Aug. 17, 1954 E. J. HAUCK 2,686,500

VAPOR GENERATOR

Filed Sept. 1, 1949 3 Sheets-Sheet 1

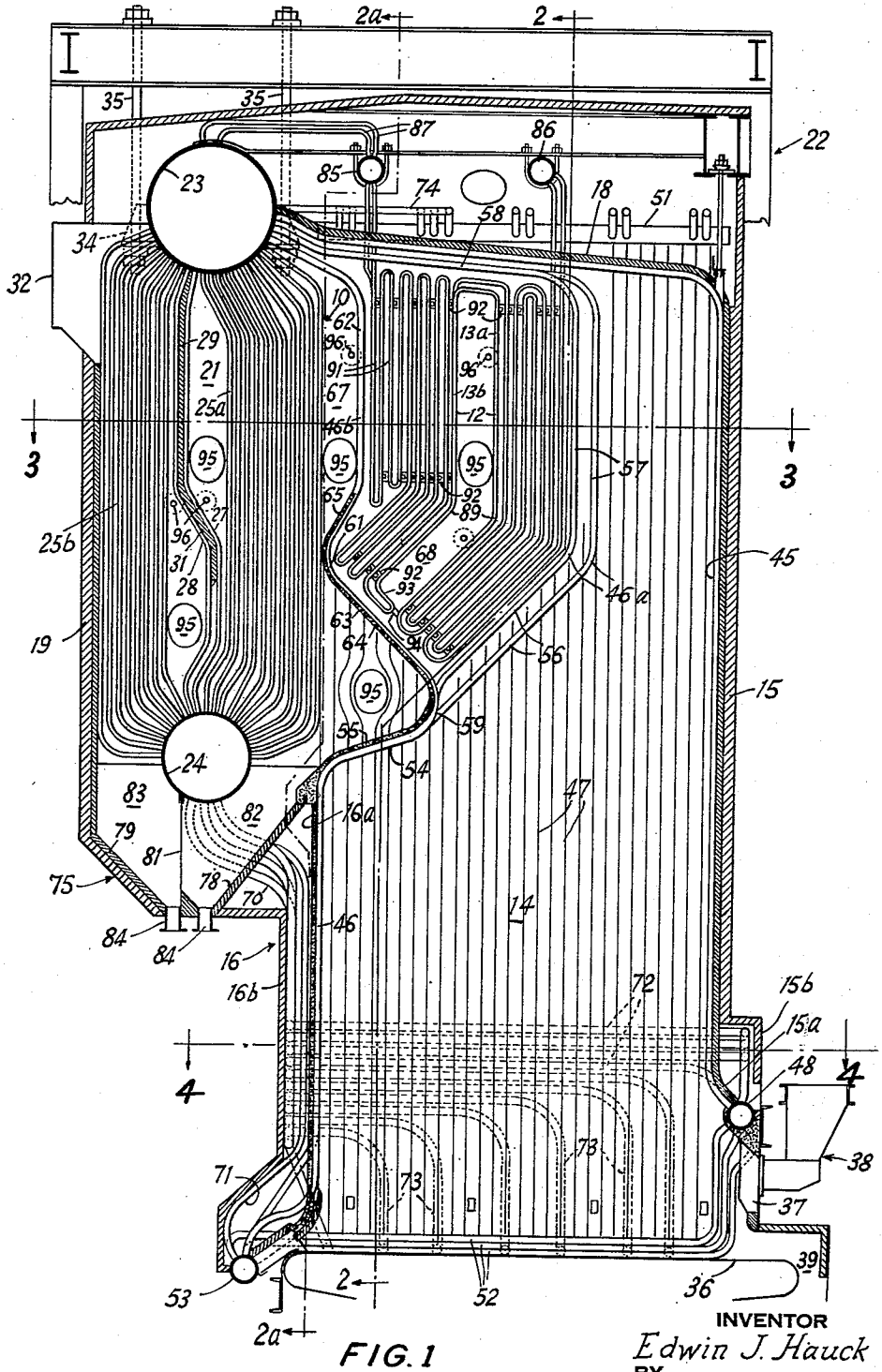


FIG. 1

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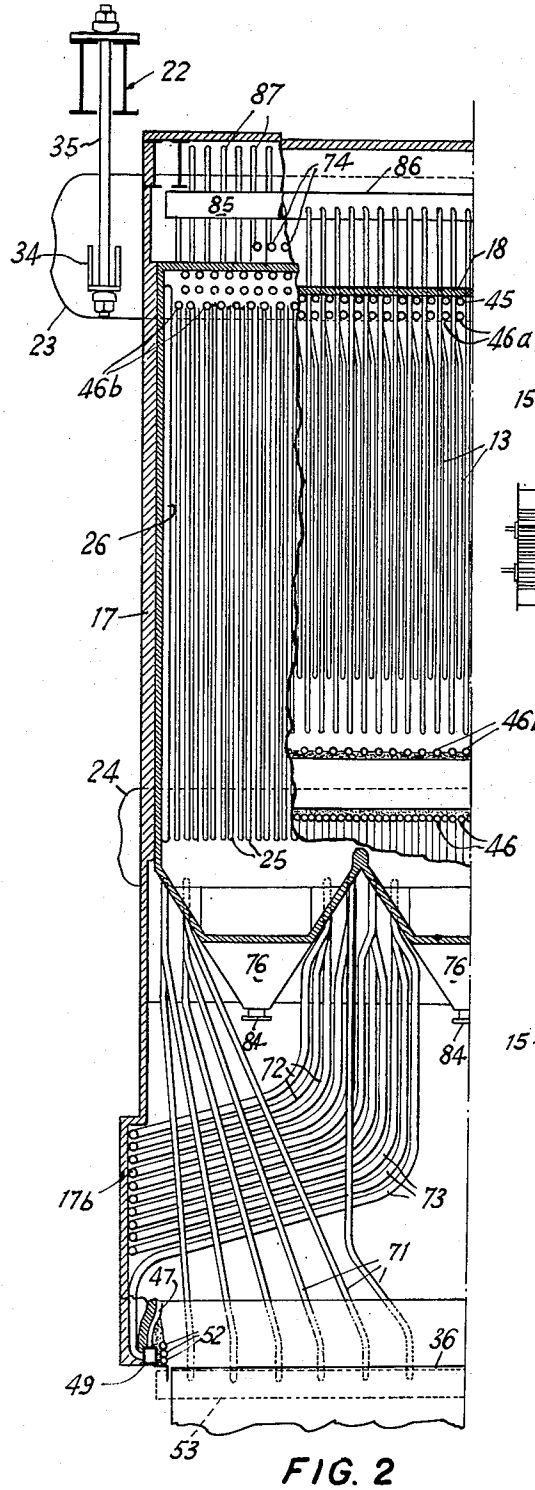


FIG. 2

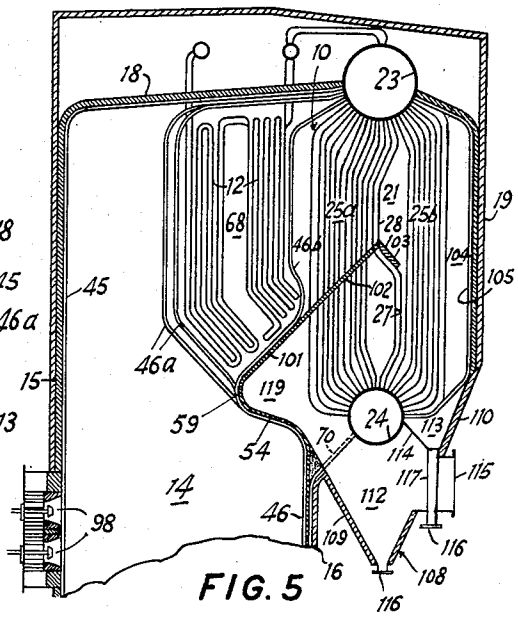


FIG. 5

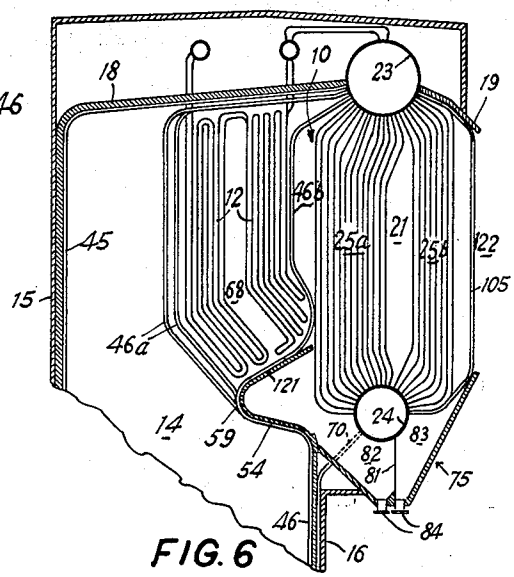


FIG. 6

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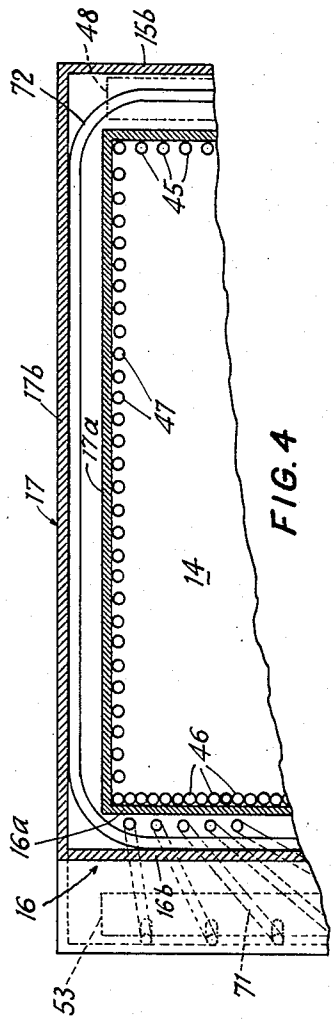


FIG. 4

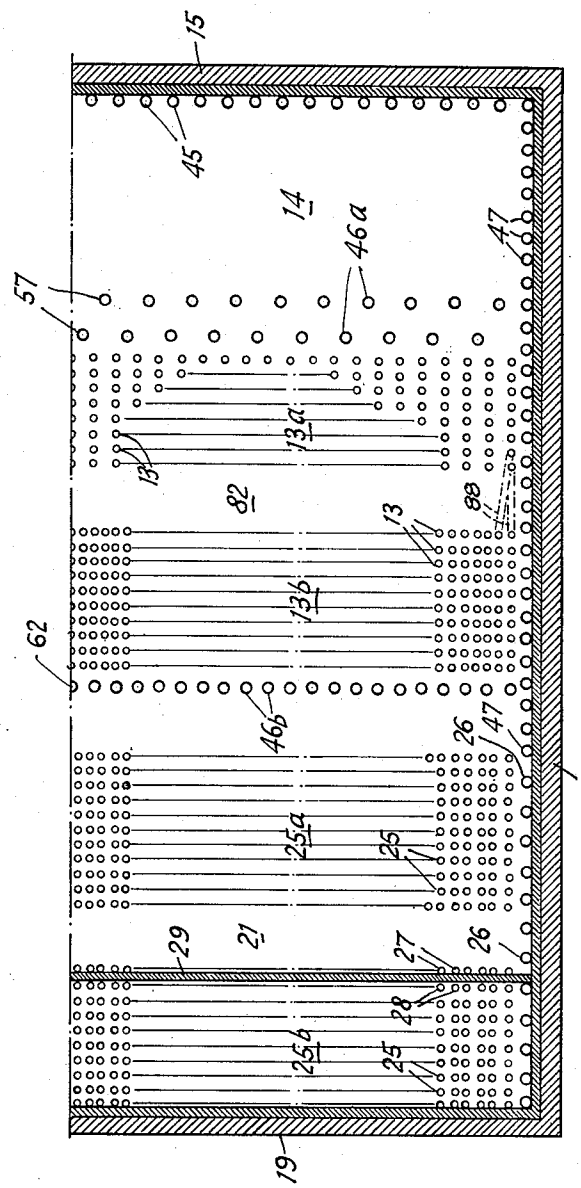


FIG. 3

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UNITED STATES PATENT OFFICE

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VAPOR GENERATOR

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Application September 1, 1949, Serial No. 113,559

6 Claims. (Cl. 122—333)

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The present invention relates in general to the construction and operation of fluid heating apparatus of the class known as vapor generators and having provision for superheating the vapor generated therein. More particularly, my invention relates to steam generators of the type embodying tubular steam generating and steam superheating elements and deriving heat from the combustion of fuel in an associated furnace.

The vapor generator of my invention is adapted for various methods of firing including, for example, firing by means of a traveling grate stoker located at the bottom of a fluid cooled combustion chamber, below the location of convection heating surface components or sections, in and adjacent an upper portion of the chamber. The furnace chamber extends throughout the height of the setting and a bent tube boiler section is offset therefrom in a space adjacent the roof. A superheater is positioned forwardly of the boiler section and overlies a substantial area of the horizontal cross section of the combustion chamber. In accordance with certain objects of my invention, provision is made for accommodating a superheater of considerable depth in comparison with the depth of combustion chamber space available, and for protecting the tubular superheater elements from intense radiant heat, while permitting an appreciable amount of radiant heat to penetrate the superheater tube bank or banks so as to obtain a more nearly uniform superheat temperature throughout a relatively wide range of vapor output capacities. It is also my purpose to indicate the adaptability of my invention to vapor generators having different arrangements of gas flow paths therethrough, with provision for the effective trapping of solids discharged from the heating gases at one or more points along such paths of flow.

The various features of novelty which characterize my invention are pointed out with particularity in the claims 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 descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

Of the drawings:

Fig. 1 is a sectional side elevation of a vapor generator embodying various features of my invention;

Fig. 2 is a sectional front elevation of one-half

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of the illustrated embodiment taken along line 2—2 of Fig. 1, partly broken away along line 2a—2a;

Figs. 3 and 4 are partial sectional plan views of the embodiment taken along lines 3—3 and 4—4, respectively, of Fig. 1; and

Figs. 5 and 6 are partial sectional side elevations showing modifications.

In more detail, Figs. 1–4 illustrate an embodiment of my invention in the form of a vapor generator comprising a two-drum water-tube boiler 10 and its associated superheater 12 deriving heat in common from a fuel fired furnace or combustion chamber 14. The vapor generator enclosure or setting is of substantially rectangular horizontal arrangement throughout its height and generally defined by fluid cooled upright walls 15, 16, and 17 which constitute the front, rear and opposing side walls, respectively, of chamber 14. Front wall 15 is extended over the combustion chamber to form an upper enclosing wall or roof 18, while rear wall 16 includes a rearwardly offset upper portion 19 to provide a boiler tube space 21 laterally adjoining the upper portion of combustion chamber 14. The lower portion of rear wall 16 may include, as shown, an inner wall section 16a directly adjacent chamber 14, and an outer casing wall section 16b spaced therefrom and forming an enclosure for circulatory connections later to be described. The lower portions of front wall 15, and each side wall 17, may be similarly formed with spaced inner and outer portions 15a, 15b, and 17a, 17b, substantially as shown. The complete vapor generator assembly is suitably suspended from an overhead load supporting structure indicated at 22.

The boiler 10 is of a two-drum, bent-tube type comprising horizontally disposed upper and lower drums 23 and 24 of which the upper drum 23 is of larger diameter than the lower drum 24, and the longitudinal drum axes are disposed in a common upright and substantially vertical plane. Upright boiler tubes 25 extend between drums 23 and 24 and are connected thereto at their opposite ends, the tubes 25 being arranged in transversely spaced banks 25a and 25b and throughout each bank are spaced apart in longitudinal and transverse parallel rows, with the upper and lower end portions of the tubes being bent as shown for radial entry into the respective drums. Tubes 25, as shown, are suitably of 2" O. D. throughout, and in all transverse rows are arranged at alternate center-to-center spacings of 3" and 4⅛" to facilitate tube removal. However, as will be understood, tubes 25 of other

diameters, at other spacings, may be utilized, such as tubes of 2½" O. D. equally spaced on 3½" centers in each transverse row, for example, and swaged to 2" O. D. at their drum ends for adequate ligament strength. Other boiler tubes 26 connecting drums 23, 24, and of larger diameter than tubes 25, are arranged in rows adjacent the respective side walls 17.

In two intermediate rows, boiler tubes 27 and 28 are reversely bent intermediate their ends as indicated and thereby provide opposite end tube portions associated with separate banks. An upright gas directing baffle 29 extends downwardly between these rows of tubes 27, 28 from upper drum 23 to a point upwardly and vertically spaced from the lower drum 24 at a lesser distance than its vertical displacement from upper drum 23, the baffle 29 having its shorter lower vertical portion forwardly offset from its longer upper vertical portion and connected thereto by an inclined intermediate portion 31. A gas outlet 32 is provided in rear wall 19 adjacent upper drum 23. Brackets 34 secured to upper drum 23, at opposite sides, may be utilized in conjunction with hangers 35 for supporting the weight of boiler section 10.

As herein illustrated, the combustion chamber 14 is fired by means of a spreader stoker delivering fuel to a traveling grate 36 located at the bottom of the chamber and providing top-run grate movement toward front wall 15 wherein the customary fuel delivery opening 37 is provided, the fuel feeding mechanism being indicated generally at 38. A fuel such as crushed coal is thus projected into the combustion chamber toward rear wall 16, in upwardly spaced relation to grate 36, and over substantially the entire grate area. With air supplied in the usual manner from beneath the grate, and through the grate, the finer fuel particles are burned in suspension while the coarser particles fall to the grate and are burned thereon. In the course of operation, combustion takes place at the highest rates adjacent rear wall 16, opposite the wall through which fuel is introduced, and thus results in the creation of a zone of intense radiant heat, and maximum temperature conditions, in this part of the chamber. Residual ash is carried forwardly by the grate and discharged at a point 39 adjacent front wall 15. The walls of combustion chamber 14 are lined throughout with fluid cooling tubes which in the front, rear and side walls comprise the upright fluid cooling tubes 45, 46 and 47 respectively.

In front wall 15, the tubes 45 are spaced apart, for example, and have their lower ends connected to header 48 which extends transversely of the setting at an elevation above fuel delivery opening 37, the tubes 45 being extended along the roof 18 and having their upper ends connected to upper drum 23.

In each side wall 17, the tubes 47 are spaced apart, for example, and extend upwardly from a lower header 49, located adjacent the top run of grate 36, to an upper header 51 located adjacent the uppermost part of chamber 14. Other tubes associated with each side wall 17 include a group of horizontally arranged tubes 52 disposed adjacent the furnace face of side wall header 49 to provide a heat barrier between the fuel bed and the header, the tubes 52 having fluid inlet end portions bent downwardly and connected to a transverse header 53 at the rear of grate 36, below top-run level, and having fluid outlet end portions bent upwardly and connected to the front wall header 48, above top-run level.

In rear wall 16, the tubes 46 are suitably more closely spaced than the tubes in other walls and are connected at their lower ends to the rear wall header 53. In the form shown, tubes 46 are tightly spaced throughout the width of rear wall 16 so as to place successive tubes of the row in contacting relationship, substantially as indicated in Fig. 4. From their lower end connections to header 53, tubes 46 extend upwardly along the lower rear wall portion 16*a* to approximately the centerline elevation of the lower boiler drum 24, at which elevation the tubes 46 are bent forwardly toward the front wall 15 to form an arch 54 extending forwardly and upwardly over the rear end of stoker grate 36. Selected tubes 46*a*, such as all alternate tubes of the tube row 46, for example, are continued forwardly and upwardly in vertically spaced rows 56 to a location forwardly of superheater 12 where they are extended vertically in horizontally spaced rows 57 to an elevation adjacent the roof 18. From this elevated position, tubes 46*a* are extended over the superheater in a single upwardly inclined row 58 toward drum 23 to which the upper ends of tubes 46*a* are connected. The remaining alternate tubes 46*b* are bent upwardly and rearwardly to form a rounded nose 59 of arch 54 at a distance from rear wall 16 of approximately one-fourth to one-third of the total depth of combustion chamber 14 between the inner faces of front and rear walls 15 and 16. From the arch nose 59, the tubes 46*b* are continued upwardly and rearwardly below superheater 12 to a point adjacent the front boiler bank 25*a* where the tubes 46*b* are bent in the reverse direction as at 61 to a forward position adjacent superheater 12 where the tubes 46*b* continue upwardly in a single vertical row 62 and thereafter are extended rearwardly in an upwardly inclined direction toward upper drum 23 for connection thereto in a single row below the row 58 of tubes 46*a*.

A refractory backing 55 is applied to the rearward side of tubes 46 forming arch 54, while above the nose 59 the spaces between successive tubes 46*b* are closed by suitable known intertube space closure means so as to form a baffle 63 extending upwardly between the boiler and superheater and terminating at an elevation approximately half-way of the vertical distance separating the boiler drums 23 and 24. The baffle 63 thus includes a lower portion 64 inclined upwardly from the arch nose 59 toward boiler section 10, and a forwardly inclined upper terminal portion 65 disposed at substantially the same elevation as the oppositely inclined intermediate portion 31 of boiler baffle 29. The vertical space between the upper end of baffle portion 65 and the roof 18 provides a gas flow opening 67 connecting the superheater cavity 68 with the boiler tube space 21.

The circulatory connections for the furnace wall tubes include a group of downcomers 70 which extend downwardly from lower drum 24 between the inner and outer rear wall sections 16*a* and 16*b*. Tubes 71 of this group are connected to rear wall header 53, while tubes 72 and tubes 73 extend forwardly between side wall sections 17*a* and 17*b* and are connected at spaced intervals to the front wall header 48 and to a lower side wall header 49 respectively. Riser tubes 74 connect each upper side wall header 51 to the upper boiler drum 23.

A hopper 75, comprising a series of hopper sections 76, is provided beneath boiler section 10 throughout the width of the setting between opposite side walls 17, with each hopper section having its inclined front wall 78 extending from the juncture of the lower rear furnace wall section 16a with arch 54, and its inclined rear wall 79 forming a lower end continuation of the upper setting wall portion 19. The end walls of the hopper sections are suitably shaped, as indicated in Fig. 2, to provide spaces enabling the downcomers 70 to be connected to the lowermost part of drum 24, without passing through any part of the ash collecting space of the hopper. The hopper 75 is divided longitudinally of the drum by an upright partition 81 in each section so as to separate the hopper into front and rear compartments 82 and 83 of which each is provided with a separate lower end outlet 84.

The superheater 12 is positioned above arch 54 between the upright tube rows 57 and 62 which are formed by upper length portions of the rear furnace wall tubes 46. The divided, and substantially right-angled upwardly divergent arrangement of selected rear wall tubes 46a and 46b beyond the arch thus provides a large superheater cavity 68 forwardly of the boiler section 10 and at the same time provides a staggered tube screen 56, 57 forwardly of the superheater and throughout the height of the cavity. The superheater is of the pendant continuous-tube type having multiple loop coils or platens arranged in parallel planes, equally spaced across the width of cavity 68 between opposite side walls 17. The entire weight of the superheater is transmitted to the overhead structure 22 through the superheater inlet and outlet headers 85 and 86. The superheater tubes 13, suitably of 2'' O. D., are arranged in two spaced banks 13a and 13b, and in transverse rows in which the tubes are more widely spaced in the front bank 13a than in rear bank 13b, such as at center-to-center spacings of 6'' and 3'', in the respective banks. End tube lengths in the rearmost row of rear bank 13b are connected to inlet header 85 to which inlet tubes 87 from drum 23 are connected. End tube lengths in the two front rows of front bank 13a are connected to outlet header 86. Cross over connections 88 are provided for connecting each pair of tube coils in two planes of inlet bank 13b to a pair of tube coils in a single plane of outlet bank 13a.

The superheater loops are formed so as to provide the maximum amount of superheater surface which can reasonably be accommodated within the cavity 68. The upper portions of all loops are accordingly arranged vertically and thus parallel to the screen tube rows 57 at the front and to the vertical row 62 of wall tube extensions 46b at the rear. The majority of the loops are provided with bends 89 intermediate their lengths, and at progressively higher elevations from front to rear of the banks, so as to position the lower end portions of such bent loops substantially parallel to the inclined screen tube rows 56 at the front and to the inclined upper baffle portion 65 at the rear. The lower portions of the angularly formed, bent loops thus extend substantially normal to the inclined lower baffle portion 64, with their lower return bends closely adjacent thereto and positioned rearwardly of a vertical plane tangent to the arch nose 59 so as to be shielded from the intense radiant heat from the furnace zone below the arch. The remainder of the cavity space, rearwardly of the bent loops, is occupied by straight vertical loops 91, of different lengths, directly adjacent the gas outlet 67 from the cavity.

Adjacent loops of each bank are tied together in the customary manner at several elevations, as indicated at 92, suitably by known means permitting limited longitudinal movement of one loop relative to another. In bank 13b, the lower end portion 93 of each foremost loop is extended forwardly and downwardly across the interbank space toward the rearmost loops of the front bank 13a where other suitably short connecting ties 94 are provided.

Ample provision is made for maintaining the various heating surface components free from excessive accumulations of fly ash and other solid products of combustion. For example, the arrangement of the total heating surface is such as to provide spaces between or adjacent heating surface sections for the advantageous application of access openings 95 and soot blowers 96.

In the operation of the unit illustrated in Figs. 1–4, the heating gases resulting from the combustion of fuel in chamber 14 are directed through successive heating surface sections in three successive passes, namely, a first pass generally transverse of tubes 13 throughout the height of superheater 12; a second, downward pass longitudinally throughout the first boiler bank 25a; and a third, upward pass longitudinally throughout the second boiler bank 25b, to gas outlet 32. In entering the superheater cavity 68, the gases in the uppermost part of chamber 14 follow a generally horizontal path into and through the upper portion of the cavity, while the gases at a lower elevation tend to follow a diagonally upward path into and through a lower portion of the cavity. Thus, with superheater loops, as disclosed, having upper portions in vertical planes and lower portions extending rearwardly at an angle to such planes, the resultant flow of all entering gases, at all elevations, is generally transverse of superheater loops throughout the height of the cavity. The direction of gas flow with respect to the superheater tube lengths thus traversed is therefore, from a practical standpoint, substantially uniform throughout the height of the cavity so as to provide a corresponding uniformity of gas flow resistance over the entire length of superheater loops adjacent the furnace and thus obviates bypassing of gases across lower portions of loops as would be expected if the customary completely vertical loops were correspondingly suspended so as to position an equally large proportion of superheater surface forwardly of the arch nose 59.

The disclosed arrangement of superheater also enables a shorter overall depth of unit to be utilized for an equivalent amount of superheater surface, than if the screen tubes were extended in vertical planes substantially tangent to or adjacent the arch nose 59 with the entire superheater surface disposed to the rear of such planes. Thus, by extending the screen tubes 46a to positions forwardly of the arch and close to the front furnace wall 15, the available size of superheater cavity is increased without increasing the horizontal depth of unit as measured from the front wall 15 to the first boiler bank 25a. Furthermore, by forming the superheater loops as described, with lower loop portions extending rearwardly at an angle to their upper loop portions, the lower return bends of the loops are brought into positions above arch 54 where they are adequately shielded from intense radiant heat from the furnace chamber 14. An additional advantage in operation results from the wider transverse spacing of superheater tubes in the

forward bank 13a than in the rearward bank 13b, and also the provision of a widely spaced tube screen 56, 57 forwardly of both banks. In such an arrangement, an appreciable amount of radiant heat is allowed to penetrate into the superheater bank or banks and thus acts to flatten the curve of superheat temperatures at increasing vapor output capacities.

The modifications illustrated in Figs. 5 and 6 are to be understood as embodying a majority of the features described in connection with the embodiment of vapor generator shown in Figs. 1–4. For this reason, much of the detail construction has been omitted from the drawings so as to direct attention more particularly to the distinct modifications involved. Elements corresponding to elements of Figs. 1–4 are accordingly identified by the same reference characters in Figs. 5 and 6. The burners 98, indicated in front wall 15, may be utilized separately as the sole firing means for chamber 14 or, if desired, may be utilized alternately with, or simultaneously with, a stoker firing means in a lower part of the chamber.

Referring to Fig. 5, the vapor generator is arranged for cross pass flow of heating gases throughout the boiler tube banks 25a and 25b. In order to provide such an arrangement, the baffle 101 associated with intermediate portions of selected rear wall tubes 46b, is extended as at 102 across the first boiler bank 25a and across the two intermediate rows of tubes 27 and 28 which have end portions associated with the respective banks. The baffle 101 extends upwardly and rearwardly from the arch nose 59, in a plane adjacent the lower ends of the superheater loops and thus defines in part the superheater cavity 68 in addition to defining gas flow passes through the boiler. A short baffle section 103, forming a continuation of baffle 101, extends downwardly and rearwardly along the inclined intermediate portion of tubes 28. In this modification, the rear wall 19 is separated from the boiler tube bank 25b so as to provide additional space 104 for gases flowing around the end of baffle 101. A tube row 105 of bank 25b, or an additional row, is positioned adjacent rear wall 19, in spaced relation to the main body of tubes of the bank.

A hopper 108, having inclined front and rear walls 109 and 110, respectively, is positioned beneath both banks of boiler section 10, as in the previously described embodiment, and similarly divided into sections throughout the width of the setting, with downcomers 70 disposed between successive sections, as heretofore disclosed. The hopper is separated into front and rear compartments 112 and 113 by means of an inclined partition 114 extending from the lower drum 24 to the upper margin of the gas outlet 115 which is provided in the hopper rear wall 110. Each compartment is formed with a bottom outlet 116, and the compartment 113 of each hopper section having a discharge spout 117 which extends across the gas outlet duct 115.

The gases from combustion chamber 14 thus pass to the upper side of baffle 101 to enter the superheater cavity 68 and then continue around the upper end of the baffle to provide two pass flow transversely of the front and rear boiler banks 25a and 25b and, upon arriving at space 119 rearwardly, of the arch nose 59, are directed between drum 24 and the front hopper wall 109 into the front hopper compartment 112 from whence they pass into the gas outlet 115. During the two-pass flow of gases over the second boiler bank 25b, solid particles discharged from the gas stream are directed into the rear hopper compartment 113, while particles remaining in the gas stream are discharged into the front compartment 112.

Fig. 6 illustrates the adaptability of the vapor generator to single pass gas flow throughout all heating surface sections. In this form, the inclined baffle 121 associated with intermediate portions of selected rear wall tubes 46b, extends upwardly and rearwardly toward the boiler section 10 and terminates at a point directly in advance of the first row of tubes of the front bank 25a. In the absence of all boiler baffling, the gases are directed across both banks 25a and 25b in a single substantially horizontal pass and leave the setting through a gas outlet 122 which is formed in the upper rear wall portion 19, the outlet 122 being positioned opposite the space between the drums, and having a height practically equal to the vertical distance separating the drums.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form of my invention now known to me, 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 my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

Certain features disclosed herein are also disclosed, and are claimed, in the copending application of Charles L. Marquez, Jr., Serial No. 112,802, filed August 27, 1949.

I claim:

1. A vapor generator having walls defining a combustion chamber and a boiler space in laterally adjoining front and rear relation within a common setting, said walls including a front upright wall through which fuel is introduced into said chamber and opposite upright walls of which the first forms the rear outer wall of said chamber and a second forms the rear outer wall of said boiler space, a tubular boiler section in said space comprising an upper drum adjacent the upper boundary of said space and having upright tubes extending downwardly from said drum and connected thereto at their upper ends, an arch extending forwardly from said first rear wall above the elevation of fuel introduction into said chamber and providing an arch nose rearwardly spaced from said front wall, an upper arch portion extending upwardly from said nose in a plane intersecting all of said upright tubes in downwardly spaced relation to said upper drum to define a gas flow opening into said boiler space, the lower portion of said arch lying in a plane intersecting said front wall at an elevation lower than the uppermost end of said upper arch portion which continues to at least a position forwardly adjacent said boiler section tubes, a tubular superheater disposed above said arch and in part between said arch and said front wall, wall cooling tubes associated with said first rear wall having portions associated with said arch and having other length portions extending upwardly clear of said arch and forming a tube screen between said superheater and the fuel introduction zone of said chamber therebelow, and other tubes associated with said first rear wall and said arch having portions extending upwardly between said superheater and said boiler section tubes.

2. A vapor generator as claimed in claim 1 wherein said boiler section tubes are arranged in front and rear banks and a baffle directly succeeding said arch is disposed throughout between the major portions of said banks and extends downwardly from said upper drum to an elevation below said gas flow opening.

3. A vapor generator as claimed in claim 2 comprising a lower boiler drum disposed at approximately the elevation of said arch and to which the lower ends of said banks of upright tubes are connected, and walls forming a separate hopper compartment beneath each of said banks, said arch having an outer wall surface defining an enlargement of said boiler space having direct communication with the hopper compartment beneath said front bank, said hopper compartment walls including a side wall inclined downwardly and rearwardly in continuation of an inclined outer surface portion of said arch and a wall extending downwardly from said lower drum and separating one compartment from another.

4. A vapor generator as defined in claim 1 and further comprising a stoker-fed grate in a lower portion of said combustion chamber onto which grate the introduced fuel is deposited, said boiler section including a lower drum adjacent the lower boundary of said space, to which lower drum the lower ends of said upright boiler tubes are connected, said boiler section tubes being arranged to form a front and a rear bank, said superheater above said arch comprising depending loops of angular formation having upright upper straight length portions positioned beyond said arch and rearwardly inclined lower return bend portions disposed adjacent said arch in overlying relation thereto, said upper arch portion continuing rearwardly to form a baffle extending across said front boiler bank in spaced relation to said upper and lower drums and defining therewith a two-pass gas flow path across upper and lower portions of said front bank, and means including hopper walls below said lower drum for directing gases to a gas outlet at the rear of the setting.

5. A vapor generator having fluid cooled walls defining a combustion chamber and a boiler space in laterally adjoining front and rear relation within a common setting, said walls including a front upright wall extending throughout the height of said chamber and opposite upright walls of which the first forms the rear wall of said chamber and a second forms the rear wall of said boiler space, said first rear wall providing a heating gas outlet from an upper part of said chamber and said second rear wall providing a gas outlet from said space, a tubular boiler section in said space comprising an upper drum adjacent the upper boundary of said space and a lower drum adjacent a lower boundary of said space at an elevation intermediate the height of said setting, upright boiler tubes arranged in front and rear banks within said space and extending between and connected at opposite ends to said drums, fuel firing means in a lower portion of said chamber creating a maximum temperature zone adjacent said rear wall, an arch extending forwardly from said first rear wall at an elevation above said firing means and said zone and providing an arch nose at a distance from said first rear wall less than one-half of the horizontal depth of said chamber, said arch having an inclined upper section formed as a baffle extending rearwardly and upwardly to a position forwardly adjacent said front bank of boiler tubes, said upper arch section lying in a plane intersecting the planes of said two rear walls at elevations below said upper drum and also intersecting said front wall at an elevation above said fuel firing means, means including said baffle for directing gases into said front tube bank in a pass including at least the upper portions of tubes forming said bank, a row of upright wall cooling tubes in said first rear wall having portions entering into the formation of said arch, selected tubes of said row entering into the formation of said baffle and other tubes of said row extending upwardly from said nose in widely divergent relation to said baffle tubes and forming a tube screen having its lower portion inclined upwardly toward said front wall and its upper portion extended vertically in rearwardly spaced relation thereto, and a superheater disposed above said arch and having depending loops in each of a plurality of parallel upright planes arranged normal to said first rear wall, said loops being of angular formation in said planes corresponding to the formation of said screen and providing upper loop portions forwardly of said nose and lower loop portions directed toward said inclined baffle section at a steep angle and terminating in return bends confined to the horizontally projected area of said arch.

6. A vapor generator as defined in claim 1 wherein said upper arch portion terminates at said position forwardly adjacent said boiler section tubes so as to direct gases transversely of said tubes in a single pass.

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