July 4, 1950 J. H. JACOBS 2,513,328

STEAM GENERATOR

Filed Dec. 22, 1945 3 Sheets-Sheet 1

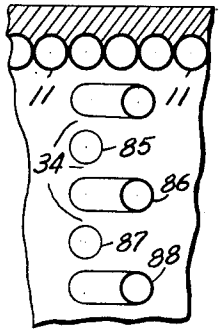


Fig. 10

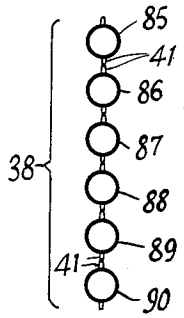


Fig. 8

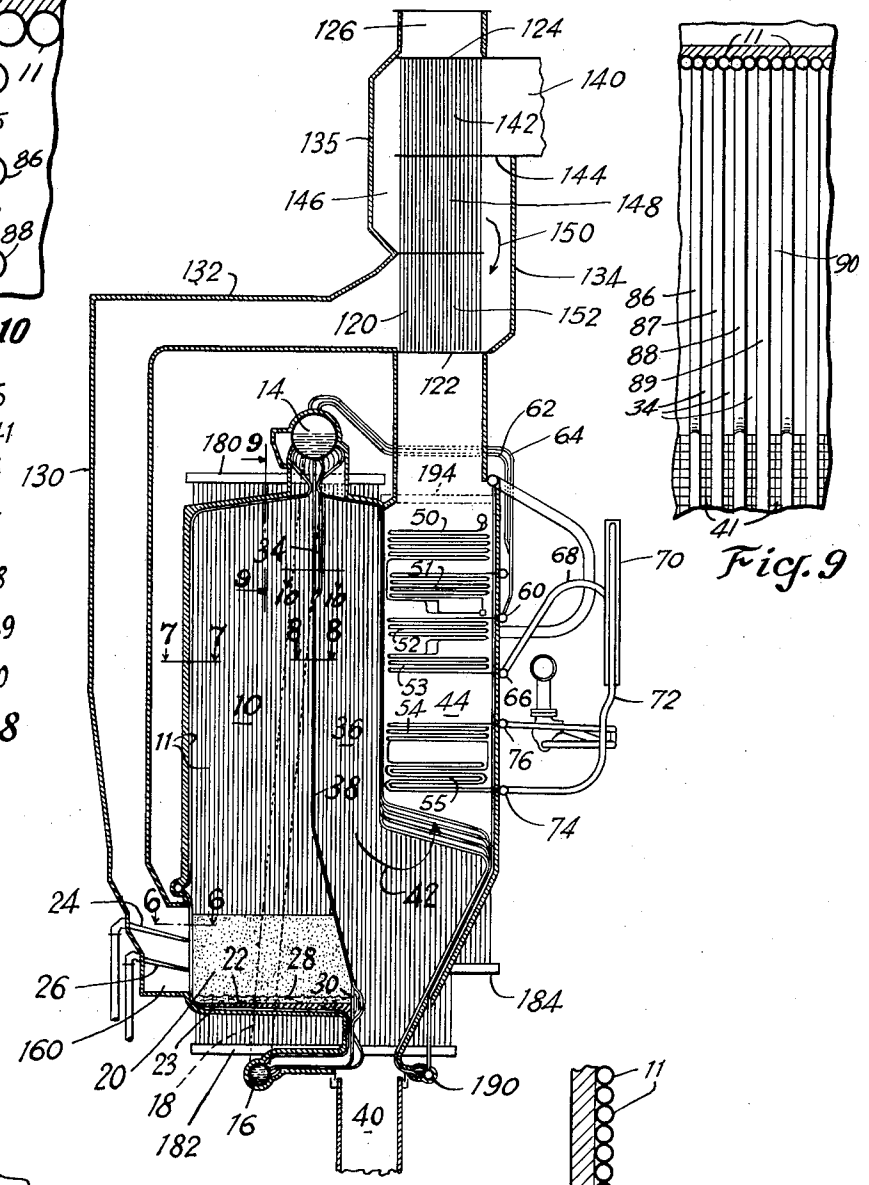


Fig. 1

Fig. 9

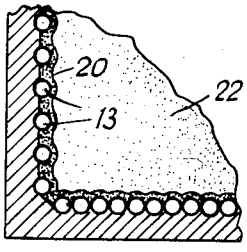


Fig. 6

Fig. 7

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STEAM GENERATOR

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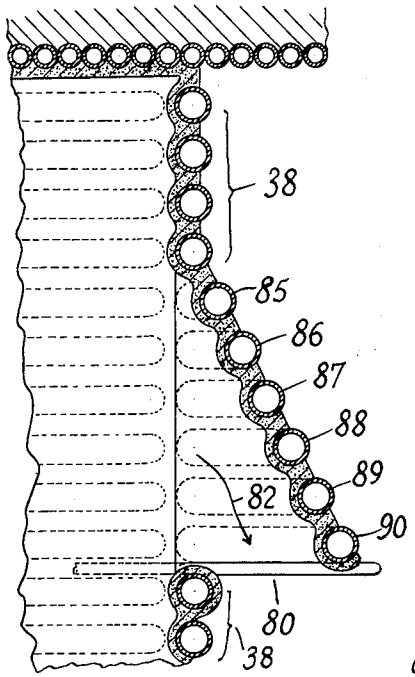


Fig. 3

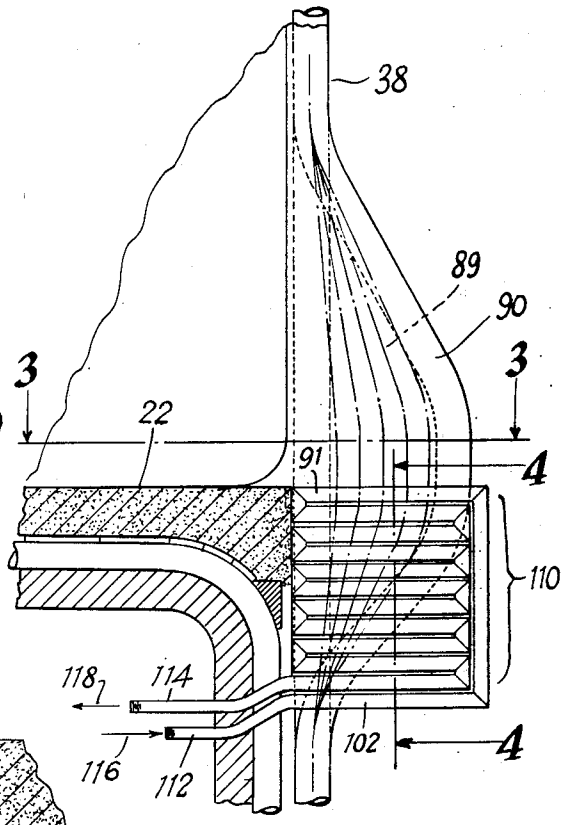


Fig. 2

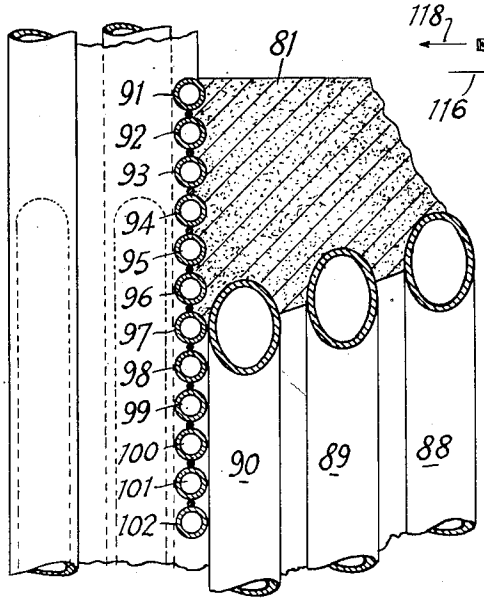


Fig. 4

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STEAM GENERATOR

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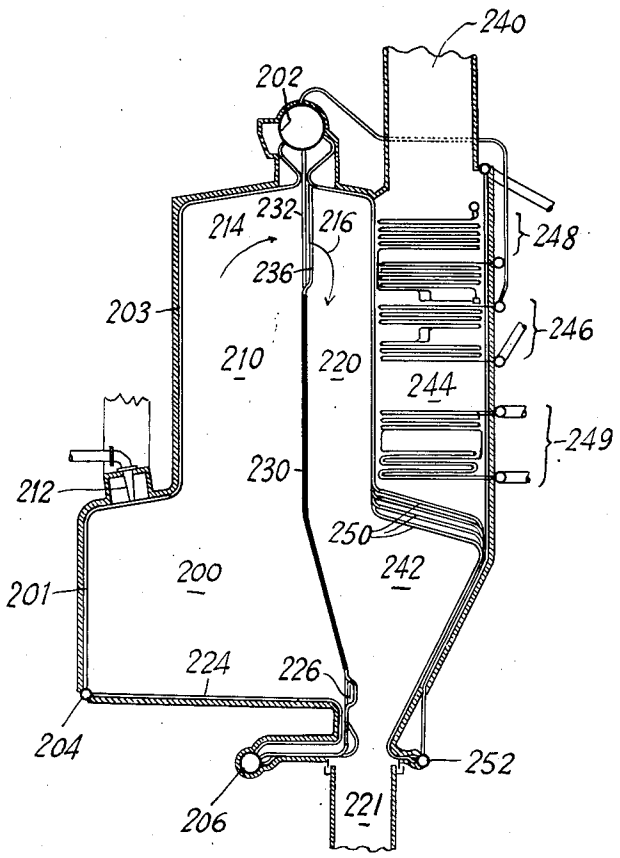


Fig. 5

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UNITED STATES PATENT OFFICE

2,513,328

STEAM GENERATOR

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Application December 22, 1945, Serial No. 636,908

3 Claims. (Cl. 122—235)

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This invention relates to a pulverized coal fired steam generator in which the major portion of the steam is generated by heat radiantly transmitted to furnace wall tubes. It is an improvement in the type of vapor generator utilizing the open-pass method of chilling of molten ash carried from the furnace with the products of combustion.

An object of the invention is the enhancement of the separation of molten ash in the high temperature gas zones of the furnace.

A further object of the invention is to increase the flexibility of operation in that ash bearing fuels having ash of high fusing and melting temperature characteristics can be separated and discharged from the furnace at comparatively low ratings of unit steam output.

A further object of the invention is the attainment of high rates of heat transfer to radiantly heated steam generating tubes, whereby an optimum extent of heat absorbing surface is required to accomplish radiant cooling of furnace gases.

These objects and others are attained by a steam generator in which a high temperature combustion zone is provided adjacent a molten slag discharge port, with a subsequent high temperature combustion gas zone bounded by steam generating tubes of high heat absorptive capacity in open radiant heat transfer relationship to the first zone, followed by a shielded "open-pass" gas and ash chilling zone discharging the residual products of combustion to the convection heat absorbing water and steam heating surfaces which are presented primarily by economizer and superheating tubes.

Various features of novelty of the invention are pointed out with particularity in the claims annexed hereto and forming a part of this specification, and, for a better understanding of the invention and the specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

In the drawings:

Fig. 1 is a vertical section through a high capacity steam generating installation of the open pass type, constructed in accordance with the teachings of the invention;

Fig. 2 is a view in the nature of a vertical section through the furnace floor and adjacent steam generating tubes opposite the burners;

Fig. 3 is a horizontal section on the line 3—3 of Fig. 2;

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Fig. 4 is a vertical section on the line 4—4 of Fig. 2;

Fig 5 is a vertical section of a modified steam generator, within the scope of the invention;

Fig. 6 is a fragmentary horizontal section on the line 6—6 of Fig. 1 and indicating the refractory lined furnace wall construction employed in the high temperature zone of the furnace;

Fig. 7 is a fragmentary horizontal section on the line 7—7 of Fig. 1, showing the bare tube wall construction of the furnace chamber;

Fig. 8 is a fragmentary horizontal section on the line 8—8 of Fig. 1 showing the finned tube construction of the wall between the high temperature furnace and the open pass;

Fig. 9 is a vertical section on the line 9—9 of Fig. 1, showing the furnace gas outlet at the upper part of the furnace chamber 10 in elevation; and

Fig. 10 is a partial horizontal section on the line 10—10 of Fig. 1.

The steam generating installation indicated in Fig. 1 of the drawings includes an upwardly extending elongated high temperature furnace chamber 10 to which pulverized solid fuel is introduced at the lower portion. The boundary surfaces are delineated by upright heat absorbing steam generating tubes 11 communicating at their upper ends with the steam and water drum 14 and at their lower ends with the submerged header or drum 16. The circulatory system including the tubes is completed by one or more large diameter external water downcomers, such as 18, connecting the steam and water drum 14 and the lower drum 16.

The high temperature furnace chamber 10 has a comparatively high temperature zone extending transversely of the chamber and having a highly refractory wall lining, as indicated at 20, carried on the inner faces of the tubes 13. This lining extends to a position above the burners and has a controlling influence upon the heat flow from the high temperature zone to the covered tube portions. It also acts to minimize tube metal wastage resulting from constituents of the molten ash occurring in this zone. A similar highly refractory covering 22 covers the other tube portions 23 which are extensions of the front wall tubes 13, forming a heat resistant floor to support a pool of separated molten ash resulting from the combustion of pulverized fuel introduced to the furnace with high temperature air by the turbulent type burners 24 and 26.

The burners provide for quick ignition and rapid combustion of the fuel with the high tem-

perature products of combustion directed across the furnace toward one or more molten ash or slag outlets at the opposite side of the furnace. Such an outlet is indicated at 30, and the detailed construction of the tube portions and the refractory material delineating the outlet is indicated by Figs. 2, 3, and 4 of the drawings.

From the lower high temperature zone at the burner level the open unrestricted furnace 10 extends upward to provide a high gas temperature zone of substantially rectangular cross-sectional flow area from which the gaseous products of combustion are discharged through the laterally positioned tube screened outlet 34 to the top of the open pass 36. The construction of the upper portion of the furnace 10 is distinctive in that the tubes 11 are closely spaced to provide a substantially closed bare metallic lining for the side and front walls, while the rear wall 38 which is common to the furnace 10 and the open pass 36 is formed of more widely spaced tubes (such as 85—90) with metallic space closures 41 as indicated by Fig. 8 taken along section 8—8 of Fig. 1.

The upper portions of the tubes of wall 38 are bent out of alignment at their upper ends to provide a gas outlet from furnace 10 to gas pass 36 while screening the latter from radiant heat transmission from the upper portion of furnace 10. These tubes are connected at their upper ends to the steam and water drum which is located above and between the furnace 10 and the open pass 36. The walls of the open pass are delineated by highly heat conductive steam generating tubes connected in a circulatory arrangement with the steam and water drum.

Below the level of the molten slag outlet 30 and below the open pass 36 is an ash and slag discharge pit 40 for the disposal of solids separated from the gases passing downwardly through the open pass and turning as indicated by arrow 42 into the pass 44 of the convection section. As shown, this convection section consists of banks 52—55 of spaced convection superheater tubes arranged as horizontal coil sections extending across the path of the gases. The superheater inlet header 60 is connected by the tubes 62 and 64 to the steam space of the steam and water drum 14, and saturated steam passes from the header 60 through the series connected tubes of the superheater banks 52 and 53 to the intermediate outlet header 66. From that outlet header, the steam passes through the conduit 68 to an attemperator 70 for controlling the final steam temperature.

From the attemperator, the steam passes through a conduit 72 to the inlet header 74 of a second section of the superheater consisting of the banks of tubes 54 and 55. From this section, the steam passes to the outlet header 76 and thence to a point of use.

In the illustrative steam generating and superheating installation, where superheat temperatures of the order of 900° to 950° F. are desired, it is essential to provide heating gas temperatures at the superheater gas inlet high enough to provide sufficient temperature differential between the gas and the tube metal to economically attain sufficient heat transfer. On the other hand, in the interest of decreased outage for cleaning as well as operation at substantially uniform high superheat temperatures it is most important that an external heat insulating accumulation of slag or ash originating from the products of combustion on the superheater tubes

be avoided as far as economically possible. The ash constituents of the products of combustion are to be eliminated, in so far as economically desirable, before the heating gases contact the superheating surface, while retaining the gases at temperatures of the order of 2000° F. at which deposits of residual ash particles will be at a minimum and the gas temperature is sufficient for effective superheater performance.

The present invention accomplishes these objects by effecting a high degree of radiant heat absorption and a separation of a major portion of the molten ash constituents of the products of combustion, in the high temperature furnace zone, and then utilizes the open pass cooling of gases and gas borne ash particles for further reduction of temperature and gas ash content to a degree acceptable as heating gases for the convection superheater.

In the operation of the present steam generating installation the turbulent combustion in the higher temperature zone in the lower portion of the furnace can be considered to give an adiabatic combustion temperature of the order of 3600° to 3700° F., thereby insuring a gas temperature in that zone which will enhance the molten ash separation due to the proximity to the slag pool but will also be effective in maintaining the superposed open zone of the furnace at high gas temperature as the result of radiant heat transfer. With the high temperature gases moving upwardly through the upper zone, which is surrounded by highly effective metallic walls, a high rate of heat transfer to the walls is attained and the molten ash deposited thereon is maintained in a highly fluid condition permitting it to flow downwardly to the pool without material accumulation on the wall surface. With the arrangement shown the gas temperature reduction will be to a temperature corresponding approximately to the melting temperature of the fuel ash and the open-pass will reduce the temperature down to the desired level.

With the arrangement as above discussed, I have found that in addition to accomplishing the desired degree of gas temperature reduction and ash separation, a material reduction in the extent of radiant water cooling surface necessary is attained. This reduction may in certain cases, depending upon the characteristics of the fuel, amount to as much as 17% of radiant heat absorbing surface as compared with shielded surface arrangement for the gas cooling zone beyond a high temperature combustion zone, with a corresponding reduction in cost.

A reduction in furnace draft loss also results from the specified arrangement of operative elements of the high temperature furnace.

Figs. 2, 3, and 4 show the details of one of the fluid cooled slag outlets for the high temperature furnace section at the burner zone. Such an outlet is indicated at 80 in Fig. 3, and the associated arrow 82 indicates the general flow of fluid slag to the outlet. Some of the tubes such as 85—90 of the heat absorbing wall 38 common to the furnace chamber 10 and the open pass 36 have portions near the furnace floor 22 which are bent outwardly as indicated in Fig. 3 to form the slag outlet 80. The positioning of these tubes at the slag outlet is further indicated in Fig. 2 and Fig. 4 shows a body 81 of highly refractory ceramic material disposed on the lower sections of the bent portions of the tubes 85—90 to form a continuation of the upper surface of the furnace floor 20 for slag flow over the outlet barrier

presented by the series connected tube sections 91—102 of the fluid cooled coil indicated generally by the numeral 110. This coil is supplied with water or other fluid under such temperature and rate of flow conditions that damage by the high temperature slag is substantially prevented. Such fluid enters the coil inlet 112 and, after proceeding through the sections of the coil passes out through the outlet 114 as indicated by the arrows 116 and 118 in Fig. 2.

Referring again to Fig. 1, the gases after leaving the banks of superheater tubes 52—55 pass across the banks of tubes 50—51 which are economizer tubes. Thereafter, the gases pass through the airheater tubes 120 connecting the tube sheets 122 and 124. Thence the gases pass from the outlet 126 to a stack.

The duct work sections 130—132 and the air heater casement sections 134—135 direct air from the airheater inlet 140 over the airheater tubes in the first air pass 142, and then around the baffle 144 to the entrance 146 of the second air pass 148. After passing over the air tubes in this second air pass, the gases turn as indicated by the arrow 150 and pass through the last air pass 152, through the duct work sections 132 and 130, and then to the secondary air chamber 160 from which the heated air passes into the high temperature furnace section to support combustion of the fuel supplied by the burners 24 and 26.

Fig. 1 also discloses headers 180—182—184 for the side wall tubes. The lower headers are connected either to the lower water drum 16 and the upper headers such as 180 and 194 are connected to the steam and water drum 14.

The modified steam generator illustrated in Fig. 5 has a high temperature furnace chamber section 200 the boundary surfaces of which are formed by steam generating tubes such as those defining the walls 201 and 203. These tubes are connected into a circulatory system including steam and water drum 202, the header 204 and the submerged drum or header 206.

Above the high temperature furnace chamber 200 is the furnace chamber 210, the wall tubes of which are subject to radiation from the high temperature chamber 200. This results in increased rates of heat absorption through the tubes defining the secondary chamber 210, and, when pulverized fuel is utilized by the burner 212, the residual solids along the walls of the chamber 210 are maintained in a fluid state.

From the top of the furnace chamber 210, the gases flow in the direction of the arrows 214 and 216 into the top of the open pass 220. In this pass the gases flow downwardly toward a solids deposition zone 221 toward which fused slag from the furnace floor 224 flows through the outlet 226.

The open pass 220 is separated from the furnace chambers 200 and 210 by a common heat absorbing wall 230 formed by steam generating tubes such as 232 and 236 directly connecting the drums 202 and 206 as shown. Preferably, at least the furnace sides of the tubes of the walls 230 are covered with a highly refractory material and the slag outlet 226 is formed in a manner similar to that previously described in connection with the description of the steam generator of Fig. 1.

Between the flue 240 and the gas turning zone 242, the gases pass upwardly through the gas pass 244 over the tubes of the superheater sections 246 and 249, as well as tubes of the economizer section 248. At the inlet of the convection section gas pass 244, the gases pass over a fluid cooled screen 250 formed by parts of steam generating tubes which directly connect the steam and water drum 202 and the lower header 252 as indicated in the drawings.

What is claimed is:

1. In a vapor generator, rows of upright vapor generating tubes delineating a vertically elongated and unobstructed combustion chamber of rectangular horizontal cross-section, fuel burners at the lower part of the combustion chamber and firing the latter with a high temperature ignition section at the lower part of the combustion chamber, the combustion chamber extending vertically to an extent several times the height of the high temperature section without such diminution in the horizontal cross-section area of the combustion chamber as to create substantially higher gas velocity, additional rows of upright vapor generating tubes combining with some of the first mentioned tubes to delineate a vertically elongated upright open gas pass the inlet of which communicates with the combustion chamber at the top of the latter, said open pass inlet being positioned laterally of the upper zone of the combustion chamber which is delineated by substantially completely metal surfaces presented by the upper portions of some of the first mentioned tubes, one of said first mentioned rows of tubes delineating a separating wall common to the combustion chamber and said gas pass, the vertical height of the open gas pass being of the same order as the vertical height of the combustion chamber, means constituting a convection section and including a gas pass the lower end of which is in gas flow communication with the open pass at substantially the same level as that of the high temperature section of the combustion chamber, other vapor generating tubes delineating a combustion chamber floor normally retaining a pool of molten ash deposited from the fuel, said fuel burning means normally directing burning fuel across said slag pool and toward a slag discharge opening through said separating wall, the slag discharge opening being disposed outside the main path of furnace gases from the combustion chamber to the convection section, the metallic walls of the first mentioned rows of tubes being directly exposed to the products of combustion throughout the major portion of the combustion chamber height and also directly exposed to radiant heat of said high temperature ignition section, and means maintaining fluid circulation through said tubes.

2. In a vapor generator, rows of upright vapor generating tubes delineating a vertically elongated and unobstructed combustion chamber of rectangular horizontal cross-section, fuel burners at the lower part of the combustion chamber and firing the latter with a high temperature ignition section at the lower part of the combustion chamber, the combustion chamber extending vertically to an extent several times the height of the high temperature section without such diminution in the horizontal cross-section area of the combustion chamber as to create substantially higher gas velocity, additional rows of upright vapor generating tubes combining with some of said first mentioned tubes to delineate a vertically elongated upright open gas pass the inlet of which communicates with the combustion chamber at the top of the latter, said open pass inlet leading from the combustion chamber at a position where the inlet faces metallic walls formed by the highly heat conductive upper por-

tions of the first mentioned tubes, one of said first mentioned rows of tubes delineating a separating wall common to the combustion chamber and said gas pass, the vertical height of the open gas pass being of the same order as the vertical height of the combustion chamber, means constituting a convection section and including an upright gas pass the lower end of which is in gas flow communication with the open pass at a level substantially the same as that of the high temperature section of the combustion chamber, other vapor generating tubes delineating a combustion chamber floor normally retaining a pool of molten ash deposited from the fuel, the lower portion of said separating wall being inclined and thereby facing downwardly toward the slag pool at the bottom of the combustion chamber, said fuel burning means normally directing burning fuel across said slag pool and toward a slag discharge opening through said separating wall, the slag discharge opening being disposed outside the main path of furnace gases from the combustion chamber to the convection section, the metallic walls of the first mentioned rows of tubes being directly exposed to the products of combustion throughout the major portion of the combustion chamber height and also directly exposed to radiant heat of said high temperature ignition section, and means maintaining fluid circulation through said tubes.

3. In a vapor generator, rows of upright vapor generating tubes delineating a vertically elongated and unobstructed combustion chamber of rectangular horizontal cross-section, fuel burners at the lower part of the combustion chamber and firing the latter with a high temperature ignition section at the lower part of the combustion chamber, the combustion chamber extending vertically to an extent several times the height of the high temperature section without such diminution in the horizontal cross-section area of the combustion chamber as to create substantially higher gas velocity, additional rows of upright vapor generating tubes combining with some of said first mentioned tubes to delineate a vertically elongated upright open gas pass the inlet of which communicates with the combustion chamber at the top of the latter, said open pass inlet leading from the combustion chamber at a position where the inlet faces metallic walls formed by the highly heat conductive upper portions of the first mentioned tubes, one of said first mentioned rows of tubes delineating a separating wall common to the combustion chamber and said gas pass, the vertical height of the open gas pass being of the same order as the vertical height of the combustion chamber, means constituting a convection section and including an upright gas pass the lower end of which is in gas flow communication with the open pass at a level substantially the same as that of the high temperature section of the combustion chamber, other vapor generating tubes delineating a combustion chamber floor normally retaining a pool of molten ash deposited from the fuel, said fuel burning means normally directing burning fuel across said slag pool and toward a slag discharge opening through said separating wall, the lower portion of said separating wall being inclined to thereby face downwardly toward the slag pool and form a lower portion of said high temperature section extending toward the gas burning zone below the open pass and the convection section, the slag discharge opening being disposed outside the main path of furnace gases from the combustion chamber to the convection section, the metallic walls of the first mentioned rows of tubes being directly exposed to the products of combustion throughout the major portion of the combustion chamber height and also directly exposed to radiant heat of said high temperature ignition section, and means maintaining fluid circulation through said tubes.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,268,559	Bailey	Jan. 6, 1942
2,268,560	Bailey	Jan. 6, 1942

Certificate of Correction

Patent No. 2,513,328 July 4, 1950

JOHN H. JACOBS

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 8, line 26, for the word "burning" read *turning*;

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of January, A. D. 1951.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.