

May 8, 1951

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2,551,945

FLUID HEAT EXCHANGE APPARATUS

Filed Oct. 23, 1947

4 Sheets-Sheet 1

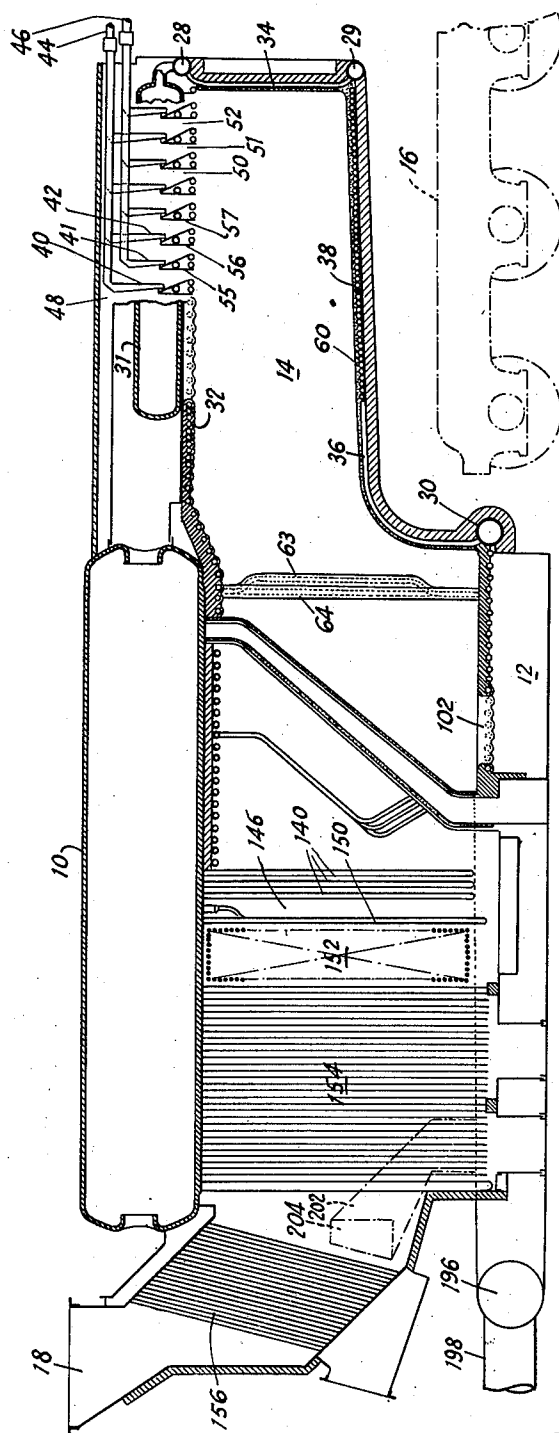


Fig. 1

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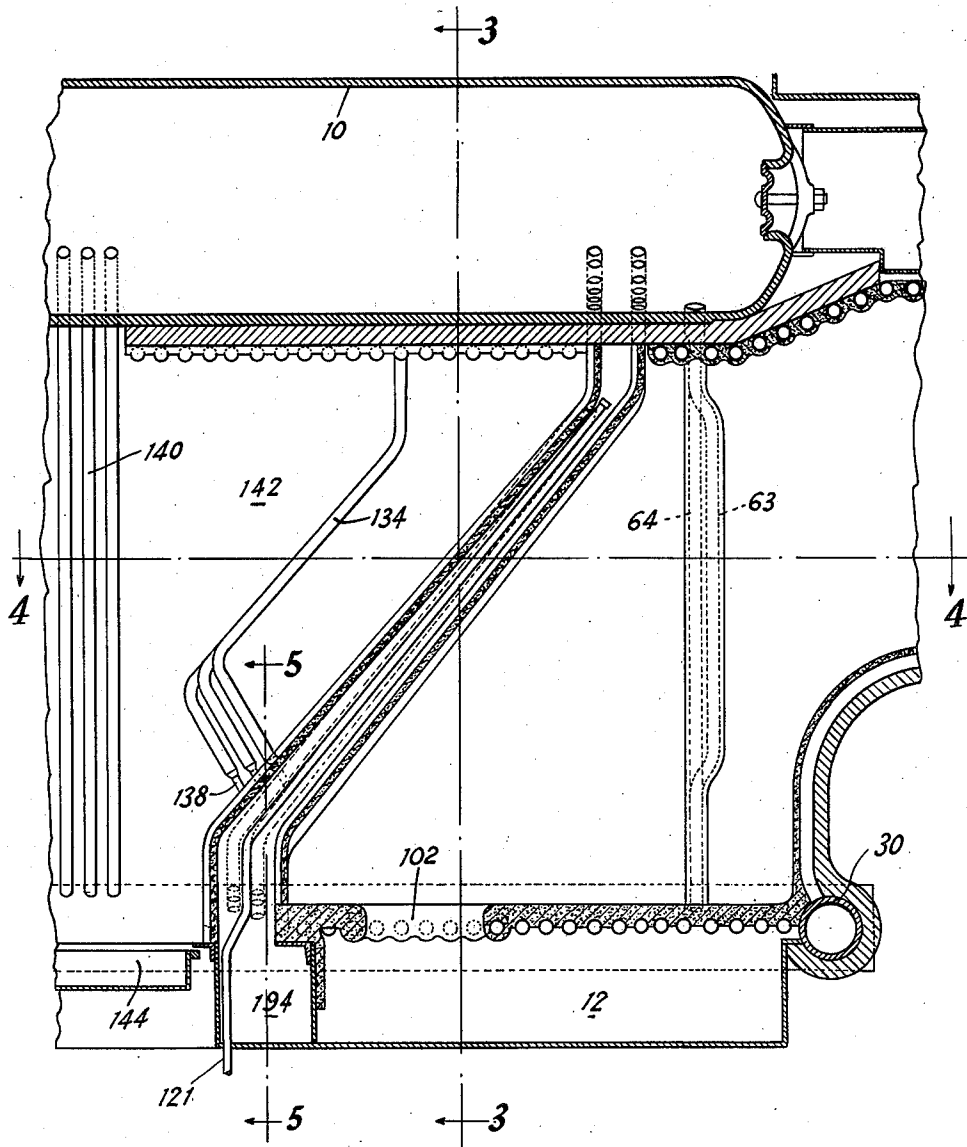


Fig. 2

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4 Sheets-Sheet 3

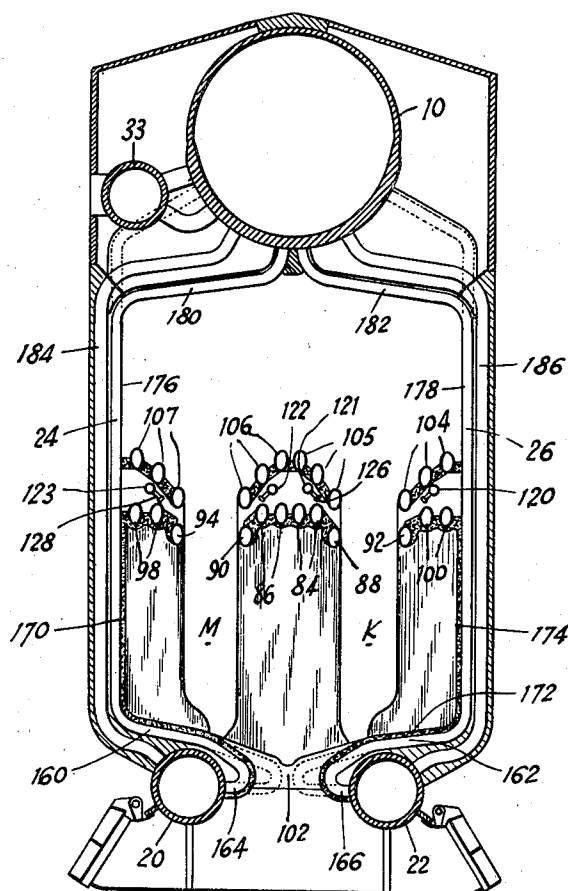


Fig. 3

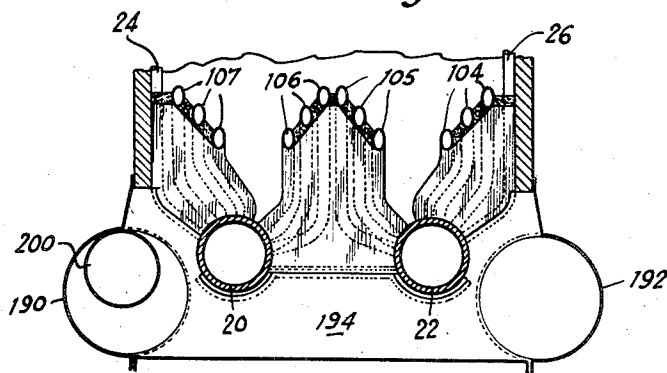


Fig. 5

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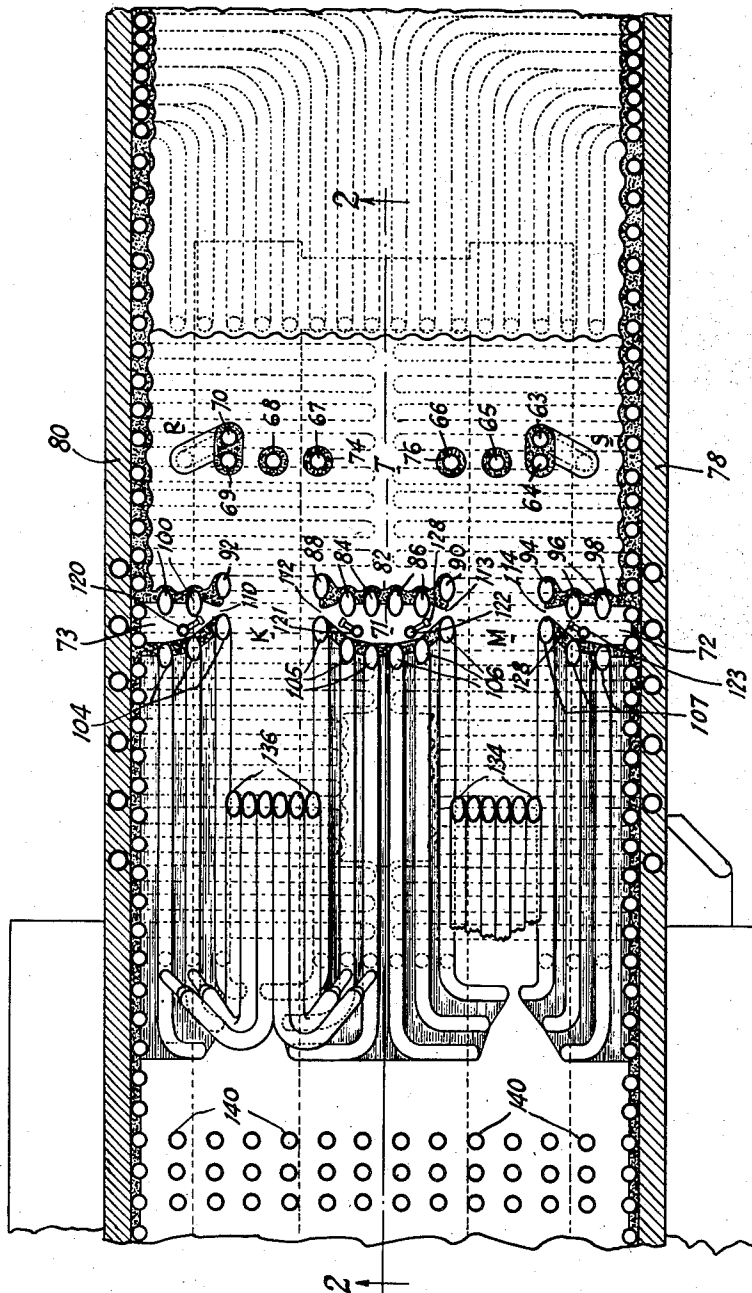
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FLUID HEAT EXCHANGE APPARATUS

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4 Sheets-Sheet 4



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FLUID HEAT EXCHANGE APPARATUS

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10 Claims. (Cl. 122-235)

1

This invention relates to fluid heat exchange apparatus, as exemplified by an installation burning a slag forming fuel at high rates of heat release and utilizing the products of combustion therefrom in the generation of superheated steam.

The invention is specifically concerned with improvements in an installation burning a slag forming fuel under furnace temperature conditions conducive to the release and maintenance of ash and molten particles and to the subsequent conditioning of the high temperature combustion products delivered by the furnace. The invention involves a specific apparatus whereby the condition of such high temperature products is quickly changed from a molten state to a solid or semi-solid state by cooling the furnace gases in which the molten solids are carried in suspension. This cooling is accomplished by the mixture with the furnace gases of a low temperature tempering fluid under optimum conditions.

The invention provides an installation adapted for the burning of pulverized coal at high combustion rates and in a furnace of such space restrictions as those imposed by mobile power units, such as steam locomotives, delivering products of combustion carrying suspended residual ash particles in a physical form conducive to sustained high capacity heat absorption by the convection steam generating surfaces.

In a more specific sense, the invention involves a tempering fluid duct structure in which the marginal part of a duct wall across the path of oncoming furnace gases containing suspended molten ash particles, is arranged in a forward position relative to the remainder of that wall so as to promote the optimum tempering of the furnace gases by the tempering fluid by minimizing the concentration of the suspended slag particles at a position adjacent that part of the duct.

Various structural features comprising the invention are pointed out with particularity in the subjoined claims forming a part of this specification, and for a better understanding of this invention, its advantages and the specific objects attained by its use, reference should be had to the accompanying drawings in which a preferred embodiment of the invention has been illustrated.

In the drawings:

Fig. 1 is a longitudinal vertical section of the steam generator showing one of the forwardly inclined tempering fluid ducts at the outlet of the primary furnace;

Fig. 2 is a partial vertical section on the line 2-2 of Fig. 4, showing the tempering fluid duct section of the Fig. 1 installation on a larger scale;

2

Fig. 3 is a transverse vertical section on the line 3-3 of Fig. 2;

Fig. 4 is a horizontal section of the line 4-4 of Fig. 2; and

Fig. 5 is a partial vertical section on the line 5-5 of Fig. 2.

Fig. 1 of the drawings illustrates a water tube steam generator for a locomotive, the height of the installation, from its steam and water drum 10 to the bottom of the slag pan 12, being consequently limited by the restrictions of standard railway practice. The width of the installation is similarly restricted.

As an indication of the adaptability of the illustrative steam generator for railway use, Fig. 1 shows the furnace or combustion chamber 14 as disposed above the railway track 15. Consequently, the furnace is considerably foreshortened in its vertical dimensions, this limitation imposing difficult conditions relative to the burning of the slag forming fuel at high combustion rates.

The entire installation, including the furnace 14, is supported by a suitable locomotive frame, and provides for the substantially horizontal flow of combustion gases from the furnace straight through the installation, beneath the steam and water drum 10 to the flue 18, the walls and other boundary surfaces being formed by steam generating tubes connected into the fluid circulation system including the steam and water drum 10 and lower side headers 20 and 22. Fig. 3 indicates the manner in which such circulatory components are arranged, disclosing the opposite wall tubes 24 and 26 leading from the headers 20 and 22, respectively, to the steam and water drum 10.

The circulatory system providing wall cooled surface for the furnace 14 also includes the front wall headers 28 and 29, roof tubes 32, front wall tubes 34, floor tubes 36 and 38, and side wall tubes such as those indicated in Fig. 3. The floor tubes lead from lower header 30 along the floor and along the furnace walls to an upper auxiliary header 31 which is connected to the drum 10 by header 33, and appropriate connections.

The furnace is fired by a series of pulverized fuel burners such as 40-42, supplied with a mixture of pulverized fuel and primary air through burner tubes 44 and 46. The burners extend through a secondary air chamber 58 and direct fuel and air into the combustion chamber through downwardly tapering burner throats such as those indicated at 50-52. These burner throats are formed between successive deflectors

such as 55—56, supported by the roof tubes in the manner shown and more particularly indicated in the co-pending patent application of E. G. Bailey, Serial No. 86,172, filed April 8, 1949.

Flames from the burners impinge against a stratum of molten slag upon the rearwardly inclined floor 80 of the furnace, and furnace gas and molten slag particles in suspension flow from the furnace across and between the upright shadow tubes 63—70 (Fig. 4).

The shadow tubes are appropriately connected into the fluid circulation of the installation, and they are arranged in two groups disposed directly forwardly of the furnace gas tempering passages K and M, disposed between the tempering fluid ducts 71—73. The shadow tubes are stud tubes, covered with high temperature refractory material as indicated at 74 and 76. This construction promotes the removal of molten solids by flow downwardly along the refractory coverings of the tubes and toward the slag pan 12.

It will be noted that shadow tubes 70 and 63 are offset inwardly from the adjacent walls 78 and 80. This construction, together with the group arrangement of the shadow tubes, forms the relatively wide gas passages R and S directly in front of the forward walls of the tempering fluid ducts 73 and 72. The two groups of shadow tubes are also widely spaced to form the wide central gas passage T forwardly of the front concave wall 82 of the tempering fluid duct 71.

After passing the shadow tubes, the combustion products including the furnace gases and their suspended solids flow through the passages K and M between forwardly inclined groups of steam generating tubes arranged to form the tempering fluid ducts 71—73. The inlets of these ducts, disposed at their lower ends, are appropriately connected with a source of tempering fluid, such as low pressure steam, which may be advantageously exhaust steam from prime mover.

The middle tempering fluid duct 71 is delineated by the intermediate stud tubes 84 and 86 which are arranged in wall formation such as that shown in Fig. 4. Beyond these intermediate tubes, the marginal stud tubes 88 and 90 are forwardly offset as shown in the drawings. All of these wall tubes are preferably substantially uniformly spaced, with the inter-tube spaces closed by high temperature refractory.

The forward walls of the tempering fluid ducts 72 and 73 are of a construction similar to that just described, with the marginal stud tubes 92 and 94 offset forwardly of the remainder of those walls. Thus, the tube 94 is offset forwardly relative to the intermediate tubes 96 and the wall formed therealong by refractory 98. Similarly, the marginal tube 92 is offset forwardly relative to the tubes 100 and the wall formed by the connecting refractory material.

The above described concave construction of the forward walls of the tempering fluid ducts acts to overcome or minimize the tendency of the high velocity gases to carry the predominant proportion of the suspended molten solids through the passages K and M. This construction also promotes the movement of the molten solids towards the ash pan 12 and the slag discharge opening 102. The forward walls of the tempering fluid ducts, by reason of their forward inclination, tend to give such suspended solids downward components, and the flow of such suspended solids downwardly is increased by the inverted trough-like construction of the walls.

The rearward walls of the tempering fluid

ducts 71—73 are formed by the rows of stud tubes 104—107 constructed with the intervening refractory to form the inclined slots 110—114 through which the tempering fluid is transversely injected into the furnace gases and become mixed therewith.

For the purpose of periodically clearing the inclined slots 110—114 of slag accumulations high pressure steam tubes 120—123 extend into the ducts. These tubes are provided at vertically spaced positions with steam jet nozzles such as 126 and 128 directed toward the adjacent slots.

Rearwardly of the tempering passages K and M are the tube plattens 134 and 135. Tubes forming these plattens have the major parts of their lengths inclined in the same manner as the tubes forming the tempering fluid ducts and each platten consists of six contiguous tubes which are appropriately connected into the fluid circulation. Preferably, their upper ends are connected to the steam and water drum 10 and the lower parts of some of the tubes forming the ducts 71—73. Such a connection is indicated at 138 in Fig. 2. These plattens form radiant heat shields and gas flow deflectors, and they divide the chamber between the bank of widely spaced screen tubes 140 and the tempering fluid ducts into the two zones, the rearward zone 142, being free of transverse tubes or other obstructions. This arrangement promotes the distribution of the furnace gases and the separation therefrom of fly ash which is collected in the subjacent ash pan 144.

After passing between the widely spaced tubes of the screen 140 the furnace gases pass through the flow equalizing space 146 and then between and around the closely spaced tubes of the superheater screen 150. The gases next pass over the closely spaced tubes of the convection superheater 152 and then over the tubes of the bank of upright steam generating tubes 154. Beyond this point, the gases pass across the bank of air heater tubes 156 to the flue 18.

Fig. 3 of the drawings indicates the construction of the installation at a position rearwardly of the shadow tubes and looking toward the lower parts of the furnace gas tempering passages K and M. As here indicated, the wall tubes have floor extensions such as 160 and 162 which are reversely bent on opposite sides of the slag discharge opening 102, for connection with the headers 20 and 22, as indicated at 164 and 166. The floor tube sections 160 and 162 and the lower parts of the wall tubes 24 and 26, forwardly of the tempering fluid ducts have their furnace sides covered with high temperature refractory as indicated at 170—174. However, for the purpose of promoting the cooling of the gases beyond the point of entry of the tempering gases through passages M and K, the upper parts of the wall tubes are bare as indicated at 176 and 178. The roof tube extensions 180 and 182 of these tubes are similarly bare.

Exteriorly of the wall tubes 24 and 26 are rows of downcomers 184 and 186 connected at their upper ends to the steam and water drum 10 and connected at their lower ends to the headers 20 and 22 as indicated in Fig. 3.

Fig. 5 indicates the manner in which the tubes forming the walls of the tempering fluid ducts are connected to the lower water headers 20 and 22. This figure also indicates the longitudinally extending large diameter tempering fluid conduits 190 and 192 which are transversely connected to the lower ends of the tempering

5

fluid ducts by the chamber 194. The ducts 190 and 192 extend along either side of the installation from a transverse conduit 196 receiving tempering fluid from a conduit 198.

For the purpose of maintaining the zone of the slag discharge opening 192 above the fusion temperature of the slag, the slag pan 12 is appropriately connected with a conduit 200 which extends through the larger conduit 190 to a position where it is connected to the bypass duct 202 having the outlet 204 just forwardly of the air heater 156. Bypass flow of high temperature furnace gases from the primary furnace through the slag discharge opening and then to the air heater may be controlled by an appropriately positioned damper.

Although this application discloses the pulverized fuel fired installation for a steam generator in which a tempering fluid is caused to be mixed with the products of combustion in the furnace, this application is limited to that subject matter with the added construction of the forward walls of the ducts through which the tempering fluid is caused to flow in the furnace. The general organization minus this particular construction of the forward walls of the ducts is claimed in the co-pending application of Ervin G. Bailey and Ralph M. Hardgrove, Ser. No. 86,171, filed on April 8, 1949.

What is claimed is:

1. In a water tube steam generator, a furnace having its boundary surfaces delineated by steam generating tubes and having means associated therewith for burning pulverized fuel at furnace temperatures above the fusion temperatures of the non-combustible in the fuel, a convection section including a bank of spaced steam generating tubes, and inclined tempering fluid ducts extending transversely of the furnace gas flow between the furnace and the convection section and having their walls formed by groups of steam generating tubes connected into the circulation of the generator the steam generating tubes of the front walls of said ducts immediately marginal relative to said passage being offset toward the furnace from the adjacent tubes.

2. Apparatus for conditioning products of combustion of pulverized coal flowing horizontally in a gas pass from a high temperature furnace to a convection section including closely spaced fluid heating tubes, said apparatus including a fluid cooled furnace adapted to have a slag stratum flowing over its floor to a slag discharge opening, a tempering fluid system including fluid cooled ducts for introducing and mixing a tempering fluid with the horizontally flowing stream of furnace gases between the ducts, said ducts being inclined and extending upwardly and forwardly of said opening through the furnace gases and having opposite tempering fluid discharge ports opening toward the stream of furnace gases, and means supplying tempering fluid to said ducts, the forward walls of said ducts (presented toward oncoming furnace gases) having their marginal portions extending forwardly of the remainder of said walls.

3. In a water tube steam generator, a primary furnace having means associated therewith for burning pulverized fuel at furnace temperatures above the fusion temperatures of the non-combustible in the fuel, the primary furnace having boundary surfaces defined by wall cooling steam generating tubes, groups of forwardly inclined steam generating tubes connected into the cir-

6

culution of the generator and arranged to present a furnace gas cooling barrier across the vertical extent of the furnace with a passage between the groups of tubes for the exit of furnace gases from the furnace, said groups of tubes being also arranged to form inclined tempering fluid ducts of relatively large free flow area extending into the furnace and having tempering fluid ports at the sides of said passage, means for supplying said ducts with a supply of tempering fluid for discharge of that fluid through said ports into mixing relationship with the furnace gases, and a convection section including a bank of steam generating tubes and a superheater disposed rearwardly of said tempering fluid ducts, the forward walls of said tempering fluid ducts having their edge parts marginal to said passage offset forwardly relative to the remainder of the forward walls.

4. In a steam generator, a pulverized coal burning furnace operating at gas temperatures in excess of the fusion temperature of the incombustible residue from the fuel, burners, water cooled tubes defining the furnace boundary surfaces, a convection section including closely spaced steam generating tubes, spaced groups of steam generating tubes delineating the front and rear walls of inclined tempering fluid ducts with their outlets leading to furnace gas passages between said groups, and means supplying a tempering fluid to said ducts, the front wall tubes of said groups marginal to said passage being offset forwardly of remainder of the front walls.

5. In a water tube steam generator, a primary furnace having means associated therewith for burning pulverized fuel at furnace temperatures above the fusion temperatures of the non-combustible in the fuel, the primary furnace having boundary surfaces defined by wall cooling steam generating tubes, groups of forwardly inclined steam generating tubes connected into the circulation of the generator and arranged to present a furnace gas cooling barrier across the vertical extent of the furnace with a passage between the groups of tubes for the exit of furnace gases from the furnace, said groups of tubes being also arranged to form inclined tempering fluid ducts of relatively large free flow area extending into the furnace and having tempering fluid ports at the sides of said passage, means for supplying said ducts with tempering fluid for discharge of that fluid through said ports into mixing relationship with the furnace gases, and a convection section including a bank of steam generating tubes and a superheater disposed rearwardly of said tempering fluid ducts, the forward walls of said tempering fluid ducts being of trough-like formation with their channels opening toward the primary furnace.

6. In a water tube steam generator, a furnace having its boundary surfaces defined by steam generating tubes and having means associated therewith for burning pulverized fuel at furnace temperatures above the fusion temperature of the non-combustibles in the fuel, a convection section including a bank of steam generating tubes, and tempering fluid ducts having outlets directed transversely of the flow of furnace gases between the furnace and the convection section, said ducts having front walls extending transversely of the flow of furnace gases and having marginal portions offset forwardly of the remainder of said walls.

7. In a vapor generator, a furnace having its boundary surfaces defined by vapor generating

tubes and having means associated therewith for burning pulverized fuel at furnace temperatures above the fusion temperature of the non-combustibles in the fuel, a convection section including a bank of vapor generating tubes heated by gases from the furnace, and tempering fluid ducts having outlets directed transversely of the flow of furnace gases between the furnace and the convection section, said ducts having front walls extending transversely of the flow of furnace gases and having marginal portions offset forwardly of the remainder of said walls, said front walls thereby presenting channels opening toward oncoming furnace gases.

8. Apparatus for conditioning products of combustion of pulverized coal flowing horizontally in a gas pass from a high temperature furnace to a convection section including closely spaced fluid heating tubes, said apparatus including a fluid cooled furnace adapted to have a slag stratum flowing over its floor to a slag discharge opening, a tempering fluid system including transversely spaced fluid cooled ducts for introducing and mixing a tempering fluid with the horizontally flowing stream of furnace gases between the ducts, said ducts being inclined and extending upwardly and forwardly of said opening through the furnace gases and having opposite tempering fluid discharge ports opening toward the stream of furnace gases, the forward walls of said ducts (presented toward oncoming furnace gases) having their marginal portions extending forwardly of the remainder of said wall, and upright shadow tubes connected into fluid circulation and grouped across the furnace gas flow at positions forwardly of the spaces between said adjacent fluid cooled ducts.

9. In a water tube steam generator, a primary furnace having means associated therewith for burning pulverized fuel at furnace temperatures above the fusion temperatures of the non-combustible in the fuel, the primary furnace having boundary surfaces defined by wall cooling steam generating tubes, groups of forwardly inclined steam generating tubes connected into the circulation of the generator and arranged to present a furnace gas cooling barrier across the vertical extent of the furnace with a passage between the groups of tubes for the exit of furnace gases from the furnace, said groups of tubes being also arranged to form inclined tempering

fluid ducts of relatively large free flow area extending into the furnace and having tempering fluid ports at the sides of said passage, means for supplying said ducts with a supply of tempering fluid for discharge of that fluid through said ports into mixing relationship with the furnace gases, a convection section including a bank of steam generating tubes and a superheater disposed rearwardly of said tempering fluid ducts, the forward walls of said tempering fluid ducts having their edge parts marginal to said passage offset forwardly relative to the remainder of the forward walls to present concave faces to oncoming furnace gases, and upright shadow tubes connected into the fluid circulation of the steam generator and arranged across furnace gas flow at a position forwardly of said passage to direct fused ash particles against the forward walls of said ducts.

10. In a steam generator, a pulverized coal burning furnace, burners, water cooled tubes defining the furnace boundary surfaces, a convection section including closely spaced steam generating tubes extending across gas flow from said furnace, spaced groups of steam generating tubes delineating the front and rear walls of inclined tempering fluid ducts with side outlets leading to furnace gas passages between said groups, means supplying a tempering fluid to said ducts, the front wall tubes of said groups marginal to said passage being offset forwardly of remainder of the front walls, and upright shadow tubes connected into the fluid circulation of the steam generator and disposed in groups across furnace gas flow at positions forwardly of said passages.

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