June 20, 1961 A. M. FRENDBERG ET AL **2,989,039**

FLUID HEATING UNIT WITH GAS TEMPERING PROVISIONS

Filed Aug. 27, 1954 3 Sheets-Sheet 1

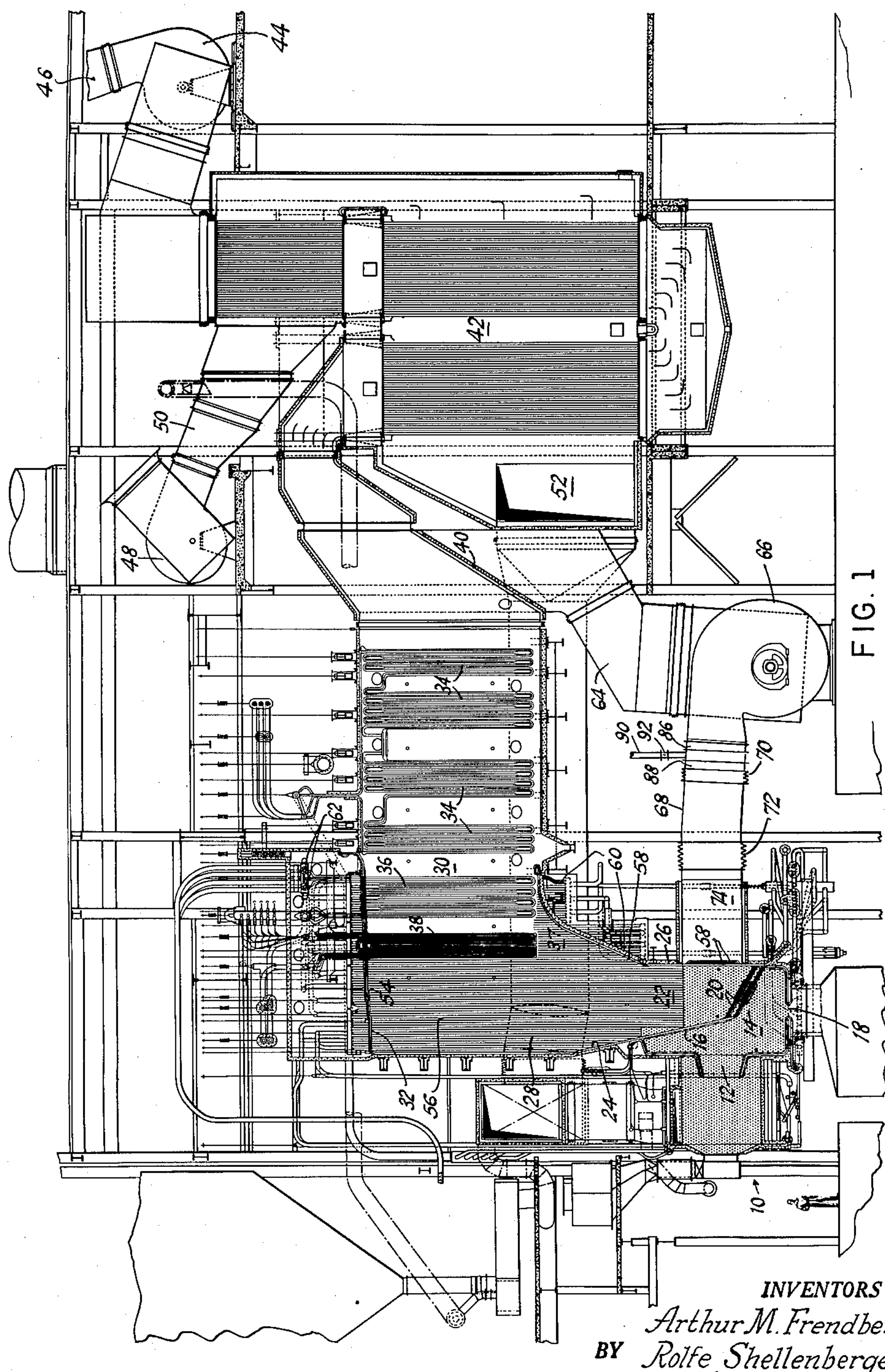

FIG. 1

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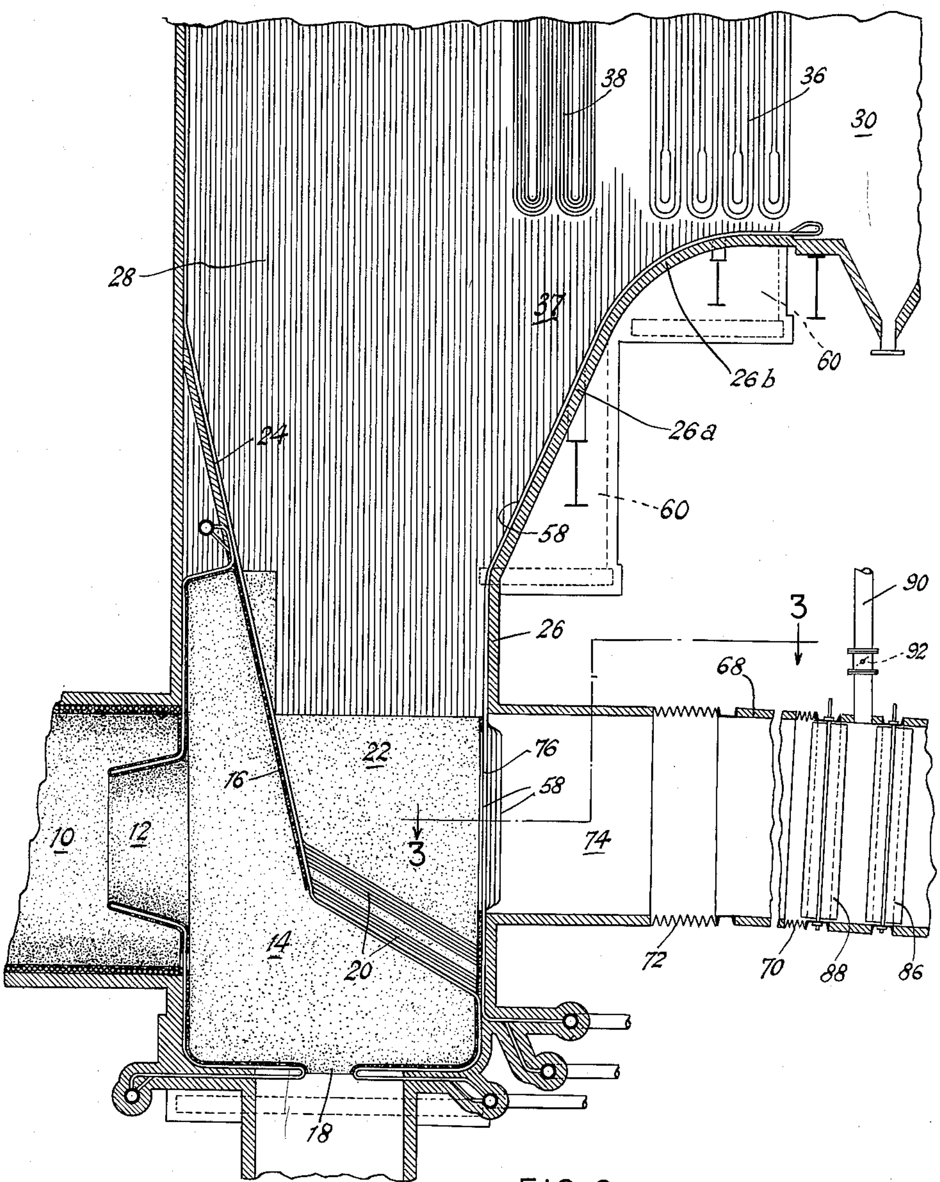

FIG. 2

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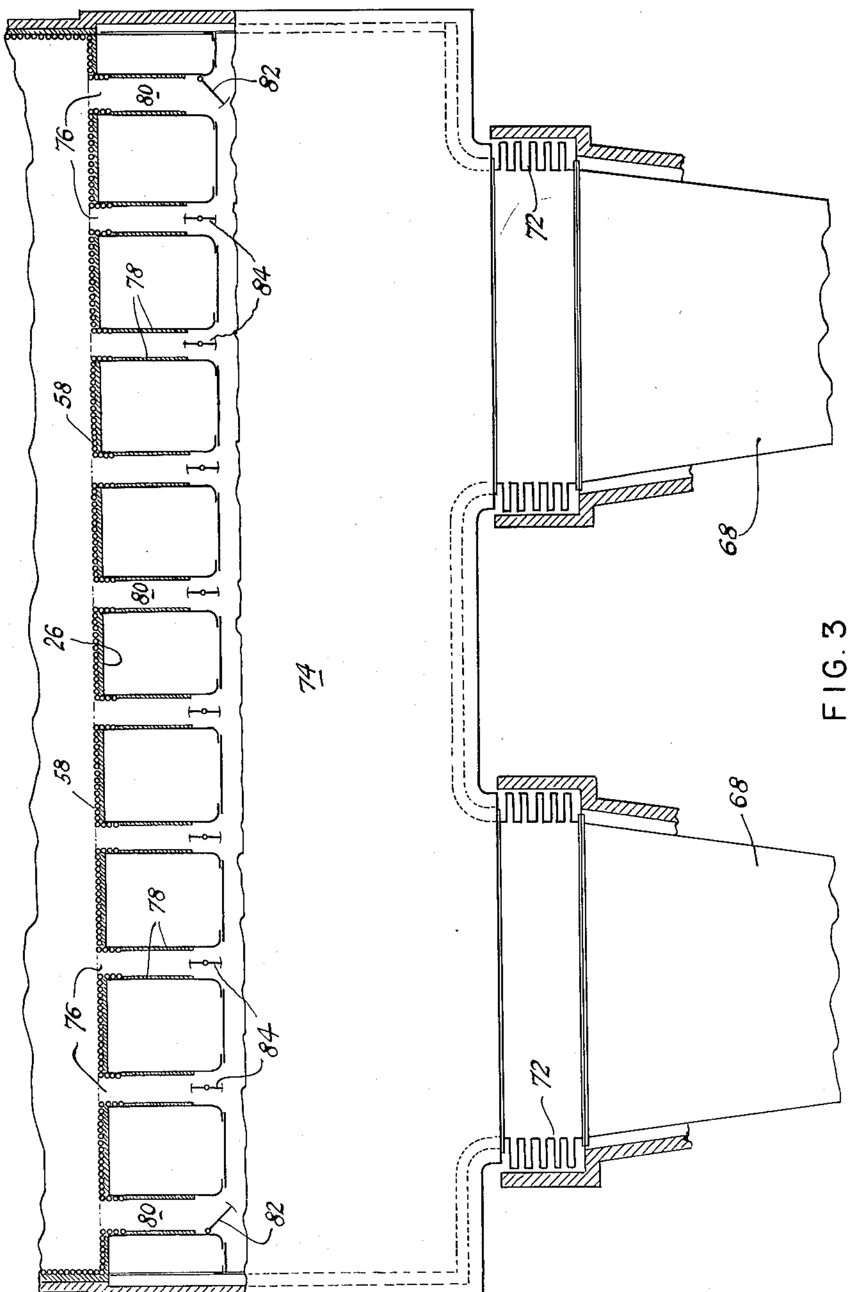

FIG. 3

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FLUID HEATING UNIT WITH GAS TEMPERING PROVISIONS

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1 Claim. (Cl. 122—478)

The present invention relates in general to the construction and operation of fluid heating units in which a fluid is to be heated in high duty convection surface by heating gas at a relatively high temperature and velocity, and more particularly to vapor generating and superheating units of this type in which vapor superheating tubes are heated by a mixture of high temperature ash-laden gaseous products of combustion and a relatively low temperature tempering gas.

The general object of the invention is the provision of a furnace construction and configuration for a fluid heating unit of the character described affecting a thorough mixing of the low temperature tempering gas with the high temperature products of combustion before the gases reach the convection heated surface and in conjunction therewith a gas flow restricting arrangement of fluid heating surface to provide a substantially uniform gas mass flow distribution across the highest temperature tubes in the convection pass, so as to avoid tube metal temperatures in the convection surface above those which the tube materials and wall thicknesses employed could safely withstand, and, when an ash-forming fuel is burned in the unit under combustion zone temperatures above the fuel ash fusion temperature, to avoid fouling of the convection surfaces by the deposition thereon of fly ash in a "sticky" condition.

A further object is the provision of a fluid heating unit of the character described in which the furnace volume is held to a minimum and molten ash from the combustion zone or depositing on the furnace walls or initial portion of the convection surface can be readily drained from the unit.

A still further object is the provision of a vapor generating and superheating unit of the character described in which an ash-forming solid fuel is burned in one or more cyclone furnaces at temperatures above the fuel ash fusion temperature and substantially all of the fuel ash separated by cyclonic action and drained into a "primary" furnace into which the gaseous products of combustion and remaining ash in suspension are discharged at a high velocity and temperature, and the gases then directed upwardly through a "secondary" furnace or radiation chamber in which the gas temperature is reduced to the desired value by heat radiation to the chamber walls and by the introduction of low temperature gas recirculated from the low temperature section of the unit to the radiation chamber so as to thoroughly mix with the ash-laden gaseous products of combustion therein, the radiation chamber being especially shaped and arranged to promote the desired gas mixing and in conjunction with a special arrangement of vapor superheating surface to provide a substantially uniform gas mass flow distribution across the highest temperature tubes in a convection pass extending laterally from the upper end of the radiation chamber.

The various features of novelty which characterize the invention are pointed out with particularity in the claim annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and

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descriptive matter in which we have illustrated and described a preferred embodiment of the invention.

Of the drawings:

FIG. 1 is a partly diagrammatic sectional elevation of a steam generating and superheating unit constructed in accordance with the invention;

FIG. 2 is an enlarged view of a portion of the unit shown in FIG. 1; and

FIG. 3 is a plan section taken on the line 3—3 of FIG. 2.

In the drawings the invention has been illustrated as embodied in a top-supported forced flow once-through steam generating unit designed for the production of superheated steam at pressures and temperatures in excess of the critical pressure of 3206 p.s.i. and the critical temperature of 705° F., a unit of this general construction being disclosed and claimed in a copending application of W. H. Rowand et al., Serial No. 364,378, filed June 26, 1953, now Patent No. 2,902,982.

The main portions of the unit illustrated include a plurality of independently operable cyclone furnaces **10** of relatively small volume and water cooled boundary wall area and into each of which granulated coal and combustion air are introduced so as to burn the fuel at high rates of heat release in a helical path along the cylindrical wall thereof while maintaining furnace temperatures above the fuel ash fusion temperature. Combustion of the fuel is completed or substantially completed in the cyclone furnace. The fuel ash is substantially all separated from the burning fuel stream and deposited on the chamber walls as a molten slag and subsequently discharged through the end wall of the cyclone onto the floor of a "primary" furnace **14**. The gaseous products of combustion with the remaining ash in suspension are discharged at a high velocity and a temperature of the order of 3100° F. through a reentrant throat **12** into the furnace **14**. A vertically inclined fluid cooled baffle **16** directs the heating gases downwardly adjacent one or more slag discharge openings **18** in the floor of the primary furnace, facilitating the discharge therethrough of the slag depositing on the floor of that furnace in a molten condition. The gas stream then passes around the lower end of the baffle **16** and upwardly through a slag-collecting screen formed by fluid heating tubes **20** projecting at an acute angle from the baffle **16**, with adjacent tubes bent and grouped in vertical alignment and the groups transversely spaced. The baffle **16** is arranged at an angle of approximately 13 degrees to the vertical and the screen tubes at an angle of approximately 30 degrees to the horizontal. The slag screen forms the lower boundary of a vertically elongated secondary "furnace" or radiation chamber **22** of rectangular horizontal cross-section having a front wall **24**, a rear wall **26**, and a pair of opposite vertical side walls **28**.

The radiation chamber **22** opens at the upper rear side thereof into a horizontally elongated convection heating gas pass **30** of substantially rectangular vertical cross-section and the rear portion of which may be divided into two or more parallel heating gas passages. The convection heating pass is occupied by steam superheating and reheating surface in the form of groups of transversely spaced tube panels formed by multiple looped pendent tubes connected to headers arranged externally of the roof **32** of the radiation chamber and convection pass. As illustrated, the groups **34** of tube panels in the rear portion of the convection pass have corresponding tubes serially connected to form a primary steam superheater, while the serially connected tubes of tube groups **36** and **38** at the radiation chamber end of the convection pass form a secondary steam superheater. The heating gases flow through the convection pass and an outlet duct 40 leading to the tubes of a three-section tubular air heater 42, from which the gases are withdrawn by an induced draft fan 44 having a stack outlet connection 46. The air for combustion is independently supplied to each of the cyclone furnaces 10 at a positive pressure sufficiently to overcome the relatively high gas flow resistance through the unit by a forced draft fan 48 and a conduit 50 leading to the air heater. The entering air flows across the tubes of the air heater sections successively and through an outlet flue 52 from which it is regulably supplied as secondary air to the several cyclone furnaces 10.

As disclosed in said Rowand et al. application, Serial No. 364,378, now Patent No. 2,902,982, feed water is normally supplied at a high temperature level to the wall cooling tubes of the successive cyclone furnaces wherein it is heated to a temperature approaching the critical temperature, and the heated fluid then conducted to the rearmost primary superheater tube group 34, through which tube groups it flows countercurrent to the heating gas flow. The superheated steam then flows through a radiant superheater section formed by tubes 54 lining the roof and front wall of the radiation chamber and the slag screen tubes 20. The steam then passes successively through tubes 56 lining the opposite side walls 28 and tubes 58 lining the rear wall 26 of the radiation chamber. The steam then successively flows through tube panels 60 lining the side walls of the convection pass and finally to the front section 38 of the secondary superheater through which and the rear section 36 it flows in parallel flow relation to the heating gases to the superheater outlet headers 62.

With the described arrangement of vapor superheating surface and the direction of vapor flow therein, the secondary superheater section 36 will contain the highest temperature vapor and will tend to have the highest tube metal temperatures. A substantially uniform gas flow throughout the vertical extent of the tubes 36 is therefore essential for safe operation with the high superheat temperatures contemplated.

The steam generating unit illustrated is designed for a maximum continuous steam output of 675,000 lbs. of steam per hr. at a pressure of 4550 p.s.i.g. and a total temperature of 1150 F. at the superheater outlet, based on feed water being supplied at a pressure of 5500 p.s.i.g. and a temperature of 525 F. and coal firing. With such high capacity high temperature units it is necessary to have a heat content in the heating gases entering the convection pass sufficient to insure the desired final superheat temperature being attained, but it is essential that the temperature of the heating gases be sufficiently low to cause suspended slag particles in the gases to be cooled below a "sticky" temperature and thus avoid slagging of the secondary superheater tubes 38 and 36 at the entrance to the convection pass. This gas temperature must also be low enough to maintain the tube metal temperatures of the secondary super-heater tubes 36 at a safe operating level. Even though the average heating gas temperature in any cross-section of the convection pass be within the permissible range, it is also essential that the gas flow be substantially uniformly distributed across the entire flow area to avoid local over-heating of some, or parts of some, of the secondary superheater tubes 36.

In accordance with the present invention, the radiation chamber 22 is constructed with a special configuration and arrangement relative to the tubes forming the secondary superheater section, and a special arrangement of provisions for introducing a low temperature tempering gas at a particular location in the radiation chamber.

As shown in FIGS. 1 and 2, the front wall of the radiation chamber is defined by the inclined baffle 16 and a wall 24 which forms a continuation of that baffle to a point in vertical alignment with the plane of the end wall of the cyclone furnaces and then extends vertically until it intersects the plane of the substantially horizontal roof 32. The rear wall 26 of the radiation chamber extends vertically from the lower end of the slag screen 20 to a level approximating the upper end of the baffle 16, and thence upwardly and rearwardly at an angle of approximately 24 degrees in a section 26^a at a progressively decreasing distance below and spaced from the superheater tubes 38 and terminates in a convexly curved section 26^b which extends subjacent the superheater tubes 36. With this construction of the front and rear walls of the radiation chamber and the vertical side walls 28, the lower end of the radiation chamber is initially flared forwardly and then both forwardly and rearwardly to an extent that the horizontal distance between the front wall 24 and the upper end of the convex section 26^b corresponds to the vertical height of the convection heating pass 30 at the upper end of the rear wall section 26^b.

The termination of the upper end of the rear wall section 26^b closely subjacent to the lower ends of the tubes 36, while having a substantial space 37 of varying height between the lower ends of the secondary superheater section 38 and the wall section 26^a, contributes to uniform gas flow conditions across the entire height of the superheater section 36. The gas stream flowing upwardly in the radiation chamber tends to crowd against the roof 32. The tube panels 38 however are transversely spaced and proportioned to provide a flow restriction slowing the passage of these gases into the convection pass 30 and causing a substantial amount of gas to flow through the space 37 without contacting the tube panels 38 and thence across the lower portion of the tube panels 36.

In conjunction with the described radiation chamber configuration and secondary superheater tube arrangement, the unit is provided with gas tempering provisions comprising gas ducts 64 opening to the opposite sides of the outlet duct 40 at the rear side of the primary superheater section and arranged to conduct relatively low temperature heating gases from the duct 40 to a pair of gas recirculating fans 66. Each of the gas recirculating fans discharges through a horizontally flaring duct 68, having spaced expansion joints 70 and 72, into a plenum chamber 74 extending horizontally along the radiation chamber rear wall section 26 slightly above the level of the slag screen 20, as shown in FIGS. 2 and 3. Groups of tubes 58 lining the rear wall 26 are bent rearwardly and laterally to form vertically elongated openings 76 at transversely spaced points across the width of the unit for the introduction of recirculated gas streams into the lower portion of the radiation chamber. As indicated in FIG. 3, these bent tubes 58 have their intertube spaces closed with refractory and unite with the refractory covered sides of filler members 78 extending between adjoining gas inlets 76 to form gas inlet passages 80 forming a rearward continuation of the gas inlets 76. As shown in FIG. 3, the end inlet passages 80 and gas inlets are of slightly greater width than the intermediate passages and inlets. The end passages are normally partly closed by a swinging damper 82, while the intermediate passages are normally fully open and provided with pivoted dampers 84.

With the two recirculating fans 66 discharging into the common plenum chamber 74, the recirculated gases would tend to backflow into either fan in the event it was necessary to shut that fan down, and thus render it difficult to make any repairs thereon. To permit such repairs, each duct 68 is provided with spaced sets of shut-off dampers 86 and 88 between the expansion joint 70 and the corresponding recirculating fan. A cooling air duct 90 having a damper 92 therein is connected to each duct 68 at a point intermediate the dampers 86 and 88 to permit the introduction of a cooling air stream into this portion of the duct 68. The dampers 86 and 92 are preferably interconnected so that they will always move in opposite directions, i. e. when the dampers 86 are closed the damper 92 is open, and vice versa. With the described arrangement of the dampers **86** and **88** and cooling air duct **90**, either recirculating fan may be taken out of operation while the other fan is kept in operation delivering recirculated gas, at a temperature normally in the range of 750–825 F., to the recirculating gas inlet passages **80**. With the described construction and arrangement of the various parts affecting the gas flow through the unit the gaseous products of combustion discharge from the spaced cyclone furnace throats at a temperature approximating 3100 F. The gas streams are spread laterally and downwardly by the baffle **16** and enter the radiation chamber **22** through the slag screen **20** which functions to provide a substantially uniform gas flow across the width of the unit. As the gas stream flows upwardly from the slag screen into the upwardly flaring cross-section of the radiation chamber, it will be penetrated at transversely spaced points by the vertically elongated streams of recirculated gas issuing from the inlet ports **80** in the vertical rear wall section **26**, the degree of penetration and mixing being facilitated by the upwardly and forwardly flaring formation of this portion of the radiation chamber. The flaring formation reduces the gas pressure drop through the radiation chamber. The direction of introduction of the recirculated gas streams at this location counterbalances the tendency for the stream of gaseous products of combustion otherwise to hug the rear wall of the radiation chamber and by-pass a portion of the superheater tube group **38**. The mixed gas stream assumes a cross-sectional flow area substantially equal to the vertical cross-section of the convection pass before making a 90 degree turn into the convection pass. The gas flow restricting effect of the tube panels **38** tends to average out any inequalities in the gas mass distribution over the height of the convection pass and it has been found possible to maintain a mass flow upset value (peak mass flow divided by the average flow) of not greater than 1.6 at the secondary superheater section **36** under full load conditions. The most uniform mixing of the high temperature and recirculated gases was obtained with recirculated gas inlets confined to the location described and the recirculated gas inlet ports 7.5" wide x 72" high on 41" centers. It was also found that no biasing or dampering of the recirculated gas inlet ports was necessary for satisfactory operation at partial loads of the unit as good mixing and substantially uniform gas mass flow distribution across the width of the unit was obtained even when only one cyclone furnace at one side of the unit was in operation. The amount of gas recirculation is readily controlled by varying the speed of the gas recirculation fans.

With the gas stream leaving the slag screen **20** at a temperature of 3000 F. and recirculated gas introduced at 800 F. and at a rate of 72.7% of the fresh products of combustion, the mixed gas stream contacting the superheater tubes **36** will be at approximately 1900 F., a temperature which would avoid fouling of the convection surface with sticky fly ash and superheater tube metal temperatures above those for which the tube materials and wall thickness were designed.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by the claim, and that certain features of the invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

A vapor generating and superheating unit comprising means defining a furnace chamber, means for burning a slag-forming fuel in said furnace chamber at temperatures above the fuel ash fusion temperature, a vertically elongated gas radiation chamber arranged to receive at its lower end high temperature ash-laden gases from said furnace chamber, means forming a convection pass opening to the upper part of said radiation chamber, convection heated vapor superheating tubes arranged across the gas entrance end of said convection pass, and means for withdrawing relatively low temperature gases from a point in the unit gas flow path beyond said vapor superheating tubes and introducing the withdrawn gases in gas mixing relation with said high temperature ash-laden gases in the lower portion of said radiation chamber comprising a pair of gas recirculating fans, a plenum chamber along the rear wall of said radiation chamber, transversely spaced gas inlets connecting said plenum chamber with said radiation chamber, a pair of recirculated gas ducts connecting said fans to said plenum chamber, a flexible expansion joint in each of said gas ducts, spaced cut-off dampers in said duct between said expansion joint and fan and operable to close said gas duct, and means for supplying a cooling gas to the portion of said duct between said cut-off dampers.

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