Jan. 17, 1933. C. B. GRADY 1,894,270

FURNACE

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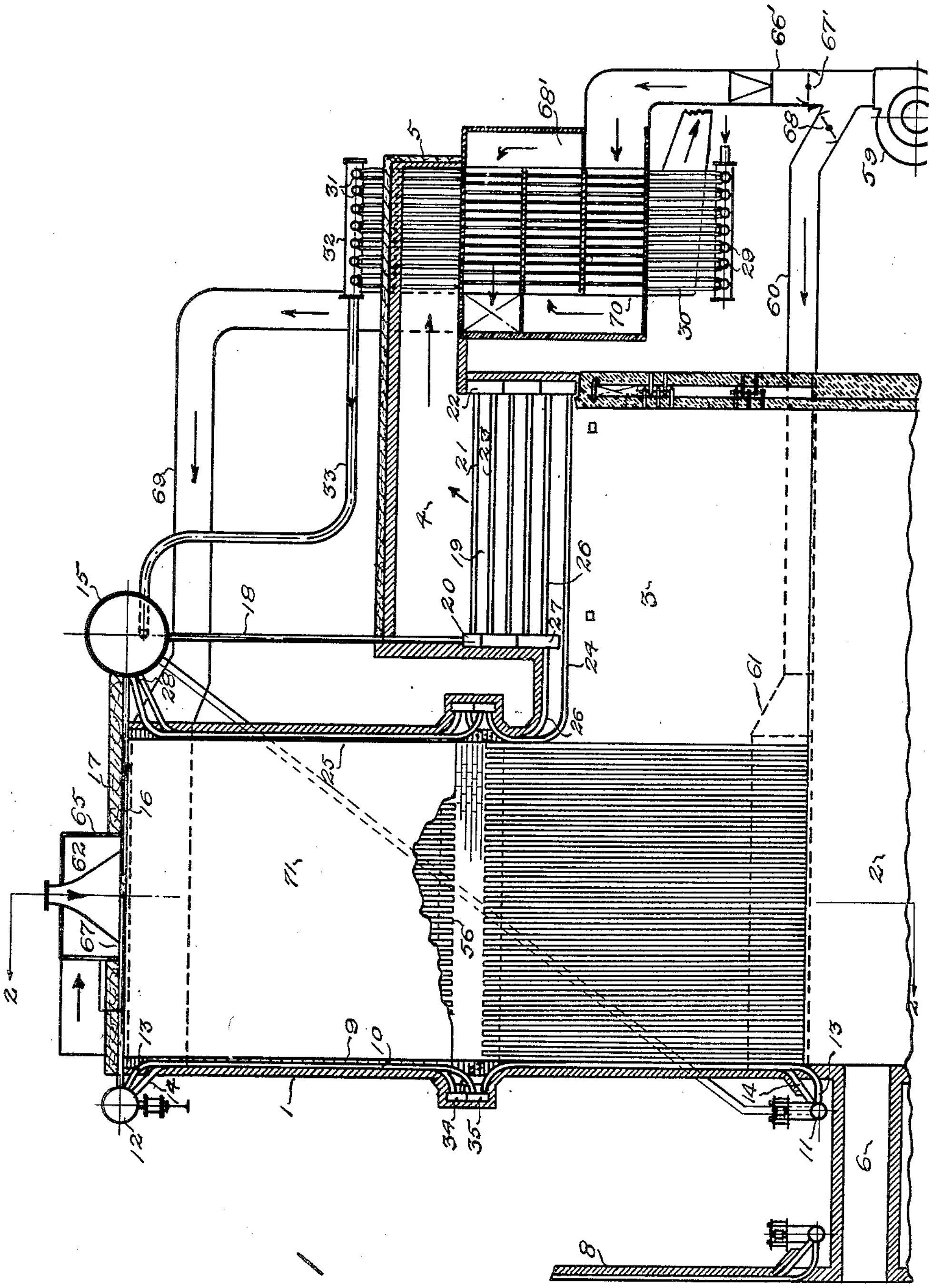

Fig. 1

INVENTOR
CHARLES B. GRADY
BY
George L. Engelhart
ATTORNEY

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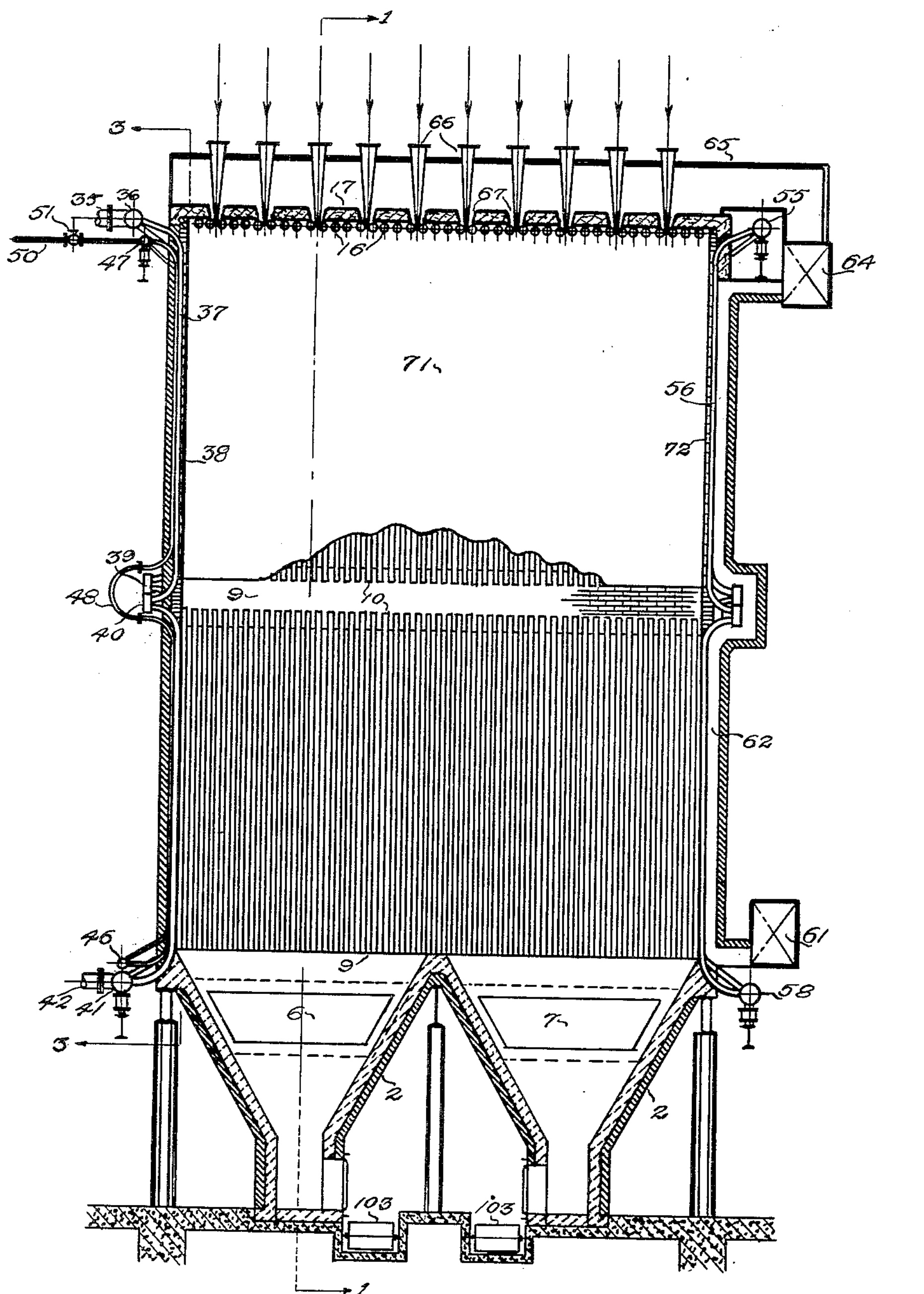

Fig. 2

INVENTOR
CHARLES B. GRADY
BY
[signature]
ATTORNEY

Jan. 17, 1933. C. B. GRADY 1,894,270

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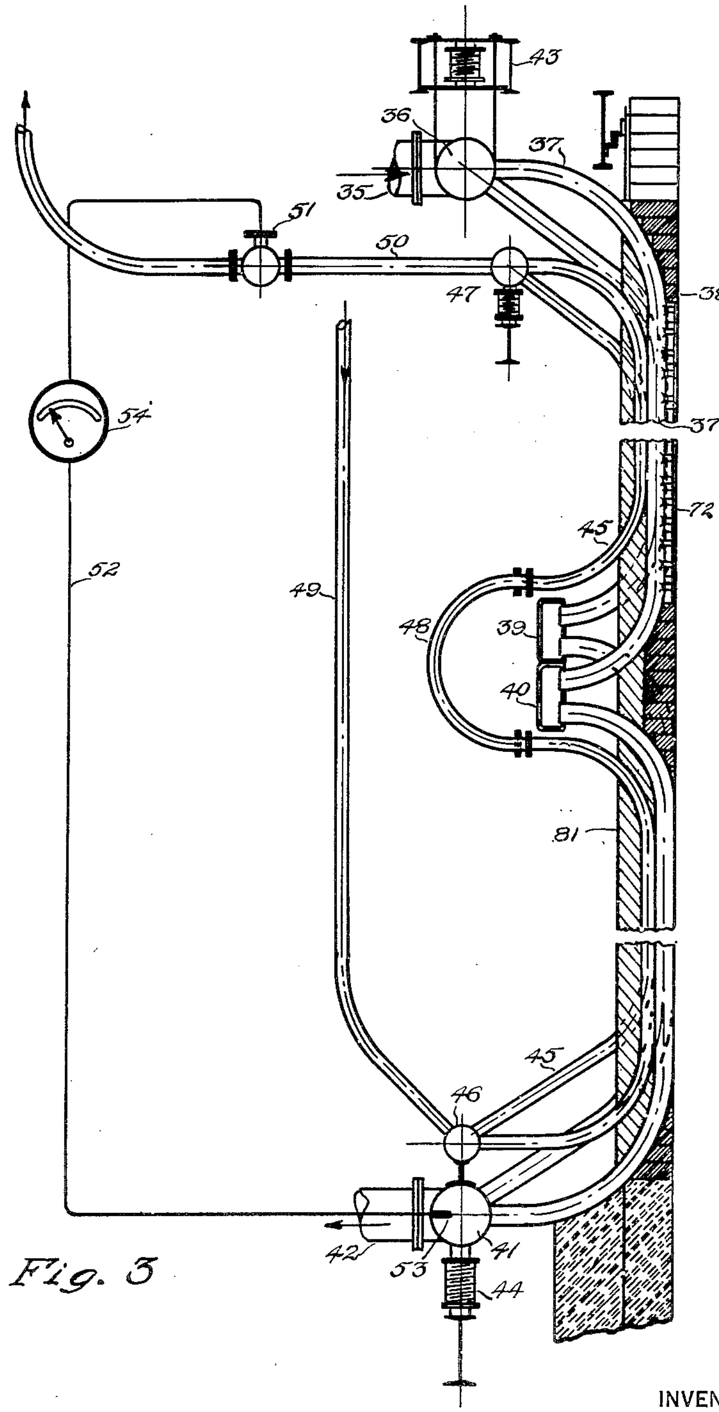

Fig. 3

INVENTOR
CHARLES B. GRADY
BY
George [signature]
ATTORNEY

Jan. 17, 1933. C. B. GRADY 1,894,270

FURNACE

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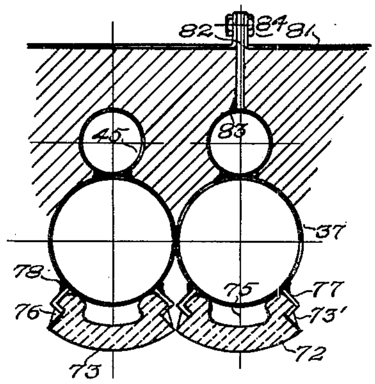

Fig. 4

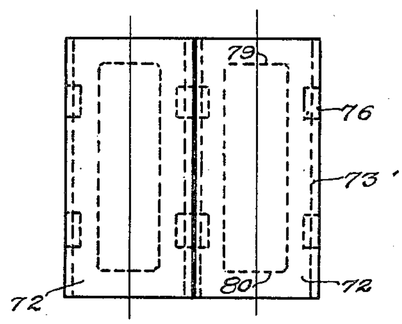

Fig. 5

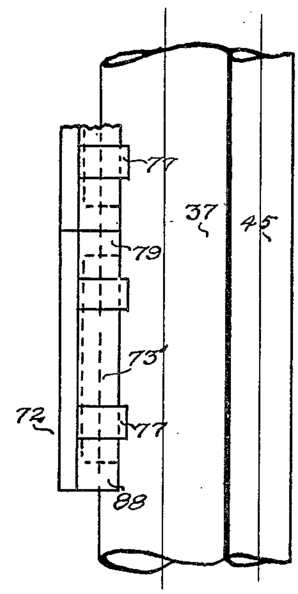

Fig. 6

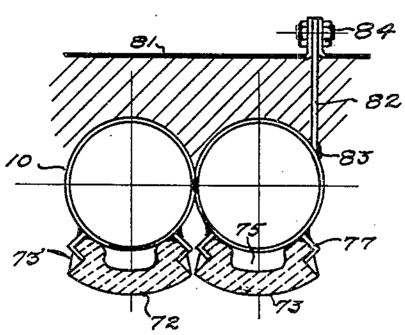

Fig. 7

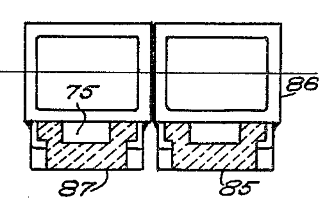

Fig 8

INVENTOR
CHARLES B. GRADY
BY
George Engelhard
ATTORNEY

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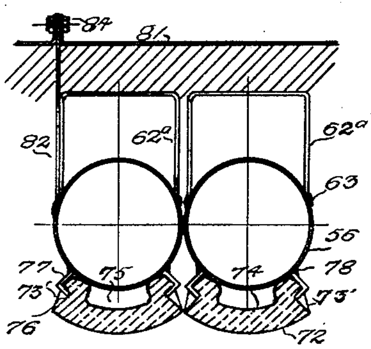

Fig. 10

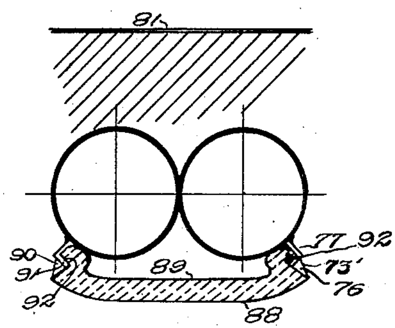

Fig. 9

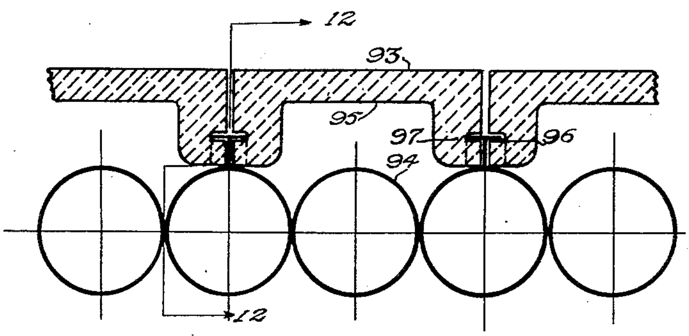

Fig. 11

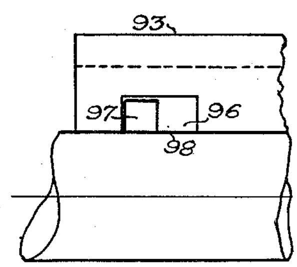

Fig. 12

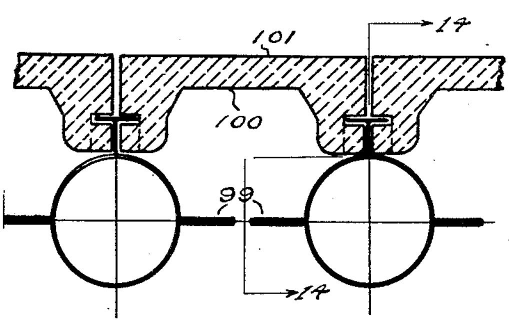

Fig. 13

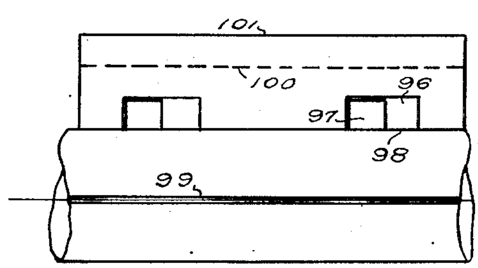

Fig. 14

INVENTOR
CHARLES B. GRADY
BY
George L. Longellow (signature)
ATTORNEY

Patented Jan. 17, 1933 1,894,270

UNITED STATES PATENT OFFICE

CHARLES B. GRADY, OF WEST ORANGE, NEW JERSEY, ASSIGNOR TO METROPOLITAN ENGINEERING COMPANY, A CORPORATION OF NEW YORK

FURNACE

Application filed March 10, 1927. Serial No. 174,315.

This invention relates to furnaces and more particularly to furnaces having walls lined with heat absorbing elements and to a method of controlling or regulating the temperatures of the liquid or vapor carried by certain of the elements.

The objects of the invention are to provide a furnace of relatively low cost capable of sustained high rates of combustion with clear flame conditions, with a maximum exposure of fluid carrying elements to the effect of radiant heat, with effcient circulation of the fluid carried by the elements, an arrangement equally well applicable to operation at high or low pressure, and a simple and positive control of the temperatures of the fluid carried by certain of the elements.

Although the invention is applicable to the distillation of oils and for kindred purposes, it will be described in its application to the generation of steam and control of superheated and reheated steam temperatures. In general, the control of temperature of fluid passing through the heat absorbing tubes is effected by causing a second fluid to pass at a variable rate through ducts or tubes in contact with or adjacent to those carrying the fluid, the temperature of which is to be controlled. Thus, as a specific example, saturated steam may be conducted from the boiler steam drum and caused to flow downwardly through tubes exposed to the effect of radiant heat and discharged as superheated steam into a steam header. Simultaneously, boiler water may be conducted from a drum and caused to flow upwardly through tubes in contact with, and preferably in the rear of the steam tubes and discharged through headers and uptakes into the steam drum, the rate of flow of water being under valve control, the valve being located, preferably, in the uptake. As the superheat temperature tends to rise, the valve is opened to permit a more rapid flow of water whereby greater quantities of heat will be transferred to the water, and conversely, as superheat decreases the valve will be partially closed to decrease the rate of flow. The control is preferably effected automatically and to this end the valve is operated by means of a circuit including a thermostat in the path of flow of the superheated steam and an indicating and regulating thermometer. This method of control has the advantage of simplicity, uniform temperature regardless of deposits of foreign matter on the tube surfaces and variable furnace conditions affecting radiation and convection currents, and permitting operation at high superheat or reheat temperatures with safety. The control fluid may be air to be preheated for combustion purposes and in this case control is accomplished automatically by a circuit including the fan motor control or a damper in the air supply conduit, and a thermostat in the path of the superheated or reheated steam.

Although the invention contemplates the use of various fuels, the furnace is particularly adapted for pulverized fuel firing and comprises a combustion chamber, the inner walls of which are provided with fluid carrying elements preferably arranged vertically to provide efficient circulation, and closely to expose a maximum surface to the effect of radiant heat. In the primary combustion zone or combustion chamber proper, the fluid carrying elements are protected from the destructive effect of the flame by blocks or tiles of refractory material of high fusion temperature and high heat conductivity. These blocks are preferably made of silicon carbide (carborundum) although aluminum oxide and graphite and fire clay compositions may be employed with favorable results. The blocks are supported by the elements or tubes and are so designed that their inner surfaces are spaced from the tube surfaces to prevent chilling of the block and darkening the inner surface during operation whereby the heat transfer to the tubes is increased by reradiation from the incandescent block. The transfer of heat is primarily by radiation but partly by conduction through that portion of the block in contact with the tube surface. The exposed surfaces of the blocks serve to reflect and re-radiate heat to the fuel and flame stream to accelerate combustion, maintain ignition and to complete combustion of the solid constituents of the fuel, to produce very hot, clear flame conditions in the vicinity of the burners, and in addition, to reflect and re-radiate heat to the exposed tube surfaces in the relatively cooler portion of the combustion chamber beyond the refractory lining.

Due to the hot, transparent combustion condition, the maximum heat transfer to the fluid carrying tubes is by radiation as the sensible heat of the gases will be relatively low; the heat of these gases is absorbed by transfer to fluid carrying tubes positioned across the path of the gases leaving the combustion chamber. In the preferred embodiment, the combustion chamber is fired downwardly and the flow of the products of combustion reverses in the lower portion of the chamber and is directed upwardly around boiler heating surfaces. During the reversal of the gas stream the solid constituents are precipitated and disposed of by suitable ash handling apparatus. The last named boiler surfaces are preferably in the form of a boiler so designed that the flow of liquid will be downwardly from a drum, serially through banks of tubes, the last bank of which discharges the fluid into the lower ends of tubes exposed to radiant heat in the combustion chamber and connected to the same drum at their upper ends. A final heat recovery from the gases leaving the boiler may be effected by any desired type of air heater or economizer, preferably a combined air heater and economizer described in detail hereinafter and particularly in my copending application Serial No. 163,065, filed January 24, 1927.

In view of the high temperature combustion conditions and the provision made for efficient circulation, the boiler may be operated at high pressures, such as 1350 pounds, and in view of the means for controlling superheat, the temperature of the steam may be maintained at 900° F. In view of these advantages, the steam at this pressure may be employed to operate a high pressure turbine and as exhausted therefrom may be returned to reheater tubing exposed in the combustion chamber at a lower pressure, for example 350 pounds. The temperature of the reheated steam may also be maintained at 900° F. and is controlled in accordance with the method above described and employed to drive the usual low pressure turbines.

In the preferred application of my invention to steam boiler firing, the high pressure boilers and turbines will be operated continuously at normal load; the low pressure turbines at approximately half load, and peak loads met by increasing the rate of combustion and diverting a portion of the hot gases through a low pressure boiler located in the same setting or one adjacent to the high pressure boiler furnace. This latter method is adaptable to existing low pressure power stations and in this case the existing boiler settings may be employed as low pressure steam generating units by providing suitable connecting flues to the high pressure boiler furnace.

It is to be understood that my apparatus and method is of equal utility as an oil still and in this case the fluid passing through the temperature control tubing may be oil to be re-boiled, air to be preheated for combustion purposes in the still or water to be converted into steam for plant purposes.

Further objects and advantages of my invention will become apparent from the following description and drawings which illustrate a preferred embodiment of my invention as applied to boiler furnaces and in which:

Fig. 1 is a sectional elevation of a complete furnace, taken on line 1—1 of Fig. 2,

Fig. 2 is a section on line 2—2 of Fig. 1,

Fig. 3 is a detail elevation, partly diagrammatic on line 3—3 of Fig. 2,

Fig. 4 is a cross section of a portion of a wall on an enlarged scale,

Fig. 5 is a front elevation showing the arrangement of the blocks,

Fig. 6 is a detail side elevation,

Fig. 7 is a cross section of a portion of a simple combustion chamber wall,

Fig. 8 is a cross section showing a modified form of blocks adaptable to tubes of rectangular cross section,

Fig. 9 is a cross sectional detail showing a modified form of block,

Fig. 10 is a cross sectional detail showing a modified form of control duct,

Fig. 11 is a cross sectional detail of a modified form of block,

Fig. 12 is a view taken on line 12—12 of Fig. 11,

Fig. 13 is a cross sectional detail of a modified form adaptable to "fin-wall" tubes, and

Fig. 14 is a view on line 14—14 of Fig. 13.

Referring to the drawings, and more particularly to Figs. 1 and 2, the apparatus is seen to consist of a high vertical chamber 1 of rectangular cross section terminating in a double hopper-bottom 2, and opening laterally into a gas outlet chamber 3, provided with an outlet flue 4 leading to an air heater and economizer 5 to be described in detail hereinafter. Flues 6 and 7 connect the lower portion of the chamber 1 with a boiler setting indicated conventionally at 8.

The preferred arrangement of heat absorbing surfaces contemplates a maximum exposure to the effect of radiant heat and to that end, the walls of the vertical chamber 1 are lined with fluid carrying tubes arranged vertically on close centers. The structure of the circulatory system is as follows: On the side wall 9, which has the greatest area, fluid carrying tubes 10 are connected at their lower ends to inlet header 11, and at their upper ends to collecting header 12. As the tubes are preferably arranged as closely as their expansion will permit, the header connections are staggered and alternate tubes are bent to conform therewith as indicated, for example at 13 and 14 at both the upper and lower ends of the tubes, although the tubes may be arranged in pairs with each pair terminating in Y connections leading to the headers, if desired. The header 12 is connected to the drum 15 by tubes 16 which cool and support the arch 17, these tubes enter the drum at approximately water level and may be inclined if desired. Circulation through the system above described is completed through the usual down-takes, not shown, from the drum 15 to the inlet header 11, it being also contemplated that feed water may be admitted to the inlet header 11. Down-takes 18 enter the drum 15 at or near the bottom and serve to conduct the water to the convection surfaces 19 disposed across the path of the gases leaving the gas outlet chamber 3. These surfaces are so arranged that the flow is serially through each bank. The water discharging from the down-takes 18 into the header 20, passes through the tubes 21 of the upper bank, into the return header 22, then through the tubes 23 of the next bank etc. The tubes of each bank are properly spaced to allow a free passage of the gas. The tubes 24 of the lowest bank are extended inwardly and are bent upwardly and line the inner surface of the wall 25. Tubes 26 are connected to return header 27 and are extended upwardly along the wall 25 alternating with the tubes 24, to provide a maximum of heat absorbing surface along this wall. The tubes 24 and 26 terminate in the drum 15, as shown at 28.

Feed water is preferably first passed through an economizer such as that shown at 5, and which is disclosed in detail in my co-pending application Serial No. 163,065, filed January 24, 1927. In this arrangement, the water enters the headers 29, and passes upwardly through tubes 30, into headers 31, collecting header 32, from which it passes to the drew 15 through up-take 33, entering the drum below water level.

In order to provide for more efficient circulation, to avoid single tubes of excessive length, to facilitate tube renewals and to permit a simple installation of a combustion chamber which will be described in detail hereinafter, the tubes lining the side walls of the vertical chamber 1 are not continuous from top to bottom but are connected to return bends or headers on each side of the chamber. In view of the close spacing of the tubes, two headers such as 34 and 35 are positioned across each wall, the tubes being connected alternately as shown.

The simple arrangement of vertical, straight tubes and the single drum is well adapted for high pressures, but it is to be understood that the invention is not limited to the use of a single large drum. The arrangement permits wide variations in rating and may be operated at high or low ratings with uniform efficiency and uniform superheat temperatures.

Superheat temperature may be controlled and maintained at any predetermined degree by the arrangement shown in detail in Figs. 2 and 3. Steam from the drum passes through the connection 35, shown on an enlarged scale in Fig. 3, and enters the inlet header 36, from which it passes downwardly through the tubes 37 lining the inner surface of the side wall 38 of the vertical chamber 1. These tubes are also spaced closely and are likewise interrupted by return bends or headers 39 and 40, in the same manner as the side wall boiler tubing and for the same reasons. The lower ends of the superheater tubes terminate in the collecting header 41, from which the superheated steam is discharged into the main steam header 42 leading, for instance, to the turbines. As the wall structure adjacent to the tubes is carried by the tubes, the headers 36 and 41 are yieldingly supported as shown at 43 and 44. Tubes 45 are positioned preferably in the rear of and in contact with the tubes 37, and are preferably welded thereto. The tubes 45 terminate at their lower ends in the inlet header 46 and at their upper ends in collecting header 47. In view of the relatively lower temperatures of the fluid passed through these tubes, simple return bends 48 may be provided to pass around the headers 39 and 40.

Water from the drum 15 is delivered to the inlet header 46 through down-take 49 and flows upwardly through the tubes 45 in heat exchange relation to the tubes 37 and the fluid therein, and is returned to the drum 15 at approximately water level through the up-take 50, the arrangement forming a simple circulatory system.

In order to control the rate of flow of water or other liquid through tubes 45, a valve 51, is positioned, preferably in the uptake 50. This valve may be manually controlled in accordance with variations in superheat temperature but I prefer to control its position automatically. To this end, the valve 51 may be any suitable electrically operated type, connected in a circuit 52 including a thermostat 53 located preferably in the path of the discharging steam in the collecting header 41, and an indicating and regulating thermometer of any suitable type, such as that indicated conventionally at 54.

The control of temperature of fluid carried by tubes exposed to heat can be accomplished similarly by the use of air, an example being shown in Figs. 1 and 2, in the arrangement for controlling re-heated steam temperature. In this case the air used for control purposes is employed advantageously as preheated combustion air. Referring first to Fig. 2, exhaust steam from a high pressure turbine, or from the high pressure turbine stage enters the apparatus through the inlet header 55 and passes downwardly through the tubes 56 lining the inner surface of the wall 57 and is ultimately discharged into the collecting header 58 from which it is conducted to the low pressure turbine or stage.

The control air may be forced under pressure of the blast fan 59 into branch conduit 60, and discharged into air header 61. The air then passes upwardly through ducts 62 in the rear of tubes 56 in heat exchange relation with the tubes and the liquid carried therein. Ducts 62 may be a simple hollow wall arrangement in which provision is made to prevent leakage of air between the tubes and into the vertical chamber, but I prefer to employ ducts such as shown in Fig. 10 which comprise channels 62ᵃ, the side edges of which are welded to the tubes 56 as at 63 to form a closed duct. The air discharges from the ducts into a cross duct or air header 64, and is then led through ducts 65 surrounding the burners 66. The air is finally discharged into the chamber through orifices 67 surrounding the burners 66.

The rate of flow of the air passing in heat exchange relation with the tubes 56 may be controlled manually by means of the damper 68 in the branch duct 60, or if automatic control is desired, the damper 68 may be operated by a thermostat and regulating and indicating thermometer similarly to the arrangement shown in Fig. 3, or a separate blast fan may be operated by the same means with variable speed motor control.

Additional preheated combustion air is supplied to the burner duct 65 by the following apparatus. Air from the blast fan is forced under pressure through the duct 66′ and, under control of damper 67′ passes into and through the air heater section 68′ of the combined air heater and economizer 5, from which it is discharged into the duct 65 through the duct 69. Within the air heater section 68′ the air passes transversely one or more times around the vertical waste gas ducts 70 which surround the water tubes 30.

Within the upper portion of the vertical chamber 1, I provide a combustion chamber 71 formed of blocks or tiles of high heat conductivity such as silicon carbide (carborundum). The blocks are so supported and formed that a portion of their inner surfaces are out of contact with the tube surfaces to prevent too rapid cooling of the material and to provide for radiation from the inner surfaces to the tube surfaces. A portion of the blocks, preferably the side edges contact with the tube surface and it follows that the heat transfer is accomplished partly by radiation and partly by conduction. The function of the combustion chamber is to protect the tube surfaces from the direct effect of combustion, to reflect and radiate heat to the fuel and flame stream to increase flame temperature and accelerate combustion, and to permit radiation to the tubes as distinguished from mere conduction through refractory walls of the prior art, all as described in detail hereinafter.

The structure of the blocks or tiles and the provision made for supporting them on the tubes are shown in detail in Figs. 4 to 14 inclusive. First, with reference to Figs. 4 to 7 inclusive and Fig. 10 which illustrate the preferred form of block, the blocks 72 are shown with smooth surfaces 73 on the furnace side curved approximately to conform to the curvature of the tube protected thereby. The side edges 73′ of the blocks are symmetrical and are extended inwardly beyond the inner surface 74 to provide an open space 75 through which heat will be radiated to the tube surface. The side edges 73′ slope inwardly along or approaching the radius of curvature of the block to extend the front surface beyond the recesses 76 formed in the side edges to accommodate the supporting members or clips 77. The clips 77 are thus protected from the flame and the impingement of products of combustion. The clips are preferably welded to the tubes as shown at 78, although it is to be understood that the clips may be secured to other wall members. The upper and lower edges of the block may be extended inwardly as shown at 79 and 80 in Figs. 5 and 6 to prevent the entrance of foreign matter into the space 75. The blocks 72 are supported solely by the tubes and independently of one another by means of the clips 77 to avoid rapid deterioration due to weight and may be secured to the tubes before the latter are installed in the furnace. The spaces between the fluid carrying tubes and the exterior plates 81 are filled with any suitable insulating refractory such as magnesite and the entire structure supported by the tubes by members 82 welded to the tubes as at 83, and secured to the plates 81 as at 84.

In Fig. 8, I have shown a block 85 adaptable to ducts 86 of rectangular cross section, in this case the blocks present a uniform flat surface 87 on the furnace side.

The block 88 shown in Fig. 9 is similar to the block 72 excepting that it is designed to be supported by clips welded to opposite sides of the tubes and has the advantage of an inner radiating surface 89 of larger area. This type of block need not be secured to the tubes before erection but may be positioned after the tubes have been installed. In order that this may be facilitated, the recesses 90 have a vertical width at least twice the width of the clips 91 and the lower half of the recess extends through the edge of the block, as shown in dotted lines at 92, in order that the clips may enter the recesses and the blocks secured by lowering them a distance equal to the width of a clip.

This type of recess is shown in connection with the modification shown in Figs. 11 and 12, being illustrated more clearly in Fig. 12. In the modification shown in these figures, the block 93 is so supported that every third tube 94 receives heat solely by radiation from a flat inner surface 95. The recesses 96 are at least twice the width of the clips 97, the lower half extending through the edge of the block as at 98, so that the block may be lowered into position and secured as above described, and removed by raising and disengaging the clips.

In Figs. 13 and 14, I have shown a modification adaptable to walls lined with the so-called "fin-tubes", the structure being substantially the same as the arrangement shown in Figs. 11 and 12, excepting that the fins 99 occupy the space taken by the tubes 94 and receive heat radiated from the inner surface 100 of the block 101. This arrangement is particularly advantageous in that the tubes and fins are protected from the direct effect of combustion.

The operation of the apparatus is as follows: Fuel is delivered through the multiplicity of burners 66 in thin streams across the entire width of the combustion chamber, each stream being surrounded by the air streams entering through the orifices 62 and intimate mixture follows. A very high temperature combustion zone is established in the vicinity of the burners and below them due to the radiant heat reflected and radiated to the fuel and flame stream by the refractory walls of the combustion chamber 71, and it follows that the solid constituents of the fuel are consumed very quickly and the ash is rendered incandescent. Due to the clear flame condition existing in the combustion chamber, radiation to the blocks forming the side walls is not obstructed and a very rapid transfer of heat to the tubes is effected by radiation from the inner surfaces of the incandescent blocks, especially in view of the remarkably high heat conductivity of silicon carbide. The combustion chamber serves the additional function of radiating heat to the arch tubes 16 and to exposed portions of the side wall tubes below the combustion chamber. The heat transfer from the products of combustion to the exposed portions of the tubes is almost entirely by radiation and it follows that as every provision has been made to take advantage of heat transfer by radiation, the sensible heat of the gases entering the outlet chamber 3 will be relatively low.

As the gas stream reverses its direction and passes upwardly and outwardly into the chamber 3, the ash descends to the hoppers 2 and is ultimately discharged by suitable ash conveyors indicated at 103.

As the temperature of the gases leaving the outlet chamber 3 is relatively low, the convection surfaces 19 are adequate and a final heat recovery is effected in the air heater and economizer 5.

It will be assumed that it is desired to maintain a superheat temperature of 900° F. as an example. The surface area of the tubes should be somewhat in excess of the theoretical area necessary to obtain this temperature to provide for decreases in heat transfers at low ratings and the effect of foreign matter accumulating on the surfaces. Water is permitted to flow at all times through the control tubes 45 to absorb a portion of the heat transferred to the superheater tubes, the rate of flow governing the quantity of heat thus transferred. As the temperature tends to rise the valve 51 is opened more widely and likewise if temperature decreases, the valve is partially closed. Automatic operation is effected in a simple manner by the circuit 52 by merely setting the regulating thermometer to operate at the desired temperature. The control of reheated steam temperature is similarly accomplished by controlling the flow of air, but it is within the contemplated scope of my invention to effect this control with liquid in the same manner as I have disclosed in connection with the control of superheated steam temperature.

The apparatus may be employed as a steam generating unit operating at high and low pressures simultaneously in the following manner: The high pressure steam, for example at 1350 pounds, will be employed to operate a high pressure turbine at full load, the exhaust steam at low pressure, for instance 350 pounds will be returned to the apparatus and reheated to 900° F., and returned to the low pressure stage of the turbine but if the plant equipment permits, to a larger turbine operating at approximately half load. In this latter case the high pressure turbine will operate continuously at full load and when peaks are to be met, they will be carried with the low pressure turbines in the following manner: A very small part of the gases of combustion will be permitted to flow continuously through the flues 6 and 7 to the low pressure boiler indicated at 8, the quantity being merely enough to keep the boiler steaming, then to meet the peak loads, the quantity of fuel and air admitted to the main furnace will be increased and a greater quantity of the hot gases diverted to the low pressure boiler. The low pressure steam is thus supplemented and the peaks carried on the low pressure units.

The boiler and furnace wall structure described are not claimed in the present application, but are covered in a separate divisional application filed May 20, 1931, Ser. No.

538,666. Various modifications of the described apparatus and process may be made by those skilled in the art without departing from the invention as defined in the following claims.

I claim:

1. In an apparatus of the class described, the combination of a plurality of heat absorbing, fluid carrying elements exposed to radiant heat, means for causing a flow of fluid through the elements, means for flowing a second fluid shielded from said radiant heat in heat exchange relation to the first fluid within said elements, and means for controlling the rate of flow of the second fluid to vary the quantity of heat transferred to it from the first fluid.

2. In an apparatus of the class described, the combination of a plurality of heat absorbing, fluid carrying elements exposed to radiant heat, means for causing a flow of fluid through the elements, means for causing a second fluid shielded from said radiant heat to flow in heat exchange relation to the first fluid within said elements, and temperature controlled means for varying the rate of flow of the second fluid.

3. In an apparatus of the class described, the combination of a plurality of fluid carrying, heat absorbing elements exposed to radiant heat, means for causing a flow of fluid through the elements, means for causing a second fluid shielded from said radiant heat to flow in heat exchange relation to the first fluid within said elements, means for controlling the rate of flow of the second fluid and means operable by the temperature of the first fluid for operating the controlling means.

4. In an apparatus of the class described, the combination of a plurality of heat absorbing, fluid carrying elements exposed to radiant heat, means for causing a flow of fluid through the elements, means for flowing a second fluid shielded from said radiant heat in heat exchange relation to the first fluid within said elements, and a valve for controlling the rate of flow of the second fluid to vary the quantity of heat transferred to it from the first fluid.

5. In an apparatus of the class described, the combination of a plurality of heat absorbing, fluid carrying elements exposed to radiant heat, means for causing a flow of fluid through the elements, means for flowing a second fluid shielded from said radiant heat in heat exchange relation to the first fluid within said elements, a valve arranged for controlling the rate of flow of the second fluid, and means operable by the temperature of the first fluid for operating the valve.

6. In an apparatus of the class described, the combination of a plurality of heat absorbing tubes exposed to radiant heat, the tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, means for causing a second fluid shielded from said radiant heat to flow adjacent to portions of said tubes exposed to radiant heat and in heat exchange relation to the fluid carried thereby, a valve arranged for controlling the rate of flow of the second fluid, and temperature controlled means associated with the collecting header for operating the valve.

7. In an apparatus of the class described, the combination of a row of heat absorbing tubes, the tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, a second row of tubes parallel to and in contact with the first row, said second row likewise terminating in inlet and outlet headers for a second fluid, and means for controlling the rate of flow of fluid in said second row of tubes.

8. In an apparatus of the class described, the combination of a row of heat absorbing tubes, the tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, a second row of tubes parallel to and in contact with the first row, said second row likewise terminating in inlet and outlet headers for a second fluid, and a valve associated with one of the headers for controlling the rate of flow of the second fluid.

9. In an apparatus of the class described, the combination of a row of heat absorbing tubes, the tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, a second row of tubes parallel to and in contact with the first row, said second row likewise terminating in inlet and outlet headers for a second fluid, and a valve associated with the outlet header for the second fluid to control the rate of flow through said second row of tubes.

10. In an apparatus of the class described, the combination of a row of heat absorbing tubes, the tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, a second row of tubes parallel to and in contact with the first row, said second row likewise terminating in inlet and outlet headers for a second fluid, a valve associated with one of the headers for controlling the rate of flow of the second fluid and means for operating the valve comprising a circuit including a thermostat exposed to the heat of the first fluid.

11. In an apparatus of the class described, the combination of a row of heat absorbing tubes, the tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, a second row of tubes parallel to and in contact with the first row, said second row like-

wise terminating in inlet and outlet headers for a second fluid, a valve associated with the outlet header for the second fluid for controlling its rate of flow and means for operating the valve comprising a circuit including a regulating thermometer and a thermostat associated with the outlet header for the first fluid and exposed to the heat of said fluid.

12. In a furnace, a wall composed of fluid carrying tubes, blocks of high heat conductivity and high fusion temperature attached to and supported on the furnace side of the tubes, and other fluid carrying tubes on the opposite side of the first named tubes, said tubes being arranged so that the two fluids are in heat exchange relationship.

13. In a furnace, a wall comprising fluid carrying tubes, blocks of high heat conductivity and high fusion temperature attached to and supported on the furnace side of the tubes by means secured thereto and accommodated by recesses formed in the blocks, other fluid carrying tubes in contact with the other side of the first mentioned tubes to control the temperature of the fluid carrying tubes, and insulating refractory material on the other side of the last named tubes.

14. The method of producing superheated steam of a controlled temperature, which comprises exposing steam to radiant heat of combustion, simultaneously removing a part of the heat absorbed by said steam by means of water shielded from the radiant heat and passing in heat exchange relation to the steam and controlling the temperature of the steam by regulating the rate of flow of the water.

15. In apparatus of the class described, the combination of a row of heat-absorbing tubes terminating at one end in an inlet header for fluid to be heated and at the other end in a collecting header for the fluid, a row of ducts parallel to and connected to said tubes, said ducts terminating in inlet and outlet headers for a second fluid led through the ducts in heat-exchange relation with the fluid passing through said tubes, and means for controlling the rate of flow of fluid in said ducts.

16. A method of producing a heated fluid at a regulated temperature which comprises subjecting the fluid while in motion to the indirect action of radiant heat, simultaneously passing the fluid in heat exchange relationship with a cooler flowing medium while shielding said medium from the radiant heat. and controlling the rate of heat withdrawal from the fluid by regulating the rate of flow of said medium.

17. A method of producing a heated fluid at a regulated temperature, which comprises subjecting the fluid while in motion to the indirect action of radiant heat, simultaneously transferring a portion of the heat absorbed by said fluid to a cooler medium which is shielded from the radiant heat, and regulating the rate of heat transfer to control the ultimate temperature of said fluid.

18. A method of producing superheated steam at a regulated temperature, which comprises exposing the steam indirectly to the radiant heat of combustion, and simultaneously passing the steam in heat exchange relationship with a cooler flowing medium while shielding said medium from the radiant heat, and controlling the rate of heat withdrawal from the steam by regulating the rate of flow of the cooler medium.

19. A method of superheating steam to a regulated temperature, which comprises exposing the steam indirectly to the radiant heat of combustion, simultaneously passing water in heat exchange relationship with the steam, while shielding the water from the radiant heat, and varying the rate of flow of the water to control the ultimate temperature of the steam.

20. A method of superheating steam to a regulated temperature which comprises passing the steam between surfaces one of which is exposed directly to radiant heat, the other of which is cooled by a flowing medium which is shielded from the radiant heat, and regulating the ultimate temperature of the steam by controlling the rate of flow of said medium in contact with said surface.

21. Steam generating apparatus which comprises a furnace chamber, tubes along said chamber walls exposed to the radiant heat of combustion, means for passing steam through said tubes, means for simultaneously withdrawing heat from the steam during its passage through said tubes, and means for controlling the rate of withdrawal of the heat.

22. Steam generating apparatus which comprises a furnace chamber, tubes along said chamber walls exposed to the radiant heat of combustion, means for passing steam through said tubes, ducts in contact with said tube and shielded from the radiant heat, and means for passing a current of air through said duct to absorb heat from the steam and utilizing said air for combustion.

23. Steam generating apparatus which comprises a furnace chamber, tubes along said chamber walls exposed to the radiant heat of combustion, means for passing steam through said tubes, ducts in contact with said tubes and shielded thereby from the radiant heat, means for passing a cooling medium through said ducts to absorb heat from the steam, and means responsive to the ultimate temperature of the steam for controlling the rate of flow of said medium.

24. Steam generating apparatus which comprises a furnace chamber, heat-absorbing surfaces beyond said chamber, a water-circulating system connected to said surfaces, tubes along the furnace chamber walls exposed to the radiant heat of combustion, means for passing steam through said tubes,

water tubes in contact with said first tubes and shielded from the radiant heat, said water tubes being connected in said circulating system, and means for regulating the rate of flow of the water through said water tubes.

25. Steam generating apparatus which comprises a furnace chamber, heat-absorbing surfaces beyond said chamber, a water-circulating system connected to said surfaces, tubes along the furnace chamber walls exposed to the radiant heat of combustion, means for passing steam through said tubes, water tubes in contact with said first tubes and shielded from the radiant heat, said water tubes being connected in said circulating system, and means responsive to the ultimate temperature of said steam for regulating the rate of flow through said water tubes.

In testimony whereof, I affix my signature.

CHARLES B. GRADY.