13 of any suitable construction, the products of combustion passing through this water heater for the purpose of preheating water which is fed to the tank or boiler 11.

Located in the header 12 adjacent the open upper end of the heating chamber 10 is a primary pilot 14, and located in the lower end of said chamber is a secondary pilot 15 and a main distributor 16 for the combustible mixture of gas and air. Access to the primary pilot 14 for lighting it may be had through a door 12ª applied to one side of the header 12.

The numerals 17 and 18 indicate the supply lines of the gas and air respectively, the gas being delivered under service or other pressure to a pressure regulator 19 of any appropriate construction, and the air being delivered under pressure developed by a fan 20 to a similar pressure regulator 21. This fan may be operated by an electric motor 20ª or other driving unit. These pressure regulators are similar in construction, each including a chamber 22, valves 23 for controlling the passage of gas or air to the corresponding chambers, and a diaphragm 24 for regulating said valves. Connected with the chamber 22 of the gas pressure regulator is a pipe 25, and connected to the corresponding chamber of the air pressure regulator is a pipe 26 which serve to conduct the gas and air to the distributor 16. While two heating chambers have been shown in the drawings, it is to be understood that any number may be employed, and in such cases the gas and air pipes 25, 26 respectively, are provided with corresponding branches leading to the respective heating chambers. The gas pipe is provided with a main controlling valve 27, and the air pipe is provided with a controlling valve 28, the latter being preferably in the form of a slide valve, as shown in Figure 1. The gas controlling valve, as shown in Figure 8, comprises a valve member 29 attached to the lower end of a vertically-movable stem 30, said valve being held in its normally open position by a spring 31 applied to a weighted lever 32 fulcrumed at 33 and joined at one end to the valve stem. Interposed in these two pipes 25, 26 between their operating valves and the heating chamber or chambers are shut-off valves 34, 35, respectively, which are normally open for conducting gas and air to the heating chamber. It is preferable to interpose in the air pipe 26, between the operating valve 28 and the shut-off valve 35, a check valve 36 which is counter-balanced by a weight 37, so positioned relatively to the fulcrum 38 of the valve as to cause the valve to be held closed when the operating valve 28 is in its closed position.

Forwardly of the shut-off valves, 34, 35 in the respective gas and air pipes 25, 26 are fittings 39 which contain fixed or adjustable orifices for predetermining the amount of gas and air delivered as a combustible mixture to the heating chamber or chambers. The outlet ends of the gas and air pipes are connected to a common fitting or mixing tube 40 wherein the gas and air are intimately mixed before being delivered to the pipes 41 leading to the main distributor 16 of the heating chamber or chambers.

The distributor 16, which is mounted in the lower end of its corresponding heating chamber 10, is constructed of refractory material and contains a plurality of vertical openings 42 which open at their upper ends into the heating chamber 10 and at their lower ends into a nozzle 43 likewise of refractory material and communicating with the mixture inlet 41 leading from the fitting 40. As shown in Figure 5, the nozzle is fitted to the lower end of the heating chamber 10 which may be constructed of steel tubing or the like, and the distributor rests on the top side of the nozzle, these parts being held in place by a screw cap 44 through which the outlet end of the mixture conducting pipe 41 is connected. The heating chamber is filled with granular refractory material 45 which may be of irregular shapes to form a sinuous course through which the burning gases and products of combustion travel.

The primary pilot burner 14, which is disposed in the header 12 opposite the upper or discharge end of the corresponding chamber 10, consists of a conical-shaped body preferably lined with refractory material and filled with granular refractory material 46 providing a porous-like mass through which the combustible mixture of air and gas travels. The reduced or contracted inlet end of this pilot is connected to a mixture intake pipe 47 which is connected by branch pipes 48, 49 to the chambers 22 of the gas and air pressure regulators 19 and 21, respectively. The pipes 48, 49 are provided with shut-off valves 50, 51 respectively, and interposed in these pipes between said valves and the mixture intake pipe 47 are fittings 52 which contain fixed or adjustable orifices for governing the amount of gas and air to be admitted to the primary pilot burner 14. It is to be noted that the inlet ends of the gas and air pipes 48, 49 are independently connected to their corresponding sources of supply so that the pilot can operate independently of the main burner element or distributor 16

and are not affected by the operation of the main gas and air valves 27, 28.

The secondary pilot burner 15, which is disposed at the lower end of the heating chamber 10, is preferably formed integral with the distributor 16 and to this end consists of a plurality of registering pilot openings 53, 54 formed in the distributor head 16 and nozzle 43, respectively, for conducting the proper mixture of gas and air to the lower end of the heating chamber. These pilot openings are connected by mixture intake pipes 55 to a common fitting 56 having gas and air pipes 57, 58, respectively, connected thereto. As shown in Figures 1 and 6, the gas and air supply pipes 57, 58 for the secondary pilot 15 are preferably joined to the corresponding intake pipes 48, 49 of the primary pilot 14. Said pipes 57, 58 are provided with shut-off valves 59, 60 and fittings 61 having fixed or adjustable orifices for controlling the amount of gas or air delivered to the fitting 56. In the drawings, three sets of equi-spaced secondary pilot openings 53, 54 are provided for each heating chamber 10 in order to equally distribute their igniting and heating effect over the cross sectional area of such chamber. These secondary pilots serve to maintain a portion of the refractory material 45 in the lower end of the heating chamber (or chambers) in a highly heated state to facilitate the ignition and proper combustion of the main supplies of gas and air when they are turned on by the regulating mechanism hereinafter described.

It is desirable to have both the main operating gas and air valves 27 and 28, respectively, either wide open or fully closed and for this purpose they are preferably automatically actuated and governed by pressure or heat-controlled devices connected with the heating apparatus. Where the heating medium of the apparatus is steam and a sufficiently high predetermined steam pressure is to be maintained, as in the present instance, a steam tight chamber 62 is provided which is connected at its upper end by a pipe 63 with the steam space of the boiler 11 while its lower end is connected by a pipe 64 with the water space of the boiler. Contained within this chamber is a regulator governed by the pressure generated in the boiler and consisting of a flexible, piston-like diaphragm 65 having a stem 66 extending downwardly therefrom which is pivoted to one arm of a vertically-swinging lever 67 fulcrumed at 68 and having an adjustable weight 69 mounted on its other arm, as shown in Figure 1, for varying the pressure required to actuate said diaphragm. The valves 27, 28 are actuated by this regulator through the medium of a snap-action device, shown in Figures 1, 3 and 4, which preferably comprises an upright frame 70 having guide channels or ways 71 at its opposite sides for receiving the corresponding edges of a vertically movable slide-plate 72 which is limited in its movement in opposite directions by suitable stops 73 arranged at the upper and lower ends of the guide channels. This slide-plate is connected by a link 74 with the weighted arm of the lever 67. Movable relatively to the plate 72 is a push rod 75 slidable vertically in brackets 76 on the frame 70 and operatively associated at its lower end to the valves 27, 28 to first shut off the air valve 28 and then the gas valve 27 on its downward movement, and on its upward movement to first turn on the gas valve and then the air valve. The purpose of operating the valves in this order is to avoid any danger of blowing out the gas flames of the primary and secondary pilots 14 and 15, respectively. Fastened to the push-rod 75 is a yoke 77 to which are fulcrumed oppositely-disposed links 78 connected with the slide-plate 72 by rollers 79 movable horizontally in inwardly opening notches 80, formed in the opposing inner edges of said plate. One or more tension springs 81 is connected at its ends to the supporting pins 82 of the rollers.

In the operation of this snap-action device, assuming the valves 27, 28 to be open, as the piston-like diaphragm 65 is lowered or compressed by a predetermined pressure in the boiler 11, the slide-plate 72 is moved upwardly, causing the roller-bearing links 78 to swing outwardly and upwardly to a point slightly above the horizontal dead-center line of their fulcrums, when the tension springs 81 act to suddenly snap said links inwardly to force the plate against its upper stops 73 and the push-rod downwardly to effect the closing of the valves.

The connections from the snap-action device to the valves 27, 28 are arranged as before stated, to successively close the air and gas lines, respectively, on the downward movement of the push-rod 75 and to successively open the gas and air lines, respectively, on the upward movement of said push-rod. To this end, a vertically swinging rock lever 83 is fulcrumed at 84 below the slide-plate 72, the longer arm being joined by a link 85 with the air-operating valve 28 and the shorter arm being joined by a pin 86 with the push-rod. The latter is in axial alinement with the stem 30 of the gas-operating valve 27 and its lower end is provided with an adjustable foot 87 which is adapted to abut against the top of the valve-stem to close the valve. As shown in Figure 8, this foot may consist of a bolt fitted in the end of a yieldable member 88 slidably mounted on the lower end of the push-rod and housing a spring 89 which acts as a cushion during the closing action of the valve by the push-rod and prevents injury to the valve-seat.

Means are provided for automatically shutting off the supply line of gas to the pressure regulator 19 in the event that the gas or

air supply should fail, this means being so constructed that should the gas or air pressure drop below a predetermined point, the excess gas or air pressure would act to cut off the gas supply to the regulator. The preferred means for accomplishing this result is shown in Figures 1 and 9, wherein 90 indicates a controlling valve interposed in the gas supply line 17 and having a stem 91 rising therefrom. To the upper end of this stem is attached a yoke 92 forming part of a snap-action device which, in the present instance, is electrically controlled by a solenoid 93 mounted on the upper side of an open frame 94 supported from the valve-body and in turn governed by a pressure regulating device communicating with both the gas and air chamber 22 of the corresponding pressure regulators, so that when either the gas pressure or air pressure drops below a predetermined point, an electric circuit is closed which operates the solenoid and causes the snap-action device to come into play to close the gas valve. The latter is normally held in its open position by opposing inclined levers 95 resting at their lower ends on flanges or abutments 96 secured to the frame 94, while their upper ends are pointed to interlock with V-shaped notches 97 formed in the opposing edges of the yoke 92. A coil spring 98 connecting the lower ends of these levers to each other serves to maintain them in engagement with the yoke. Depending from the core or plunger 99 of the solenoid is a second yoke 100 which extends between the side walls of the first-named yoke 92 and which carries a pin 101 engaging the intermediate portion of the spring 98, so that as the solenoid-core is raised or lowered the connection of the spring to said yoke 100 causes the levers 95 to swing in a corresponding direction about their pointed ends as a fulcrum. When swung upwardly to the dotted line position shown in Figure 9, wherein the controlling valve 90 is closed, the outer ends of the levers contact with flanges or abutments 102 also mounted on the frame 94.

The pressure responsive device, which controls the circuit of the solenoid 93 to automatically effect the closing of the valve 90 through the snap-action mechanism just described whenever the gas or air pressures drop below a predetermined value, may be of any suitable construction, that shown in Figure 9 of the drawings being preferably and consisting of an air-tight chamber 103 containing a flexible piston-like diaphragm 104 exposed to the gas pressure on one side and to the air pressure on the other side and adjustably controlled by a tension spring 105. Connected to the upper end of this chamber to exert a downward pressure on the diaphragm is a gas pipe 106 joined to the corresponding pipe 25 leading from the gas pressure regulator 19 and connected to the lower end of said chamber to exert an upward pressure on the diaphragm is an air pipe 108 joined to the corresponding pipe 26 leading from the air pressure regulator 21, both of these connections being made between the pressure regulating chambers and the main gas and air valves. A stem 109 connected to this diaphragm serves to operate a vertically-swinging switch arm or lever 110 included in the circuit of the solenoid and adapted to engage one or the other of the contacts 111, 112, connected by a common wire 113 with one end of the solenoid-coil while the switch arm is connected by a wire 114 with one terminal of the battery 115 or other source of current supply.

The snap-action mechanism governed by the solenoid has companion switch elements 116 and 117 included in the circuit of the solenoid, the switch element 116 being in the form of a fixed post connected by a wire 118 with the other end of the solenoid-coil, and the other element 117 being in the form of a spring connected by a wire 119 with the other terminal of the battery and having its free end, in the normally closed position of the switch, arranged to bear at one side against the companion switch-post 116 and at its opposite side against a flange 120 extending laterally from the yoke 92 of the valve-stem 91. This switch acts as a circuit breaker after the solenoid has been actuated to close the gas valve 90; in this position the yieldable switch element 117 is moved out of contact with its companion post 116 by the lowering of the valve-yoke 92, thereby conserving the battery power.

If desired, the circuit of the fan motor 20^a may likewise be broken whenever the gas valve is closed and for this purpose another pair of switch elements 121, 122, similar to those indicated at 116, 117, are provided which are included in the circuit of said motor and which are broken or opened simultaneously with the breaking of the solenoid switch-contacts 116, 117. The circuit of the fan motor also includes a controlling switch 123.

For the purpose of restoring the solenoid-core to its normal lowered position and at the same time reopen the gas-controlling valve 90 governed by it and close the solenoid switch-contacts 116, 117, and the fan motor switch-contacts 121, 122, a handle 124 is connected to said solenoid-core through the medium of a connecting rod 125.

In the normal operation of the apparatus, the gas-controlling valve 90 and its associated parts assume the position shown by full lines in Figure 9, wherein the switch contacts 116, 117 and 121, 122 are closed and the switch arm 110 is disposed in a neutral state between the contacts 111, 112, the solenoid-circuit being normally broken at this point. As the gas or air pressure in the regulating device 103 predominates, the difference in these pressures will accordingly actuate the switch arm

110 up or down, in either case closing the solenoid circuit and automatically shifting the gas valve to its closed position through the medium of the snap-action device contained within the frame 94. After the snap-action device functions to close the valve, the circuit is broken at the contacts 116, 117 and 121, 122 to break the solenoid circuit and the motor circuit of the air supply fan 20, respectively, whereby both the gas and air supplies are cut off.

The operation of the apparatus is as follows:—

Assume, at the outset, that the various valves in the system are closed. To start up the apparatus, close the switch 123 of the fan motor circuit and close the gas-controlling valve 90 by manually actuating the snap-action mechanism in the frame 94 by depressing the handle 124 attached to the solenoid-core 99 and holding the same in this position until the gas and air pressures have attained their proper value. This act will start the fan-motor 20^a and when the pressures are correct or substantially balanced the switch-lever 110 will be automatically held clear of its companion contacts 111, 112, placing the system in readiness for starting.

The door 12^a of the header 12 in which the primary pilot (or pilots) 14 is arranged is now opened, the gas valve 50 leading to the pilot is opened and the latter ignited in the customary manner, after which the valve 51 controlling the air supply to this pilot is opened so as to deliver the requisite amount of air for combustion, it being understood that the orifices in the fittings 52 of the gas and air pilot lines 48, 49 have been properly adjusted to deliver the predetermined proportions of gas and air required for combustion. The construction of this primary pilot is such that the combustible mixture burns at and slightly within its conical body, heating its contained refractory 46 to incandescence so as to ignite any unburnt mixture coming in contact with it and at the same time protect the pilot-flame against blowing out by drafts or other disturbances. After the primary pilot is burning properly the door 12^a may be closed.

The secondary pilot (or pilots) 15, which is located in the lower end of the corresponding heating chamber 10, is then brought into operation by turning on its gas valve 60, the gas passing upwardly through this chamber being ignited when it comes in contact with the previously lighted companion primary pilot 14 disposed over the outlet end of said chamber. The air valve 59 of the secondary pilot is then turned on and the flame gradually recedes downwardly through the refractory material 45 in the heating chamber and finally continues to burn just above the distributor 16. Upon now turning on the gas and air valves 34, 35, which control the passage of these elements to the distributor, the resultant combustible mixture travels through the distributor-openings 42 into the lower end of the heating chamber where it is ignited by the secondary pilot, bringing the contents of said chamber to a high degree of heat, it having been found in practice that the entire combustion takes place in the lower portion of the heating chamber immediately above the distributor. In passing upwardly through the plurality of sinuous courses or fine streams defined by the irregular-shaped particles of refractory material in the heating chamber, the hot gases rapidly give up a large part of their heat to such particles which become incandescent and which in turn give up their heat to the walls of the heating chamber largely by radiation and conduction rather than by convection. The small irregular spaces formed between the particles of refractory material cause the hot gases to travel through the heating chamber in different directions with a high rate of heat transfer. The heat left in the gases after passing through the heating chamber or chambers is utilized to preheat the water in the heater 13, from whence they escape into the chimney, thereby obtaining a lower stack temperature and a greater efficiency.

In Figure 11 my invention has been shown as adapted for application to a hot air furnace indicated by the numeral 126. In this form of the invention, the heating element consists of a U-shaped tube or conduit 127 suitably supported in the combustion chamber of the furnace and having heat-radiating fins 128 thereon. Communicating with one end of the heating element and disposed on the exterior of the furnace is a casing 129 which houses the primary pilot 130 identical in construction with the pilot 14 and disposed within the other end of said heating element is the secondary pilot 131 and main distributor 132, which parts are identical with those of the boiler arranged as heretofore described and are operated and controlled in the same manner.

It is to be noted that the passages for the combustible mixture are so proportioned that the velocity of the mixture will exceed the flame velocity until such mixture reaches the heat-absorbing material in the heating chamber.

When the predetermined steam pressure in the boiler is obtained, the main gas and air operating valves 27, 28 are automatically closed through the medium of the snap-action device illustrated in Figures 3 and 4 and controlled by the pressure regulator 65, the air valve being closed first as hereinbefore explained, when the pressure again drops, these valves are automatically opened through the same mechanism, the gas valve being opened first.

It will be understood, that when the heat-

ing load is light, a single heating element is sufficient, while as the load is increased two or more heating elements may be used which are all controlled by the main operating gas and air valves 27, 28.

From the foregoing it will be noted that by this construction and arrangement of parts, no secondary air, that is air not mixed with the fuel in the burner, is used in the combustion process, thereby greatly increasing the efficiency of the apparatus.

When my invention is used in connection with a heating system employing vapor (low pressure steam) or hot water as a distributing element and when a thermostatic or similar control is used on a steam system, the chamber 62 with its appurtenances and connections shown in Figures 1, 3 and 4 may be omitted. Instead, reference being had to Figure 12, the push rod 75 is operated directly by a motor 134 of the type commonly used in connection with thermostats in heating systems. This motor is usually provided with a crank 135 fixed on its shaft 136 which makes one-half a revolution each time it is actuated by a thermostat (not shown), when the trend of the temperature in the space where the thermostat is located requires reversal. In this type of motor, the crank, when at rest, is at one or the other of its two positions (up or down) and the push rod 75 may be actuated by it through the medium of a link 137 or similar device.

In Figure 14 I have shown the water connections of the boiler and the means for maintaining the water in the boiler at a predetermined height, the numeral 130 indicating the return or feed pipe connected to the lower end of the preheater 13, and 139 the outlet pipe connected at one end to the upper end of the preheater and at its other end to a pipe 140 arranged alongside the boiler 11 and connected thereto above and below its water line. Contained within the pipe 140 is a valve 141 controlled by a float 142 which serves to maintain the water in the boiler at a definite height, the proper functioning of this valve being enhanced by an equalizer pipe 143 disposed between the steam or vapor space above the float 142 and the pipe line 138. In a hot water system, the float-controlled valve is eliminated and the pipe 139 is connected directly to the lower end of the boiler.

I claim as my invention:—

1. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing tube connected to the mixture inlet of said heating element, main gas and air supply pipes joined to said mixing tube for delivering predetermined amounts of gas and air thereto, operating valves in said supply pipes, a heat-responsive device, a slide-plate connected to said device and movable thereby in opposite directions, a push-rod actuated by said slide-plate, and connections between said push-rod and said valves for controlling their opening and closing movements.

2. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing tube connected to the mixture inlet of said heating element, main gas and air supply pipes joined to said mixing tube for delivering predetermined amounts of gas and air thereto, operating valves in said supply pipes, a heat-responsive device, a slide-plate connected to said device and movable thereby in opposite directions, and a push-rod actuated by said plate for directly controlling the opening and closing of one of said valves and for indirectly controlling the other valve.

3. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing tube connected to the mixture inlet of said heating element, main gas and air supply pipes joined to said mixing tube for delivering predetermined amounts of gas and air thereto, operating valves in said supply pipes, a heat-responsive device, a slide-plate connected to said device and movable thereby in opposite directions, a push-rod actuated by said plate for directly controlling the opening and closing of the gas-valve, and a connection between said push-rod and said air-valve for controlling the latter.

4. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing tube connected to the mixture inlet of said heating element, main gas and air supply pipes joined to said mixing tube for delivering predetermined amounts of gas and air thereto, operating valves in said supply pipes, a heat-responsive device, a slide-plate connected to said device and movable thereby in opposite directions, a push-rod actuated by said plate for directly controlling the opening and closing of the gas-valve, and a rock lever for controlling the air-valve, said lever being connected to the push-rod to be actuated thereby, the opening of the air-valve occurring after the opening of the gas-valve and vice versa on the closing movement.

5. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing chamber connected to the mixture inlet of said heating element, supply pipes leading to said mixing cham-

ber for delivering predetermined amounts of gas and air thereto, a power-driven fan to which said air pipe is connected, a pressure regulator in communication with the gas and air pipes, a gas shut-off valve in said gas supply pipe, and means governed by the pressure regulator for automatically closing said gas-valve and for rendering the power-driven fan inoperative whenever the difference in pressures in the gas and air pipes reaches a predetermined point.

6. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing tube connected to the mixture inlet of said heating element, main gas and air supply pipes joined to said mixing tube for delivering predetermined amounts of gas and air thereto, operating valves in said supply pipes, a power driven fan to which said air pipe is connected a shut-off valve in said gas pipe in advance of its operating valve, a pressure regulator in communication with the gas and air pipes, heat-controlled devices for automatically controlling said operating valves, and means governed by the pressure regulator for automatically closing said gas shut-off valve and rendering the power-driven fan inoperative whenever the difference in pressures in the gas and air pipes reaches a predetermined point.

7. A heating apparatus of the character described, comprising one or more heating elements closed to the atmosphere at their inlet ends and each having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a combustion space located between said inlet and said outlet, a heat-absorbing material in said combustion space, means for igniting the combustible mixture, a mixing tube discharging into said inlet, gas and air supply tubes leading into said mixing tube, and means connected with said gas and air tubes to effect a constant predetermined ratio of gas and air to the mixing tube.

8. A heating apparatus of the character described, comprising one or more heating elements closed to the atmosphere at their inlet ends and each having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a combustion space located between said inlet and said outlet, a meat-absorbing material in said combustion space, means for igniting the combustible mixtures, a mixing tube discharging into said inlet, gas and air supply tubes leading into said mixing tube, and constant pressure regulators interposed in said gas and air supply tubes.

9. In a heating apparatus, the combination of a heating chamber closed to the atmosphere and having an outlet for the products of combustion, a gas burner for said heating chamber having a mixture inlet for gas and air, separate supply lines leading to said mixture inlet for delivering gas and air thereto under pressure and at a constant predetermined ratio, and pressure regulators interposed in said gas and air lines, respectively.

10. In a heating apparatus, the combination of a heating chamber closed to the atmosphere and having an outlet for the products of combustion, a gas burner for said heating chamber having a mixture inlet for gas and air, separate supply lines leading to said mixture inlet for delivering gas and air thereto under pressure and at a constant predetermined ratio, pressure regulators interposed in said gas and air lines, respectively, operating valves in the gas and air lines between the mixture inlet of the heating chamber and said pressure regulators, and means for automatically controlling said valves.

11. In a heating apparatus, the combination of a heating chamber having a main gas burner, a pilot burner and an outlet for the products of combustion, separate gas and air supply pipes leading to said main burner and said pilot burner, means interposed in said pipe lines for maintaining a constant ratio of gas and air delivery to the main burner and pilot, and means in the main burner supply pipes for automatically controlling the admission of gas and air thereto.

12. In a heating apparatus, the combination of a heating chamber closed to the atmosphere at its inlet end and having a main gas burner, a pilot burner and an outlet for the products of combustion, said main burner and said pilot burner being arranged at the inlet end of said chamber, separate gas and air supply pipes leading to said main burner and said pilot burner, and means interposed in said pipe lines for maintaining a constant ratio of gas and air delivery to the main burner and the pilot burner.

13. In a heating apparatus, the combination of a heating chamber, a heat-absorbing material therein, a main gas burner, a primary pilot burner disposed in the upper end of said chamber above the heat-absorbing material, a secondary pilot burner disposed in the lower end of said chamber adjacent the heat-absorbing material, separate gas and air supply pipes leading to said main burner and said pilot burners, means interposed in said pipe lines for maintaining a constant ratio of gas and air delivery to the main burner and pilot burners, and means in the main burner supply pipes for automatically controlling the admission of gas and air thereto.

14. A heating apparatus of the character described, comprising a heating element having an inlet for a combustible mixture of gas and air and an outlet for the products of combustion, a mixing tube connected to the mixture inlet of said heating element, main gas

and air supply pipes joined to said mixing tube for delivering predetermined amounts of gas and air thereto, operating valves in said supply pipes, a heat-responsive device, a part arranged to be actuated in opposite directions by said device, and actuating means for said valves operatively connected to said part and including a push rod disposed in operative relation to the gas valve and a rock lever connected to the air valve, the rock lever being movable in response to the action of the push rod.

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