March 7, 1961 W. H. ARMACOST 2,973,750

STEAM GENERATOR

Filed July 27, 1953 2 Sheets-Sheet 1

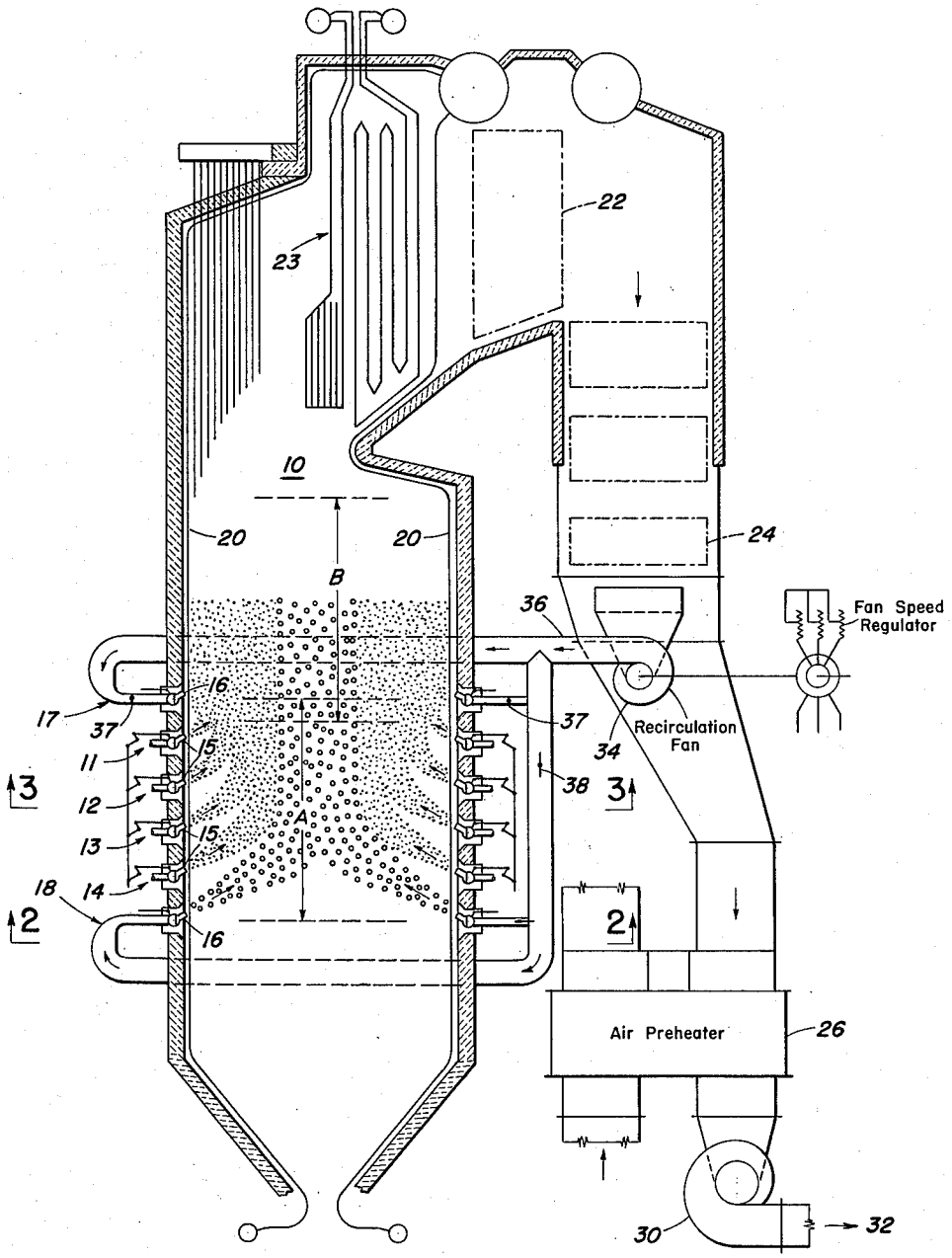

Fig. 1.

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Fig. 2.

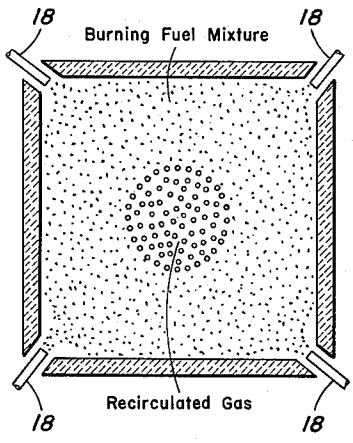
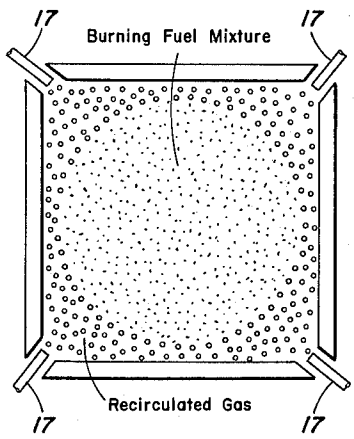


Fig. 3.



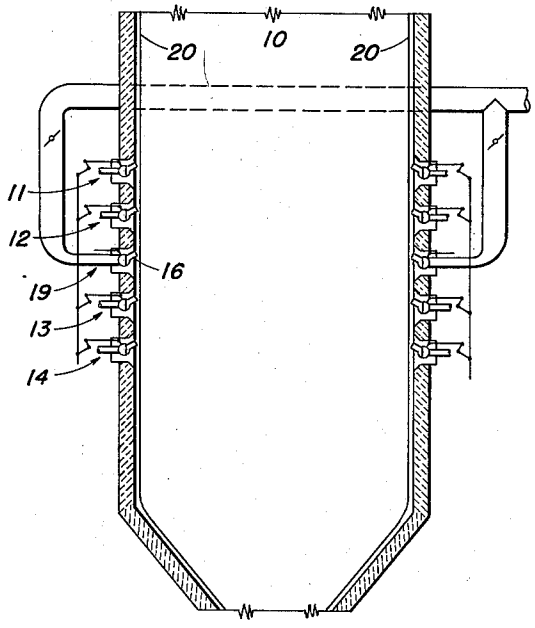


Fig. 4.

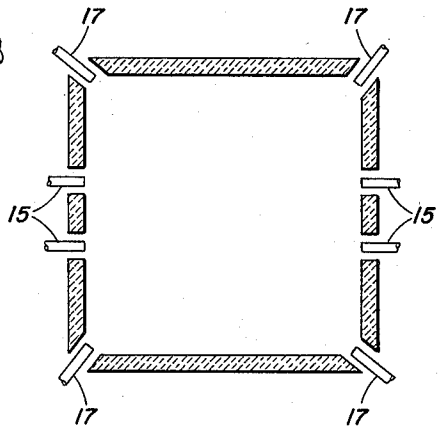


Fig. 5.

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STEAM GENERATOR

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Filed July 27, 1953, Ser. No. 370,487

12 Claims. (Cl. 122—479)

This invention relates to steam generators equipped with convectively heated superheaters or reheaters in which a portion of the gases of combustion that have passed through the installation are recirculated to the furnace chamber for increasing the volume of gases flowing over the convection superheater or reheater for the purpose of increasing the steam temperature above that which would obtain without recirculation of gases, particularly at low loads.

Various methods of controlling steam temperature in boiler installations are in use or have been proposed. One method of temperature control applicable to water cooled furnaces is disclosed in Kreisinger Patent 2,363,-875, dated November 28, 1944, and involves tilting the burners upwardly or downwardly from a horizontal firing plane so as to thus locate the zone of intense combustion nearer to or farther from the furnace outlet in order to vary the amount of heat absorbed by radiation to the furnace walls, and thereby to increase or decrease, respectively, the temperature of the gases exiting from the furnace to subsequently flow over the elements of the convection steam heater. In another method fixed burners are disposed at the corners of the furnace and project the jets of fuel and air in directions tangential to an imaginary circle whose center is the vertical axis of the furnace as in the Kruger Patent No. 2,243,909, dated June 3, 1941. The burners are arranged to be swung in a horizontal plane for varying the size of the circle and hence the distance of the zone of intense combustion from the water tube walls of the furnace, thereby varying the amount of heat abstracted from the combustion products and transferred to said water tubes and correspondingly varying the temperature of the gases available at the furnace outlet for flowing over the superheater elements. With either of these methods additional means of temperature control may be used; for example, dampers controlling the gas weight over the superheater surface or desuperheating means cooling the steam as in the Armacost Patent No. 2,640,468, dated June 2, 1953, may be used to supplement the degree of control obtainable by burner position adjustment only.

With a convectively heated superheater a given quantity of steam can be raised to the required temperature by flowing over the superheating surface either a predetermined weight of gases at a sufficiently high temperature or a greater weight of gases at a lower temperature. Recirculation of gases which have flowed over the superheating and other heat absorbing surface of the installation constitutes another method of reducing the quantity of heat absorbed by the furnace wall cooling and steam generating tubes as disclosed in De Baufre Patent 2,229,643, dated January 28, 1941. In this method gases which have passed through the installation are caused to enter the furnace chamber and mix with the fresh combustion products. The absorption of heat by radiation to the furnace walls is reduced and the mass of gas flowing over the superheater is also

increased so that a desired steam temperature may be maintained or increased at various loads according to the quantity of gas recirculated.

An object of this invention is to provide an improved steam generating and superheating installation in which the final steam temperature may be controlled by varying the weight of gases from the furnace chamber flowing over the steam superheater elements in addition to the control obtained by the effect of varying either the horizontal or vertical angle of firing by the burners as mentioned above.

It is a further object of the invention to provide an improved steam generating and superheating installation of the kind in which gases of combustion returned to the furnace for recirculation through the installation with fresh gases will be so distributed in the furnace with respect to the mass of burning fuel and gases therein as to permit either increase or decrease in the superheating effect of the gases passing from the furnace.

According to the present invention, in order to obtain the required final steam temperature, and to control such temperature, the steam generating and superheating installation comprises means for controlling the amount of heat abstracted from the fresh products of combustion within the furnace both by altering the combustion zone before such products reach the superheating surface, and means for increasing the weight of gas flowing from the furnace chamber over said superheating surface by returning to the furnace and recirculating through the installation, with the fresh products of combustion, a regulated quantity of gases of combustion which has already passed through the installation or a part thereof.

Further, according to this invention there may be interposed at some convenient location in the path of the gases recirculated through the furnace a fan or other device effective to increase or reduce the velocity of the gases to a point above or below the velocity of fuel and air entering the furnace so as to increase or decrease turbulence set up within the furnace and thereby vary the temperature of the gases discharged from the furnace to pass over the steam heater.

The gases returned to the furnace may be discharged thereinto through nozzles appropriately disposed in relation to the level of location of the burners by which the furnace is fired, and where the burners are arranged to tilt, the returned gas nozzles may also be arranged to tilt but preferably independently thereof.

The accompanying drawings diagrammatically illustrate steam generators embodying the features of the present invention for superheated steam temperature control.

Figure 1 is a diagrammatic elevational view of a steam generator embodying gas recirculation to the furnace for superheat regulation in accordance with the present invention.

Figures 2 and 3 are views along the lines 2—2 and 3—3, respectively, in Figure 1 illustrating different relations within the furnace of the mass of burning fuel and the volume of recirculated gases.

Figure 4 is a view similar to Figure 1 but illustrating a different arrangement of the fuel burners of the furnace with respect to the gas recirculation nozzles; and

Figure 5 illustrates an additional arrangement of the fuel burners with respect to the gas nozzles.

According to the embodiment of the invention illustrated in Figure 1 the furnace **10** is assumed to be fired by four sets **11, 12, 13, 14** of burners **15** disposed at the corners of the furnace, i.e. in or closely adjacent the angles formed at the junctions of the vertical walls. Other nozzles **16** discharging gases into the furnace, for recirculation through the installation also may be located at the corners of the furnace in two sets at **17, 18** con-

venient distances above and below the fuel burners 15 or as a single set 19 between the burner sets 12 and 13 as shown in Figure 4.

Any suitable means may be provided for varying independently the inclination of the fuel burners 15 in the vertical or horizontal plane and for independently varying the inclination to the horizontal of the return gas nozzles 16 in order to regulate the temperature of the gases leaving the furnace and flowing over the superheater.

In operation when all of the burners 15 are adjusted to project the fuel and air streams in substantially horizontal directions tangent to the imaginary vertical cylinder located centrally of the furnace 10, the burning fuel streams issuing from the four sets 11, 12, 13, 14 of the corner located burners 15 impinge upon one another resulting in a turbulent, rotating mixture with a consequent rapid rate of combustion. This rapid combustion produces a very high temperature in a zone A at the level of the burners near the bottom of the furnace so that there is a high rate of heat transfer from the flames to the water cooled walls 20 in this zone both by radiation and by convection. Leaving this zone the hot products of combustion pass upwardly and continue giving off heat to the water cooled walls thereabove and exit from the furnace cooled to a relatively low temperature. When all of the burners 15 are directed upwardly, the streams of fuel are still tangent to an imaginary vertical cylinder in the furnace but the impingement of the burning fuel streams upon one another is much less than when the burners are horizontally directed as above described. This results in but relatively little mixing and turbulence and consequent slower or delayed combustion. This delayed combustion occurs in a zone B, that is located higher in the furnace than the zone A, and extends well into the upper part of the furnace. Consequently the temperature of the products of combustion leaving the furnace is relatively high because of the shorter path through which they pass from the combustion zone to the outlet of the furnace 10 and because the heat transfer from the flames to the water cooled walls 20 at the bottom of the furnace is substantially less than with horizontally directed streams. The change in direction of the fuel streams from the horizontal to an upward inclination results in a rise in the temperature of the gases leaving the furnace which has been found adequate to change the rate of heat absorption by the superheater 22 so that the steam temperature may be raised to that required for satisfactory operation over a considerable range of ratings of the steam generating unit.

The gases after flowing over the superheater 22, or the superheaters and a reheater 23 if included in the unit, usually pass over an economizer 24 and other heat exchangers such as an air preheater 26. After flowing through the latter they are delivered by the induced draft fan 30 towards the chimney or stack through duct 32. An additional fan 34 is provided according to this invention and located at a suitable point in relation to the fan 22 in a conduit 36 leading back to the gas nozzles 16 from a suitable point downstream of the superheater 22. Dampers 37, 38 are provided on both ducts for regulating the volume of gas flowing through the nozzles 16 supplied by conduit 36 into the furnace 10, dampers 37 being associated with the upper nozzle sets 17 and dampers 38 with lower nozzle sets 18. Thus, a portion of the gases of combustion is delivered by the fan 30 for recirculation and as determined by the setting of the dampers 37, 38 flows from conduit 36 through branch ducts to the gas nozzles 16.

By tilting the gas nozzles 16 in unison with the fuel burners 15 the gases may be introduced in streams generally parallel with the air and fuel streams delivered by the burners, and a greater uniformity of gas distribution than heretofore is obtained without detriment to the efficiency for combustion.

When the lower set 18 of gas nozzles 16 is used alone, the recirculated gas is forced to the center of the furnace 10 due to the fuel and air coming in from burner sets 11, 12, 13, 14 thereabove, the burning fuel and air mixture having a tendency to stay closer to the walls 20 as illustrated in Figure 2. Consequently, with this method of firing more heat is absorbed in walls 20; particularly radiant, and the gas temperature leaving the furnace 10 is lower than without gas recirculation. When the upper row 17 of recirculating tilting nozzles is used, the gas therefrom would hug the furnace walls while the fuel fired tangentially below is forced out into the center of the furnace 10 as shown in Figure 3. Thus, less radiant heat would be given to walls 20 so that the gas temperature would be higher leaving the furnace than if there were no recirculation of gases.

Another variation of control may be obtained by regulating the speed of fan 34 to vary the velocity of the recirculated gas entering the furnace so that it is either above or below the velocity of the air and fuel entering the furnace through burners 15; changing the ratio of these velocities increases or decreases the turbulence set up in the furnace.

By using tilting nozzles for gas recirculation, a variation on these conditions is obtained due to increasing or decreasing the area of furnace walls 20 scrubbed by the gas recirculated coupled with the usual effect attained by tilting of the fuel and air streams, the tilting of the gas nozzles being independent of the tilting of the fuel burning equipment.

Further, by using tilting nozzles for the introduction of recirculated gases a much wider control may be obtained than by using fixed nozzles. If one row 17 of tilting recirculation nozzles is applied between rows 12 and 13 of burners as in Figure 4, results are attained at a low load or a high load that are equivalent to those accomplished by using the two individual rows 17, 18 as in Figure 1, since at low load, either the top two rows 11, 12 of burners or the two bottom rows 13, 14 of burners may be utilized to obtain the desired effect of gas recirculation on the masses of fuel and air.

Ttilting recirculation gas nozzles may also be applied in the corners of the furnace, that is, fired with horizontal fixed burners in the walls, as indicated in Figure 5 instead of tangential burners whether fixed or tilting.

It will be appreciated that by varying the angle to the horizontal of the burners 15, and also by manipulation of the hereinabove mentioned dampers 37, 38, an efficient regulation can be effected of the temperature as well as the quantity of gases flowing over the superheater, and thus the steam temperature may be controlled.

What I claim is:

1. The method of regulating temperature of steam from a heater absorbing its heat mainly by convection from gases leaving a water tube cooled furnace comprising; introducing fuel and air into the furnace for creating a gas mass to radiate heat to the water tubes thereof; maintaining, for a given load, a substantially uniform rate of fuel firing; passing the gases from the furnace over the steam heater for heating steam passing therethrough; adjusting the firing angles of the fuel burners for regulating the temperature of gases passing over the steam heater by changing the position of the zone of combustion with respect to portions of the water cooled furnace walls; and as the steam temperature varies reintroducing into the furnace a volume of gases that has already been passed over the superheater, the volume of recirculated gases being introduced between said gas mass in the zone of combustion and said tubes when the superheat temperature falls and directly into said gas mass from below said zone of combustion when the superheat temperature rises.

2. The method of regulating temperature of steam from a heater absorbing its heat mainly by convection from gases leaving the outlet of a water tube cooled furnace comprising; introducing fuel and air into the fur-

nace for creating a gas mass to radiate heat to the water tubes thereof; maintaining, for a given load a substantially uniform rate of fuel firing; passing the gases from the furnace over the steam heater for heating steam passing there through; adjusting the firing angles of the fuel burners for regulating the temperature of gases passing over the steam heater by moving the zone of combustion closer to or away from the water cooled furnace walls as the steam temperature rises or falls, respectively; and as the steam temperature varies reintroducing into the furnace a volume of gases that has already been passed over the superheater, the volume of recirculated gases being introduced above said zone of combustion when the superheat temperature falls and below said zone of combustion when the superheat temperature rises.

3. The method of regulating temperature in a steam heater absorbing its heat mainly by convection from gases leaving the outlet of a water tube cooled furnace comprising; introducing fuel and air into the furnace for creating a gas mass to radiate heat to the water tubes thereof; maintaining, for a given load, a substantially uniform rate of fuel firing; passing the gases from the furnace over the steam heater for heating steam passing therethrough; adjusting the firing angles of the fuel burners for regulating the temperature of gases passing over the steam heater by lowering or raising the position of the zone of combustion with respect to the outlet of the water cooled furnace as steam temperature rises or falls, respectively; and as the steam temperature varies reintroducing into the furnace a volume of gases that has already been passed over the superheater, the volume of recirculated gases being introduced above said zone of combustion when the superheat temperature falls and below said zone of combustion to when the superheat temperature rises.

4. A method of varying heat absorption in an elongated vertical furnace having fluid circulation tubes on its walls and from which the products of combustion flow through a passage containing heat absorbing apparatus and wherein fuel and air is introduced into the furnace in directions tangential to an imaginary horizontal circle in the furnace for creating a turbulent mass of burning fuel and products of combustion in said furnace at a level above the bottom thereof; which method comprises: the steps of increasing or decreasing the absorption of heat in said furnace wall tubes by diverting products of combustion at a point beyond said heat absorbing apparatus in the direction of gas flow and introducing the recirculated gas into said furnace from a point below the point of fuel introduction and in an upward direction toward the fuel mass in the center of the furnace so as to displace the mass of gas and products of combustion laterally from the center of the furnace toward said furnace wall tubes to increase the absorption of heat in said furnace wall tubes and from a point above the point of fuel introduction and in an upward direction between the fuel mass and the furnace wall tubes to decrease the heat absorption in said tubes.

5. A method of varying heat absorption in a furnace having fluid circulation tubes on its walls and from which the products of combustion flow through a passage containing heat absorbing apparatus and wherein fuel and air is introduced into the furnace in directions tangential to an imaginary horizontal circle in the furnace for creating a turbulent mass of burning fuel and products of combustion in said furnace at a level above the bottom thereof and gaseous products of combustion are diverted away from a point beyond said heat absorbing apparatus in the direction of gas flow, which method comprises the steps of: decreasing the absorption of heat in the furnace walls by introducing the recirculated gas into said furnace from a point above the point of fuel introduction and directing the recirculated gas upwardly adjacent the furnace walls so as to form a layer of recirculated gas surrounding the fuel mass so as to displace the mass of gas and products of combustion laterally away from said furnace wall tubes; and increasing the absorption of heat in the furnace walls by introducing the recirculated gas from below said point of fuel introduction and in an upward direction into the center of the burning fuel and gas mass for displacing the latter outwardly toward said wall tubes.

6. A method of varying heat absorption in a furnace having fluid circulation tubes on its walls and from which the products of combustion flow through a passage containing heat absorbing apparatus and wherein fuel and air is introduced into the furnace in directions tangential to an imaginary horizontal circle in the furnace for creating a turbulent mass of burning fuel and products of combustion in said furnace at a level above the bottom thereof and gaseous products of combustion are diverted from a point beyond said heat absorbing apparatus in the direction of gas flow, which method comprises the steps of: decreasing the absorption of heat in the furnace walls by introducing the recirculated gaseous products of combustion into said furnace in directions tangential to said imaginary circle from a point above the point of fuel introduction and directing the recirculated products of combustion so as to form a layer of recirculated gas surrounding the fuel mass so as to displace the mass of gas and products of combustion laterally away from said furnace wall tubes; and increasing the absorption of heat in the furnace walls by introducing the recirculated gaseous products of combustion from below said point of fuel introduction and in an upward direction into the center of the burning fuel and gas mass for displacing the latter outwardly toward said wall tubes.

7. A method of varying heat absorption in an elongated vertical furnace having fluid circulation tubes on its walls and from which the products of combustion flow through a passage containing heat absorbing apparatus and wherein fuel and air is introduced into the furnace in directions tangential to an imaginary horizontal circle in the furnace for creating a turbulent mass of burning fuel and products of combustion in said furnace at a level above the bottom thereof; which method comprises the steps of: decreasing the amount of absorption of heat in said furnace wall tubes by diverting gaseous products of combustion that have passed over said heat exchanger from said outlet and introducing the recirculated gases into said furnace at a point upstream of the point of fuel introduction in the sense of gas flow; and directing the recirculated gas to flow outwardly of the mass of burning fuel and gas mass between it and said furnace wall tubes so as to shift the burning fuel and gas mass inwardly toward the center of said furnace away from said furnace wall tubes.

8. The method of regulating temperature of steam from a heater absorbing its heat mainly by convection from gases leaving the outlet of a water tube cooled furnace comprising; introducing fuel and air into the furnace for creating a gas mass to radiate heat to the water tubes thereof; maintaining, for a given load a substantially uniform rate of fuel firing; passing the gases from the furnace over the steam heater for heating steam passing therethrough; and as the steam temperature falls, raising the temperature of gases passing over the steam heater by adjusting the firing angles of the fuel burners to move the zone of combustion closer to the furnace outlet while reintroducing into the furnace a volume of gases, that has already been passed over the superheater and other heat exchange surface, at a point above said zone of combustion and in a direction to flow adjacent the wall tubes.

9. In a steam generator having an elongated vertical furnace with fluid circulation tubes on its walls and from the outlet of which the products of combustion flow to an offtake duct through a passage containing a steam heater; a set of burners so mounted in said

walls as to introduce fuel and air into the furnace in directions tangential to an imaginary horizontal cylinder in said furnace at a level above the bottom thereof; a conduit for diverting products of combustion away from said offtake connecting with said passage at a point beyond said steam heater in the direction of gas flow; sets of tangentially mounted nozzles located in the furnace walls above and below said set of burners and connected to receive products of combustion from said conduit and introduce them into said furnace so as to vary the amount of heat absorbed in said furnace through radiation to said furnace wall tubes; means associated with the upper set of gas nozzles operable to direct the streams of gas therefrom along the furnace walls above the burning mass of fuel and between said mass and the furnace walls to decrease the radiant absorption of heat thereby; means associated with the lower set of gas nozzles operable to direct the streams of gas therefrom upwardly into the mass of burning fuel thereabove for displacing the said mass outwardly toward the furnace walls for increasing the radiant absorption of heat thereby.

10. In a steam generator having an elongated vertical furnace with fluid circulation tubes on its walls and from the outlet of which the products of combustion flow to an offtake duct through a passage containing a steam heater; a set of burners so mounted in said walls as to introduce fuel and air into the furnace in directions tangential to an imaginary horizontal circle in said furnace at a level above the bottom thereof; a conduit for diverting products of combustion away from said offtake connecting with said passage at a point beyond said steam heater in the direction of gas flow; sets of tangentially mounted nozzles located in the furnace walls above and below said set of burners and connected to receive products of combustion from said conduit and introduce them into said furnace so as to vary the amount of heat absorbed in said furnace through radiation to said furnace wall tubes; and means associated with the upper set of gas nozzles operable to direct the stream of gas therefrom along the furnace walls above the burning mass of fuel and between said mass and the furnace walls to decrease the radiant absorption of heat thereby.

11. In a steam generator having an elongated vertical furnace with fluid circulation tubes on its walls and from the outlet of which the products of combustion flow to an offtake duct through a passage containing a steam heater; a set of burners so mounted in said walls as to introduce fuel and air into the furnace in directions tangential to an imaginary horizontal circle in said furnace at a level above the bottom thereof; a conduit for diverting products of combustion away from said offtake connecting with said passage at a point beyond said steam heater in the direction of gas flow; sets of tangentially mounted nozzles located in the furnace walls above and below said set of burners and connected to receive products of combustion from said conduit and introduce them into said furnace so as to vary the amount of heat absorbed in said furnace through radiation to said furnace wall tubes; means associated with the lower set of gas nozzles operable to direct the streams of gas therefrom upwardly into the mass of burning fuel thereabove for displacing the said mass outwardly toward the furnace walls for increasing the radiant absorption of heat thereby.

12. In a steam generator having an elongated vertical furnace with steam generating tubes on its walls and from which the products of combustion flow through a passage containing heat absorbing apparatus, a set of tiltable burners so mounted in said walls as to introduce fuel and air into the furnace in directions tangential to an imaginary horizontal cylinder in the furnace for creating a turbulent mass of burning fuel and products of combustion in the furnace; a gas recirculation conduit connecting with said gas passage at a point downstream beyond said heat absorbing apparatus; gas nozzles tiltable about their horizontal axes located in the furnace walls above and below said set of burners and connected to receive products of combustion from said conduit so as to introduce streams of recirculated gas into said furnace at levels above and below said set of burners; the method of operating said steam generator which comprises; tilting said set of burners about their horizontal axes for raising or lowering the zone of combustion in the furnace to thereby decrease or increase the radiant absorption of heat by said wall tubes; and tilting said gas nozzles about their horizontal axes independently of tilting of said burner sets for directing streams of recirculated gas into the center of the burning mass of fuel and products of combustion from the lower set of nozzles and for directing said streams of recirculated gases between said burning mass of fuel and the furnace wall tubes when the upper set of burners is in operation so as to respectively increase or decrease the amount of radiant absorption of heat by said furnace wall tubes.

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