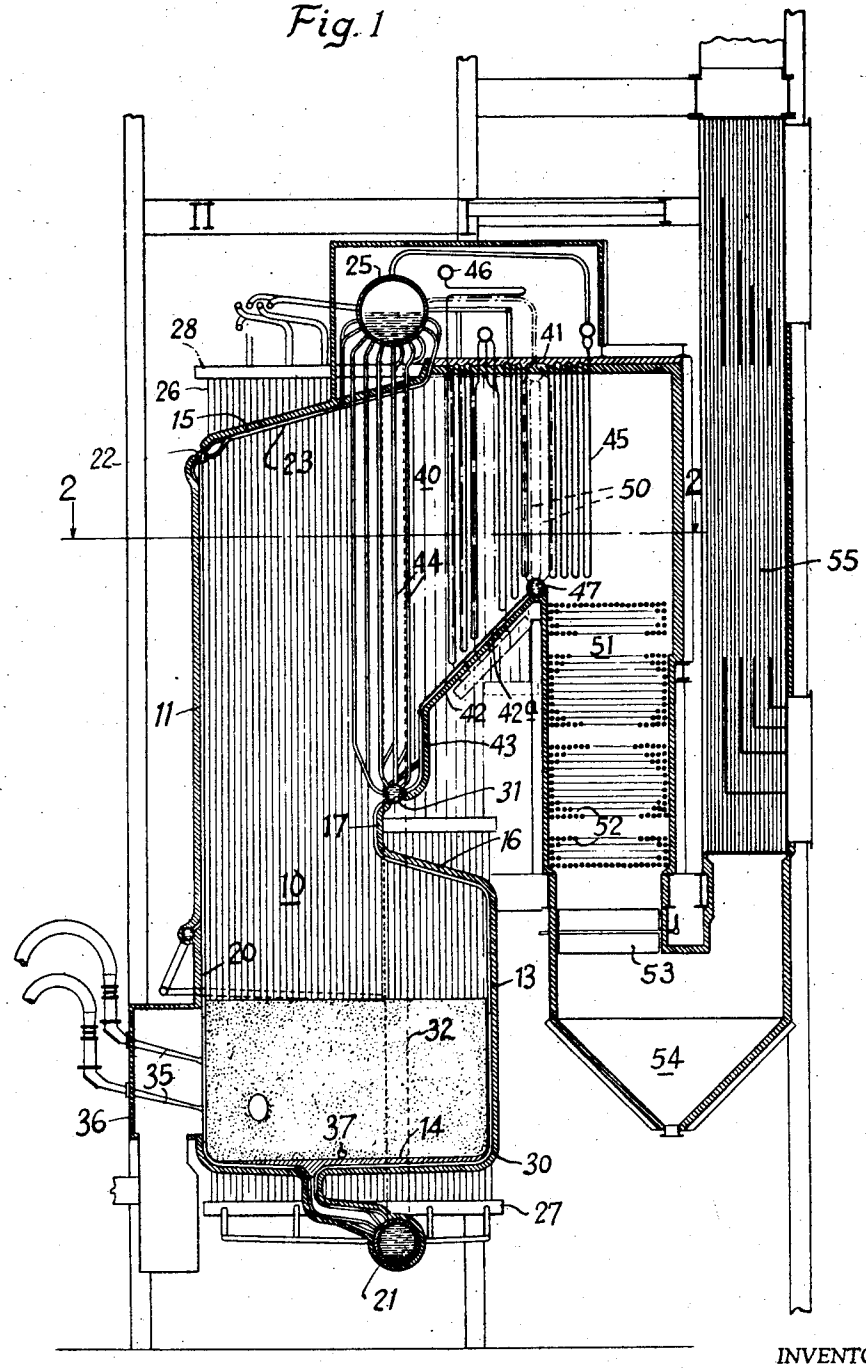
Feb. 18, 1947. P. R. GROSSMAN 2,416,053

FUEL BURNING METHOD

Filed Jan. 29, 1942 3 Sheets-Sheet 1

Fig. 1




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FUEL BURNING METHOD

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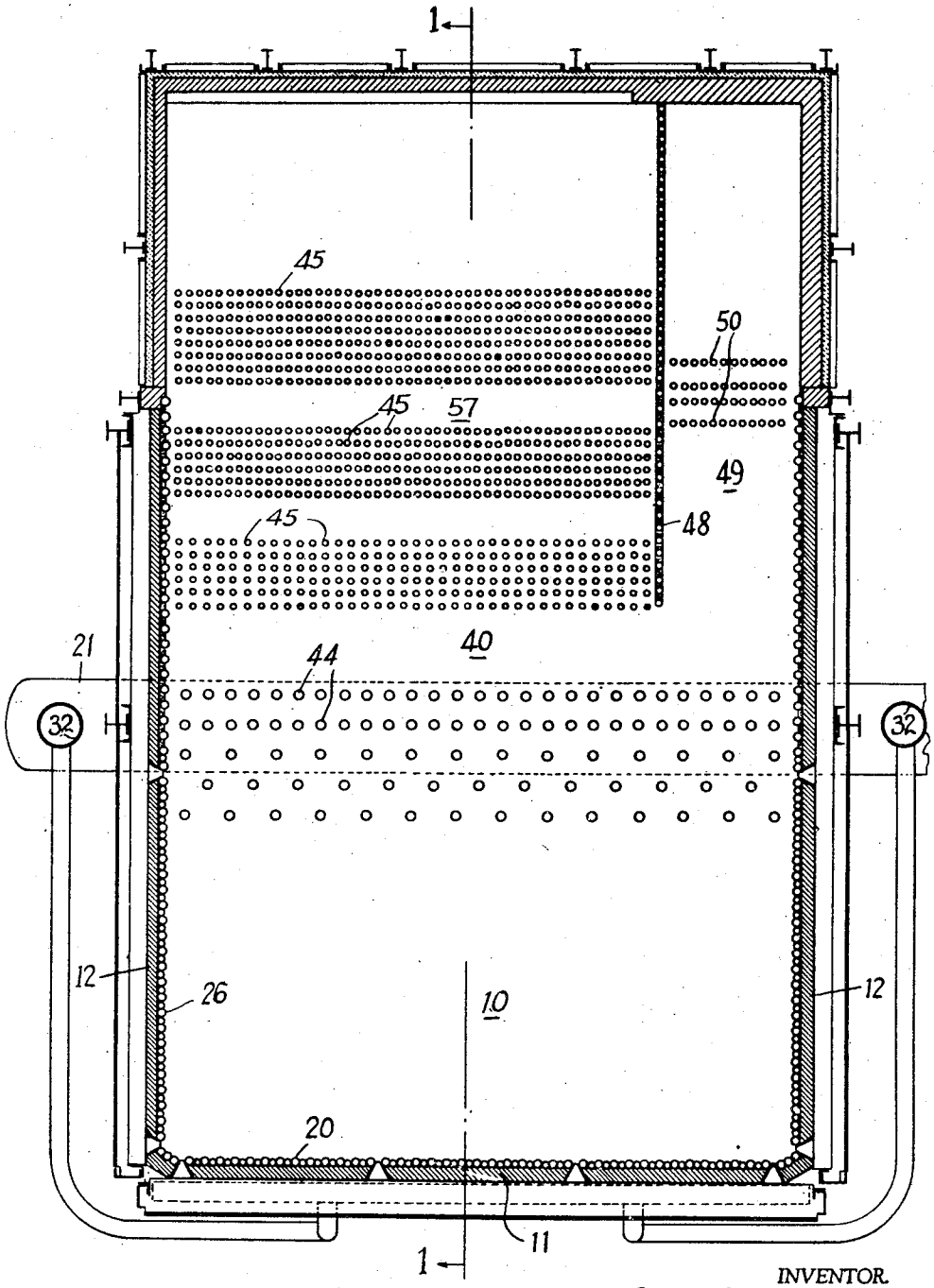



Fig. 2

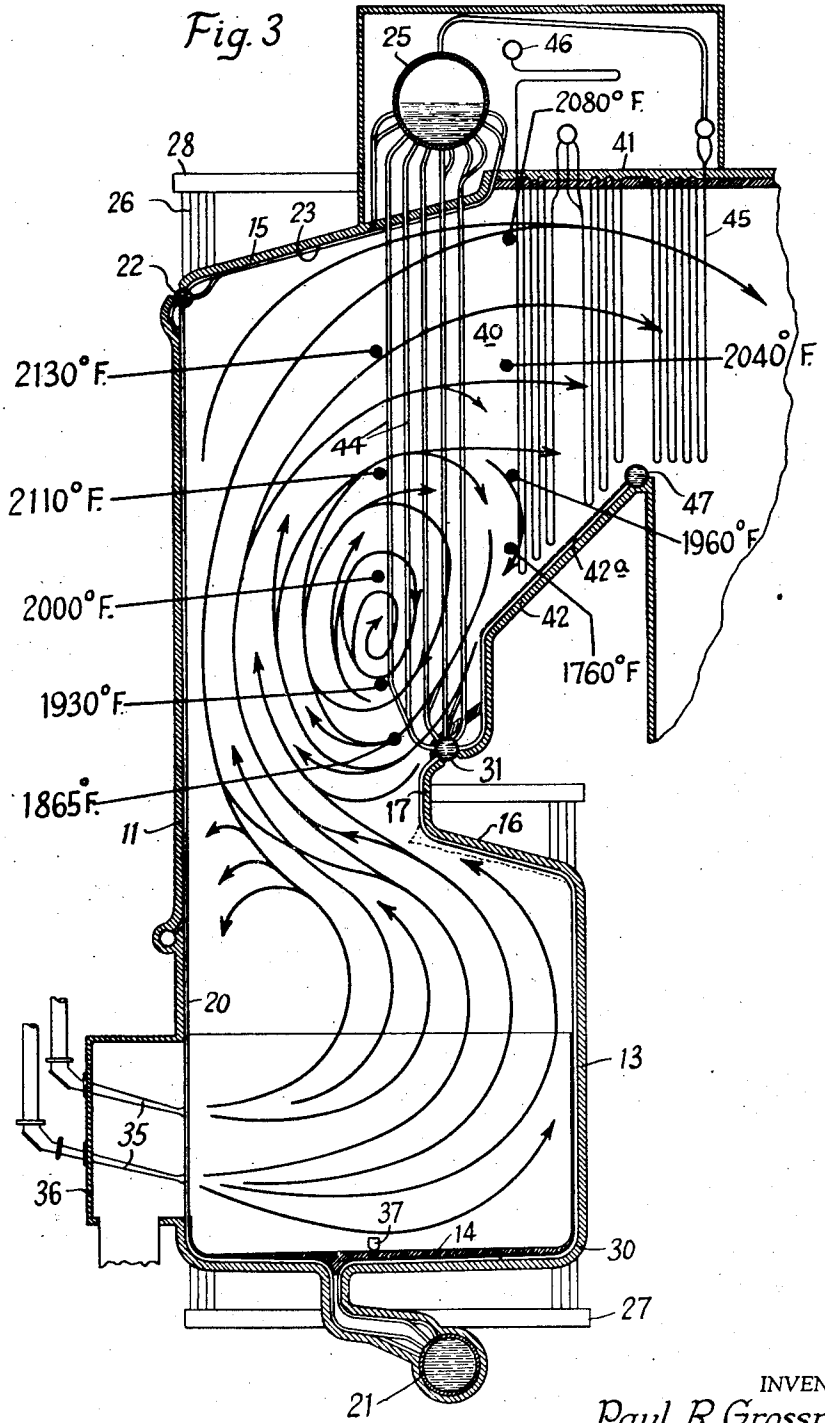
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FUEL BURNING METHOD

Filed Jan. 29, 1942 3 Sheets-Sheet 3

Fig. 3




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Patented Feb. 18, 1947 2,416,053

# UNITED STATES PATENT OFFICE

2,416,053

## FUEL BURNING METHOD

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Application January 29, 1942, Serial No. 428,724

14 Claims. (Cl. 122—235)

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My discovery and invention relates in general to the construction and operation of fluid heating apparatus, and more particularly, to the construction and operation of steam generating units in which the heat is supplied by the combustion of a pulverized slag-forming fuel.

In medium and high capacity steam generating units of the type described, the convection heated surface usually includes a bank of relatively closely spaced small diameter steam superheating tubes adapted to superheat the steam to a relatively high temperature. In such installations it is desirable to position a bank of steam generating tubes in the path of the heating gases from the furnace chamber to the superheater tubes to screen the superheater from radiation from the furnace chamber and reduce the gas temperature sufficiently that overheating of the superheater tubes is avoided while permitting the desired high degree of superheat to be obtained. In pulverized fuel fired installations of this type, such boiler screen tubes are designed to serve the additional function of reducing the temperature of slag particles in a molten or sticky condition suspended in the heating gases to a dry solid state or non-adhesive condition to thereby minimize the deposition of slag on the closely spaced superheater tubes and clogging of the intertube passages.

It has been proposed to supplement the gas cooling effect of the boiler screen tubes by returning some of the cooled heating gases to the furnace chamber at a location where the returned gases can mix with the higher temperature gases generated by the burning fuel and thus reduce the average temperature of the gas stream leaving the furnace chamber. Due to the relatively low temperature at which gases can be safely contacted with the operating parts of a fan or other gas circulating device, it has been necessary to withdraw the gases to be recirculated at a point where their temperature has been reduced by contact with a major portion of the convection heated surface of the unit. Gas recirculating arrangements of this type result in a substantial increase in the fan power requirements of the unit and thus correspondingly increase the installation and operating costs of the unit.

It is widely recognized that in the designing of convection heated fluid heating apparatus, the flow path of the heating gases should be arranged for a maximum contact between the heating gases and the heat absorbing surface while maintaining the draft loss through the unit at

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as low a value as possible to minimize the fan power requirements. For this reason it is customary to provide a flow path for the heating gases in which flow influencing elements, such as baffle and wall arrangements, tending to produce local eddy currents in the gas flow are eliminated as far as possible, so that a streamlined straight through flow of the heating gases will take place.

I have discovered however that under certain circumstances factors inducing substantial eddy currents in the gas flow are not only not harmful, but in fact can be highly beneficial in providing an inherent recirculation of a large portion of the heating gases at a location whereby the average temperature of the gases leaving the furnace chamber will be reduced to a value at which safe wall temperatures for the superheater tubes are insured and, when the unit is fired with a slag-forming fuel, the temperature of suspended slag particles will be reduced below the fuel ash softening temperature before contacting with the superheater tubes. I have discovered that a gas recirculation effect of the character described can be enhanced and maintained by a special construction of the bank of heat absorbing tubes first contacted by the heating gases leaving the furnace chamber, further by controlling the direction and velocity of the furnace gases adjacent the location at which the recirculated gases enter the furnace chamber, and still further by controlling the path of travel of the heating gases in the furnace chamber and approaching the first bank of convection heated tubes.

In utilizing my discovery, the high temperature heating gases leaving the furnace chamber should be first directed across a bank of vertically arranged fluid heating tubes constructed and arranged to have a predetermined relation of effective heat absorbing area, tube height in the gas flow passage, and gas pressure drop across the tube bank tending to establish a thermal siphon effect of the heating gases relative to that tube bank which will induce and maintain a flow of heating gases reversely across the lower portion of the bank and into the furnace chamber in position to mix with the higher temperature heating gases leaving the furnace chamber.

The inherent gas recirculation effect described can be enhanced in accordance with my discovery by providing a high velocity for the ascending high temperature furnace gas stream adjacent the location where the recirculated gases return to the furnace chamber, and directed at an angle

away from the lower portion of the first convection heated bank. Such high gas velocities will result in a lower static pressure condition at this point, and thus an additional draft effect tending to increase the flow of gas reversely across the lower portion of the tube bank. In effect the high velocity gas stream will act as a fluid jet to produce entrainment of the recirculated gases in the high temperature gas stream.

The gas recirculation effect described can be further enhanced by directing the high temperature high velocity gas stream upwardly along the front wall and roof in the upper portion of the furnace chamber, so that the inertia effect of these gases will naturally cause the hotter gases to concentrate along and flow across the upper portion of the first convection heated tube bank.

In the drawings:

Fig. 1 is a sectional elevation of a pulverized fuel fired slag tap steam generating unit taken on the line 1—1 of Fig. 2, and having a construction and arrangement of the furnace chamber and convection heated fluid heating surface providing a recirculation of a substantial amount of heating gases to the furnace chamber;

Fig. 2 is a horizontal section taken on the line 2—2 of Fig. 1; and

Fig. 3 is an enlarged view of a portion of the unit shown in Figs. 1 and 2 diagrammatically illustrating the gas flow therein.

The steam generating unit illustrated in the drawings utilizes the various features of my discovery, and comprises a vertically elongated furnace chamber 10 defined by a vertical front wall 11, opposite side walls 12, and a short rear wall 13, all of which are provided with vertical water tubes connected into the steam generating circuit of the unit. The bottom of the furnace chamber is closed by a floor 14 and the top by a rearwardly inclined roof 15. The vertical rear wall 13 extends along only the lower part of the furnace chamber, and is continued as a forwardly inclined arch 16 and a short vertical wall portion 17 at the forward end of the arch 16. The furnace chamber wall cooling provisions comprise a row of front wall tubes 20, the lower ends of which are bent along and extend below the floor level to a transverse water drum 21. The upper ends of the tubes 20 are connected to a transverse header 22, from which a row of tubes 23 extend along the roof 15 to a transverse horizontally arranged steam and water drum 25, located above the roof. Each of the side walls 12 of the furnace chamber is cooled by a row of water tubes 26 connected at their lower ends to a longitudinal header 27 supplied by the drum 21 and at their upper ends to a header 28 discharging to the drum 25. A row of tubes 30 extends from the drum 21 along the remaining portion of the floor 14 and thence upwardly along the rear wall 13, arch 16, and vertical wall section 17 to a small diameter transverse drum 31 in vertical alignment with the drums 21 and 25. Downcomer pipes 32 externally connect the bottom of the drum 25 to the drum 21.

Upper and lower rows of pulverized coal burner nozzles 35 are downwardly inclined and arranged to discharge between the portions of the tubes 20 at the lower part of the front wall 11 towards the rear wall 13. Combustion air is supplied through a windbox 36 surrounding the burner nozzles. The portions of the remaining furnace wall tubes from the floor level thereof to a level above the burner level are covered with metallic studs and refractory to promote combustion of the pulverized fuel entering that section and maintain the desired high temperature conditions therein. A slag discharge port 37 is provided in one of the side walls 12 at the floor level thereof through which molten slag depositing on the floor 14 may be discharged either continuously or intermittently. The remaining portions of the furnace wall tubes are left bare to provide a large amount of radiant heat absorbing surface throughout the remaining height of the furnace chamber.



With the described furnace wall construction the furnace chamber will be of substantial height and of rectangular horizontal cross-section, the horizontal cross-section in the lower portion below the rear arch 16 being substantially greater than the cross-section above that arch. The vertical area between the side walls 12, roof 15, and top of the wall section 17 forms the gas outlet from the furnace chamber which opens into a gas flow passage 40 of uniform width between the side walls 12. The passage 40 is further defined by a flat roof 41 forming a continuation of the roof 15 and a rearwardly inclined floor 42 having a short vertical section 43 at its forward end connecting with the top of the rear wall section 17, so that the passage 40 progressively decreases in height rearwardly of the unit. In the passage 40 is arranged the convection heated steam generating and superheating surface of the unit consisting of a bank of vertical steam generating tubes 44 and a three-section pendant type superheater 45. The steam generating tubes 44 are connected at their lower ends to the transverse header 31 and have their upper portions extending through the roof 15 and connected to the steam and water drum 25. The rearmost section of the superheater 45 is connected to the steam space of the drum 25, while the foremost superheating tubes are connected to an outlet header 46 through which the superheated steam is discharged to its point of use. The sloping floor 42 of the convection passage 40 below the superheater is lined with block covered water tubes 42a having their lower ends connected to the drum 31 and their upper ends to a transverse header 47. As shown in Fig. 2, the superheater passage 57 does not extend the full width of the unit but is separated by a water cooled baffle 48 extending parallel to the side wallls 12 from the front end of the superheater to the rear end of the unit, to provide a superheater by-pass passage 49. Rows of steam generating tubes 50 are positioned in the by-pass passage with their lower ends connected to the header 47 and their upper ends connected to an upper header and the steam and water drum 25.

The remaining portion of the gas flow path is formed by a vertical passage 51 extending downwardly at the rear end of the unit and occupied by a plurality of vertically spaced serially connected groups of horizontally arranged multiple looped transverse economizer tubes 52. The baffle 48 has an extension in the passage 51 to provide a continuation of the superheater and by-pass passages across the economizer tubes, and dampers 53 are positioned therebelow to regulate the flow of the heating gases through these passages. The gases on leaving the economizer tubes turn above an ash hopper 54 and flow upwardly through a tubular air heater 55 and induced draft fan to a suitable stack connection.

Steam generating units of the general character described are usually designed to operate in the following manner:

Pulverized fuel and combustion air are introduced through the lower portion of the front wall

11 and the pulverized fuel burned in suspension in the lower part of the furnace chamber 10, the supply of combustion elements and heat absorbing surface in the lower section of the furnace chamber being proportioned to maintain a normal mean temperature therein, particularly adjacent the floor 14, above the fuel ash fusion temperature, whereby the ash particles separating from the burning fuel will be deposited on the floor 14 as molten slag and withdrawn through the slag outlet 37. The gaseous products of combustion and any ash particles in suspension therein are designed to pass upwardly through the furnace chamber, and are cooled during their passage by the radiant heat absorption of the furnace wall tubes. Due to the furnace draft effect the high temperature heating gases and suspended ash particles move laterally in the upper part of the furnace into the gas passage 40. The temperature of the gases and suspended ash particles is reduced by their flow across the bank of screen tubes 44 to a value designedly below the fuel ash fusion temperature before they contact with the more closely spaced superheater tubes in the superheater passage 47. With pulverized fuel having the designed ash fusion temperature characteristics, the ash particles should be in a dry condition on reaching the superheater and present no slagging problems in the superheater. Any ash depositing on the superheater tubes can therefore be blown off and down the inclined floor 42 to the furnace chamber. The gases flowing through the superheater passage 57 or by-pass passage 49, or both, flow downwardly across the economizer tube banks 52 and thence upwardly through the tubular air heater 55 to the induced draft fan and stack connection. Under proper operating conditions therefore the ash in the fuel separated during combustion or during the subsequent passage of the heating gases will be removed as a molten slag through the slag outlet 37 at the furnace bottom or as a dry ash through the ash hopper 54, and the heating gases will flow through the gas passage 40 in a single pass flow over the tube bank 44, superheater tubes 45, economizer tubes 52 and air heater 55 successively. When, however, pulverized fuel having a lower fuel ash fusion temperature than that for which the unit is designed is used, or when the rate of heat absorption of the radiant heat absorbing surface and tubes 44 decreases, the suspended ash particles contacting with the superheater tubes may be in a molten or sticky condition, and as such deposit on and adhere to the superheater tubes, rapidly clogging the intertube passages.

I have discovered that the allowable minimum fuel ash fusion temperature can be considerably decreased and the range of usable fuels correspondingly increased for vapor generating units of the general character described without resulting in either overheating of the superheating tubes or deposition of the separated ash particles thereon in a molten or sticky condition, by recirculating a substantial portion of the heating gases leaving the furnace chamber after their temperature has been reduced by their passage across the boiler slag screen tubes 44, without requiring special circulating fans or other mechanical devices for this purpose and without materially adding to the fan power requirements of the unit. The gas recirculation effect, and consequently the proportion of the gases recirculated, I have found to be dependent upon several features which jointly contribute to the recirculation of a large proportion of the heating gases entering the tube bank 44.

One of these features is embodied in the steam generator illustrated, i. e., the construction and proportioning of the first bank of convection heated tubes in the gas pass 40, and particularly, the relative proportioning of the effective heat absorbing area thereof, tube height, and gas pressure drop or draft loss thereacross. By way of example and not of limitation, the tube bank 44 is shown as composed of 95 tubes 4'' O. D. arranged in five rows spaced 12'' apart. The tubes in the two rearmost rows are spaced on 9'' centers while the tubes in the forward rows are on 18'' centers. The rearmost row is spaced 3' from the adjacent row of superheater tubes. The effective length of the tubes in the bank, i. e., from the drum 31 to the superjacent roof portion is 29'6'', the width of the furnace chamber in this plane being 20'11''. The expected performance of this unit operating at a capacity of 345,300 lbs. of steam per hr. with a straight through flow and no recirculation of gases to the furnace chamber would have a gas temperature leaving the furnace chamber of 2320° F. and leaving the tube bank 44 of 2036° F. Under such conditions the gas pressure drop across the tube bank would be approximately .025 in. $H_2O$. Thus an appreciable temperature reduction in the heating gases flowing across the tube bank would occur, yet the draft loss would be of a low order. With a draft loss and heat absorption of this order, the temperature difference of the gases at opposite sides of the tube bank 44 in conjunction with the substantial height of the tube bank produces a draft differential at an elevation near the lower end of the tube bank sufficiently great to establish and maintain a gas flow forwardly through the tube bank at this position. The forward flow, or recirculation, of the gases will continue as long as there is a tendency for this draft differential to exist. The described thermal siphon action thus effects a return of some of the gases after being cooled by their passage through the tube bank 44.

Another feature of the illustrated construction which substantially promotes the gas recirculation effect is the relative arrangement of the fuel burners 35 and rear furnace arch or roof 16. As diagrammatically illustrated in Fig. 3, the fuel burners discharge downwardly and rearwardly towards the rear wall 13 so that the furnace gases generated will sweep upwardly along the rear wall and be directed forwardly and upwardly by the forwardly inclined arch 16 and at a relatively high velocity when leaving the forward end of the arch. A correspondingly low static pressure condition will thus be created in this area which will cause an additional draft effect on the gases flowing forwardly across the lower part of the tube bank 44. The ascending furnace gas stream thus acts as a fluid jet to produce entrainment of the recirculating gas flowing forwardly through the tube bank, as indicated in Fig. 3. A mixing of the lower temperature recirculated gases with the ascending high temperature gases takes place, lowering the average temperature of the gases entering the furnace side of the tube bank.

The gas recirculation effect is also aided by the direction given to the gases on leaving the rear arch 16, i. e., upwardly along the upper part of the front wall 11 and roof 15. The inertia of the gas stream tends to carry the hotter gases into the upper part of the furnace chamber, so

that these gases naturally tend to enter the upper part of the tube bank.

The steam generator illustrated is designed for burning pulverized coal and a maximum continuous steam generating capacity of 400,000 lbs. per hr., a design pressure of 900 lbs. per sq. in. and a total steam temperature of 900° F. High velocity thermocouple measurements of gas temperatures taken at different points around the tube bank 44 while the unit was operating at a capacity of approximately 350,000 lbs. per hr. are indicated on Fig. 3. The direction of gas flow at different points in this area was also determined by test. There was found to be a very substantial recirculation of the gases, as indicated by the arrows in Fig. 3. By calculating the temperature drop through the upper portion of the tube bank over which the gases were found to be flowing rearwardly with various weights of flue gas, it was estimated from observations and calculations that approximately 100% of the furnace gases generated were being recirculated at this load. An additional quantity of gas partly enters the tube bank and then returns to the furnace chamber with the recirculated gases, accounting for the higher gas temperature values in front of the lower end of the tube bank relative to that at the lower rear part thereof.

The described gas recirculation is highly beneficial in regard to ash and slag accumulations. The rear wall 13, floor 14 and rear part of the lower side walls have slag deposited thereon in a fluid state. The slag fluid zone extends to the front end of the arch 16, as indicated in broken lines in Fig. 3, but the slag fluid zone sharply ends at the lower end of the vertical wall portion 17. The recirculated gases thus cause the suspended slag particles to pass rapidly through the "sticky" stage before reaching the convection heated surface. That bare tube surface is maintained clean by the downward sweep of the cooler recirculated gases. It was also found that the tube bank 44 was maintained clean of slag accumulations and that only dry ash deposited on the sloping floors below the superheater and over the header 31, from which it was swept back into the furnace chamber by the gases.

Fluid heating apparatus utilizing the described features of my discovery will thus have an effective use of the furnace chamber volume and a mean heating gas temperature at the furnace chamber outlet which will avoid overheating of the superheater tubes and deposition of suspended slag particles in a sticky condition on the convection heated surface, without requiring separate gas recirculation devices or adding materially to the fan power requirements.

I claim:

1. The method of burning a fuel which comprises introducing the fuel and combustion air into a vertically elongated furnace chamber and burning the same in suspension in the lower part of said chamber, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a substantial height, and sufficiently low draft loss and high heat absorbing capacity to establish and maintain at substantially the maximum designed continuous rate of operation a thermal siphon effect providing a circulation of a substantial portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and causing the gaseous products of combustion flowing upwardly through the lower part of the furnace chamber to be deflected mainly along the side of said furnace chamber opposite said tube bank.



2. The method of burning a fuel which comprises introducing the fuel and combustion air into a furnace chamber and burning the same in the lower part of said chamber, directing the gaseous products of combustion in the upper part of the furnace chamber into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a height, draft loss and heat absorbing capacity proportioned to establish and maintain a thermal siphon effect providing a circulation of a portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and causing the gaseous products of combustion flowing upwardly through the lower part of the furnace chamber to be deflected at a relatively high velocity past and in a direction away from the lower portion of the tube bank to promote the gas recirculation effect and mixing of the recirculated gases.

3. The method of burning a fuel which comprises introducing a stream of the fuel and combustion air into a vertically elongated furnace chamber and burning the same in suspension in the lower part of said chamber, directing the gaseous products of combustion in the upper part of the furnace chamber into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a height, draft loss and heat absorbing capacity proportioned to establish and maintain a thermal siphon effect providing a circulation of a portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and directing the gaseous products of combustion leaving the lower part of the furnace chamber at a relatively high velocity and at an angle to the direction of recirculated gas flow across the lower part of said tube bank and reversely of the direction of entrance of the fuel and air stream to promote the gas recirculation effect and mixing of the recirculated gases.

4. The method of burning a fuel which comprises introducing the fuel and combustion air into a vertically elongated furnace chamber and burning the same in suspension in the lower part of said chamber, directing the gaseous products of combustion in the upper part of the furnace chamber into contact with a vertically arranged bank of fluid heating tubes of a substantial height and sufficiently low draft loss and high heat absorbing capacity to establish and maintain a thermal siphon effect providing a circulation of a substantial portion of the gaseous products of combustion in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and directing the gaseous products of combustion leaving the lower part of the furnace chamber at a relatively high velocity and in a direction adjacent the lower portion of said tube bank reversely of the entering fuel and combustion air and of the gas flow across the upper part of said tube bank to promote the gas recirculation effect and mixing of the recirculated gases.

5. The method of burning a pulverized slag-

forming fuel which comprises introducing the fuel and combustion air into a furnace chamber and burning the same in suspension in the lower part of said chamber under a normal mean temperature therein above the fuel ash fusion temperature, removing molten slag depositing in the bottom of the furnace chamber, and directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a height, draft loss and heat absorbing capacity proportioned to establish and maintain a thermal siphon effect providing a circulation of a major portion of the gaseous products of combustion at the maximum continuous designed capacity in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber sufficient to reduce the average gas temperature at the furnace chamber outlet below the fuel ash fusion temperature.

6. The method of burning a pulverized slag-forming fuel which comprises introducing a stream of the fuel and combustion air into a vertically elongated furnace chamber and burning the same in suspension in the lower part of said chamber, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a substantial height, low draft loss and heat absorbing capacity proportioned to establish and maintain a circulation of a substantial portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and directing the gaseous products of combustion leaving the lower part of the furnace chamber past the lower portion of said tube bank opposite to the direction of the entering stream of fuel and combustion air to promote the gas recirculation effect and mixing of the recirculated gases.

7. The method of burning a pulverized slag-forming fuel which comprises introducing the fuel and combustion air into a vertically elongated furnace chamber and burning the same in suspension in the lower part of said chamber under a normal mean temperature therein above the fuel ash fusion temperature, removing molten slag depositing in the bottom of the furnace chamber, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a substantial height and sufficiently low draft loss and high heat absorbing capacity to establish and maintain a thermal siphon effect providing a circulation of a portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber sufficient to reduce the average gas temperature at the furnace chamber outlet below the fuel ash fusion temperature, and causing the gaseous products of combustion flowing upwardly through the lower part of the furnace chamber to be deflected towards and along the side of said furnace chamber opposite said tube bank.

8. The method of burning a pulverized slag-forming fuel which comprises introducing the fuel and combustion air into a furnace chamber



and burning the same in suspension in the lower part of said chamber under a normal mean temperature therein above the fuel ash fusion temperature, removing molten slag depositing in the bottom of the furnace chamber, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and having a substantial height and high heat absorbing capacity proportioned relative to draft loss therethrough to establish and maintain a circulation of a portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and causing the gaseous products of combustion flowing upwardly through the lower part of the furnace chamber to be deflected at a relatively high velocity and in a direction away from the lower portion of said tube bank tending to promote the gas recirculation effect and mixing of the recirculated gases.

9. The method of burning a pulverized slag-forming fuel which comprises introducing the fuel and combustion air into a vertically elongated furnace chamber and burning the same in suspension in the lower part of said chamber and under a normal mean temperature therein above the fuel ash fusion temperature, removing molten slag depositing in the bottom of the furnace chamber, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes in the furnace chamber outlet and of a substantial height and sufficiently low draft loss and high heat absorbing capacity to establish and maintain a thermal siphon effect providing a circulation of a substantial portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber sufficient to reduce the average gas temperature at the furnace chamber outlet below the fuel ash softening temperature, and directing the gaseous products of combustion leaving the lower part of the furnace chamber at a relatively high velocity and in a direction adjacent the lower portion of said tube bank reversely of the direction of the entering stream of fuel and combustion air to promote the gas recirculation effect and mixing of the recirculated gases.

10. In a steam generating unit having a vertically elongated furnace chamber and a heating gas outlet at one side of the upper portion thereof, a lateral gas passage opening to said gas outlet, a vertically arranged bank of steam generating tubes in said gas passage having a substantial height, low pressure drop and high heat absorbing capacity, and a group of closely spaced steam superheater tubes in said gas passage spaced from said tube bank, the method of burning fuel in said unit which comprises burning the fuel in the lower part of said furnace chamber, directing the furnace gases in the upper part of the furnace chamber across the upper part of said tube bank, and causing the furnace gases flowing upwardly through the lower part of the furnace chamber to be deflected in a diverging direction adjacent the lower portion of said tube bank tending to promote a flow of heating gases downwardly between said tube bank and superheater tubes and reversely across the lower portion of said tube bank into the furnace chamber.

11. In a steam generating unit having a vertically elongated furnace chamber and a heating gas outlet at the rear side of the upper portion thereof, a lateral gas passage opening to said gas outlet, a vertically arranged bank of steam generating tubes in said gas passage having a substantial height, low pressure drop and high heat absorbing capacity, and a group of closely spaced steam superheater tubes in said gas passage spaced rearwardly of said tube bank, the method of burning a pulverized slag-forming fuel in said unit which comprises burning the fuel in suspension in the lower part of said furnace chamber under a normal mean temperature therein above the fuel ash fusion temperature, removing molten slag depositing in the bottom of the furnace chamber, directing the furnace gases in the upper part of the furnace chamber across the upper part of said tube bank, and causing the furnace gases flowing upwardly through the lower part of the furnace chamber to be deflected in a direction tending to promote a flow of heating gases downwardly between said tube bank and superheater tubes and reversely across the lower portion of said tube bank into the furnace chamber to an extent sufficient to reduce the average temperature of the heating gases contacting with said superheater tubes below the fuel ash softening temperature.

12. In a steam generating unit having a vertically elongated furnace chamber and a heating gas outlet at the rear side of the upper portion thereof, a lateral gas passage opening to said gas outlet, a vertically arranged bank of steam generating tubes in said gas passage having a substantial height, low pressure drop and high heat absorbing capacity, and a group of closely spaced steam superheater tubes in said gas passage spaced rearwardly of said tube bank, the method of burning a pulverized slag-forming fuel in said unit which comprises burning the fuel in suspension in the lower part of said furnace chamber under a normal mean temperature therein above the fuel ash fusion temperature, removing molten slag depositing in the bottom of the furnace chamber, directing the furnace gases in the upper part of the furnace chamber across the upper part of said tube bank, and directing the furnace gases leaving the lower part of the furnace chamber at a relatively high velocity and in a direction reversely of the direction of the entering stream of fuel and combustion air to promote a flow of heating gases downwardly between said tube bank and superheater tubes and reversely across the lower portion of said tube bank into the furnace chamber to an extent sufficient to reduce the average temperature of the heating gases contacting with said superheater tubes below the fuel ash softening temperature.

13. The method of burning fuel which comprises introducing and burning a fuel in the lower part of a vertically elongated furnace chamber having a gas outlet in one side of the upper part thereof, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes across the furnace chamber gas outlet and of a height, draft loss and heat absorbing capacity proportioned to establish and maintain a thermal siphon effect providing a circulation of a portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber, and causing the gaseous products of combustion flowing upwardly through the lower part of the furnace chamber to be deflected at a converging angle to the direction of recirculated gas flow across the lower part of said tube bank to promote the gas recirculation effect and mixing of the recirculated gases.



14. The method of burning a fluid fuel containing an incombustible ash which comprises introducing and burning a fuel in the lower part of a vertically elongated furnace chamber having a gas outlet in one side of the upper part thereof, removing molten ash from the bottom of the furnace chamber, directing the gaseous products of combustion in the upper part of the furnace chamber laterally into contact with a vertically arranged bank of fluid heating tubes across the furnace chamber gas outlet and of a height, draft loss and heat absorbing capacity proportioned to establish and maintain a thermal siphon effect providing a circulation of a portion of the gaseous products of combustion in the furnace chamber outlet in a reverse direction across the lower portion of said tube bank and into the upper part of the furnace chamber sufficient to reduce the average gas temperature at the furnace chamber outlet below the ash fusion temperature, and causing the gaseous products of combustion flowing upwardly through the lower part of the furnace chamber to be deflected at a converging angle to the direction of recirculated gas flow across the lower part of said tube bank to promote the gas recirculation effect and mixing of the recirculated gases.

PAUL R. GROSSMAN.


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## Certificate of Correction

Patent No. 2,416,053. February 18, 1947.

PAUL R. GROSSMAN

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Column 9, line 42, claim 6, before the word "opposite" insert *in a direction*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 28th day of September, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
*Assistant Commissioner of Patents.*