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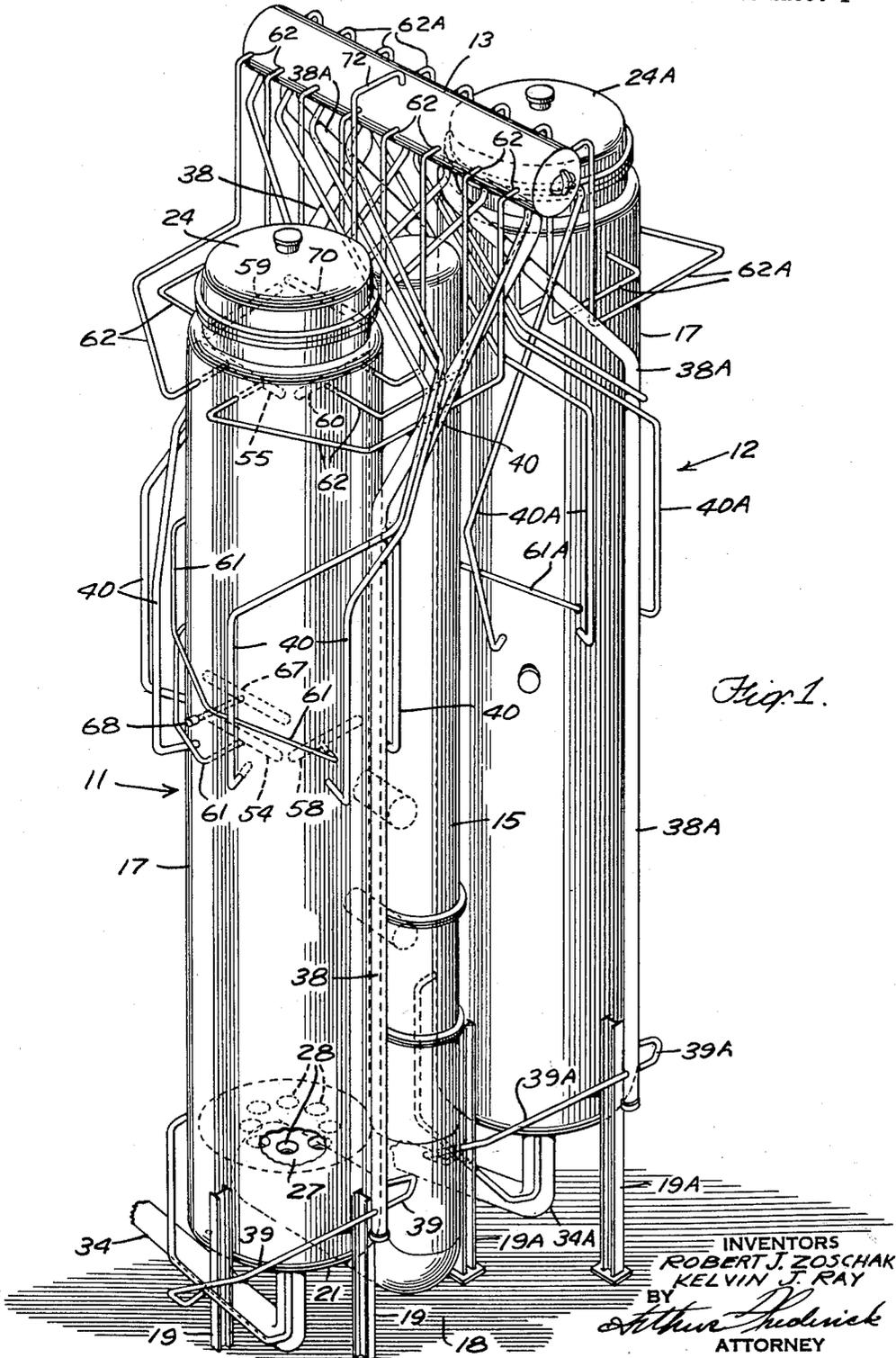
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3,072,109

SUPERCHARGED VAPOR GENERATOR

Original Filed May 28, 1958

5 Sheets-Sheet 1



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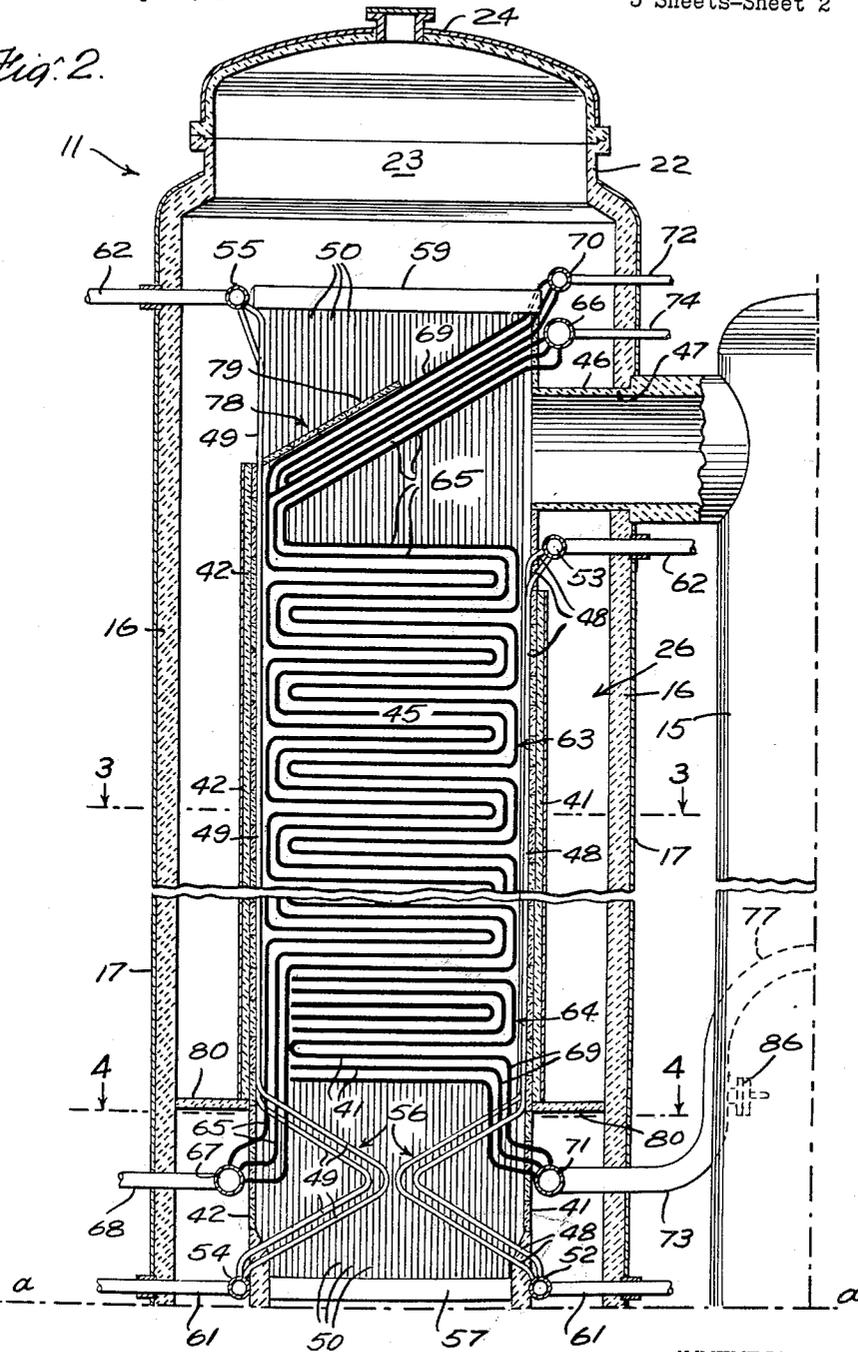
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Fig. 2.



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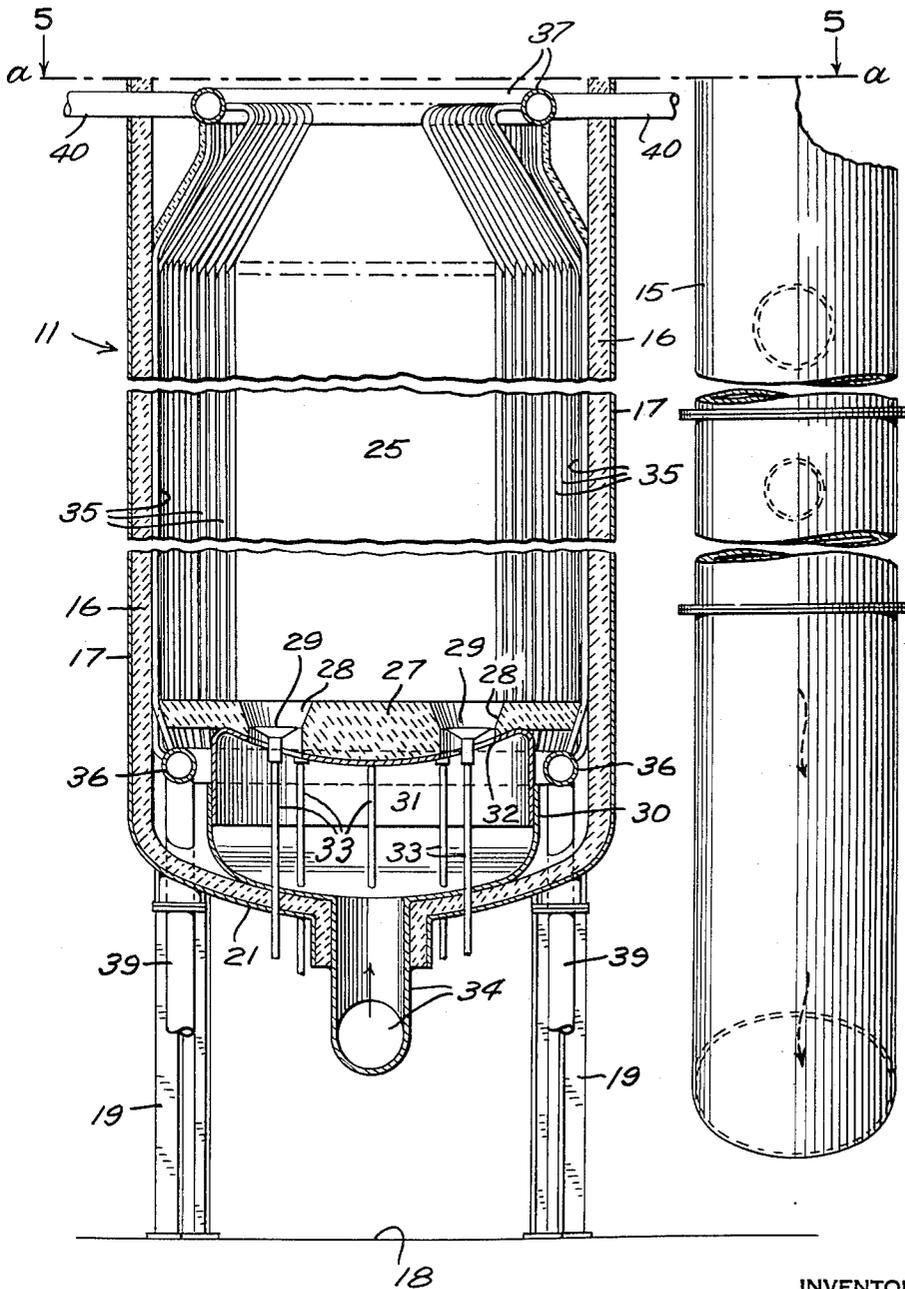


Fig. 2A.

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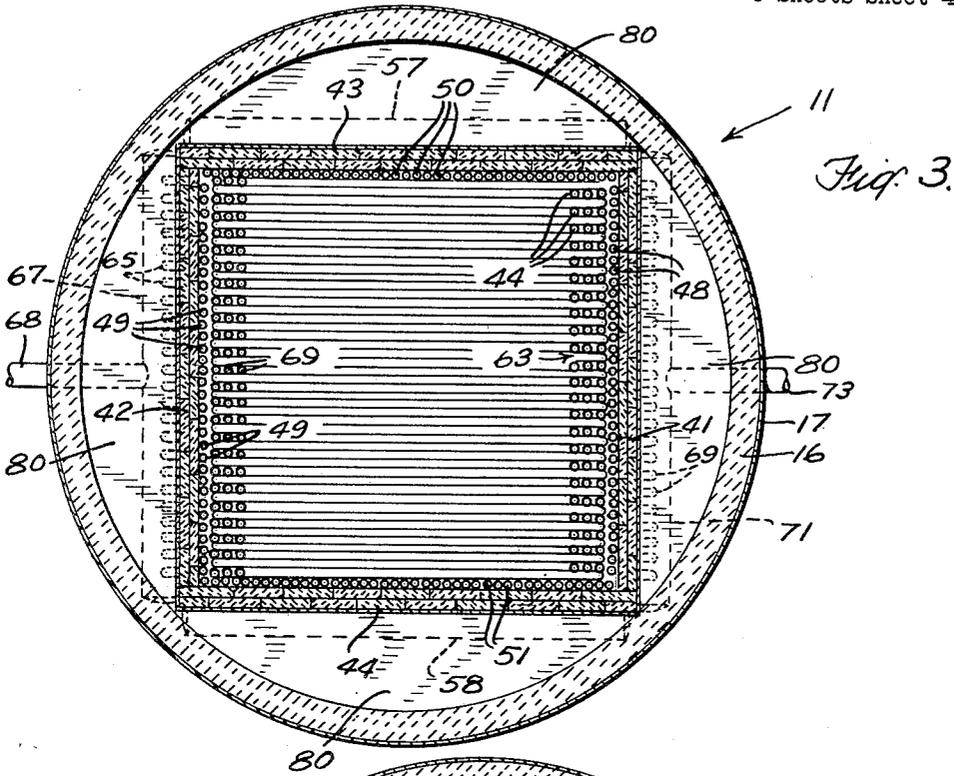


Fig. 3.

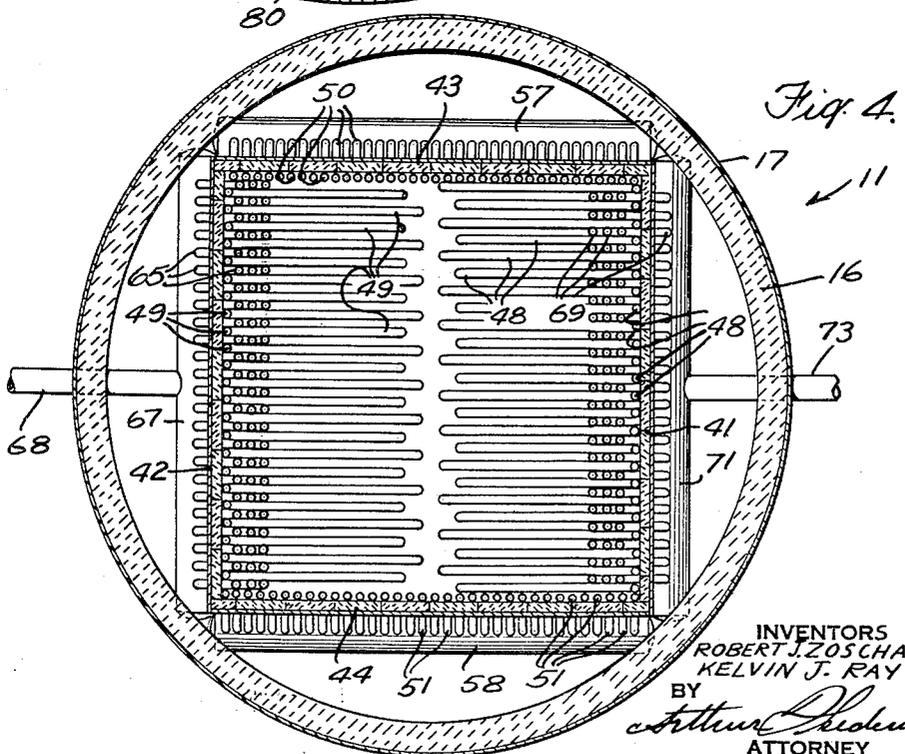


Fig. 4.

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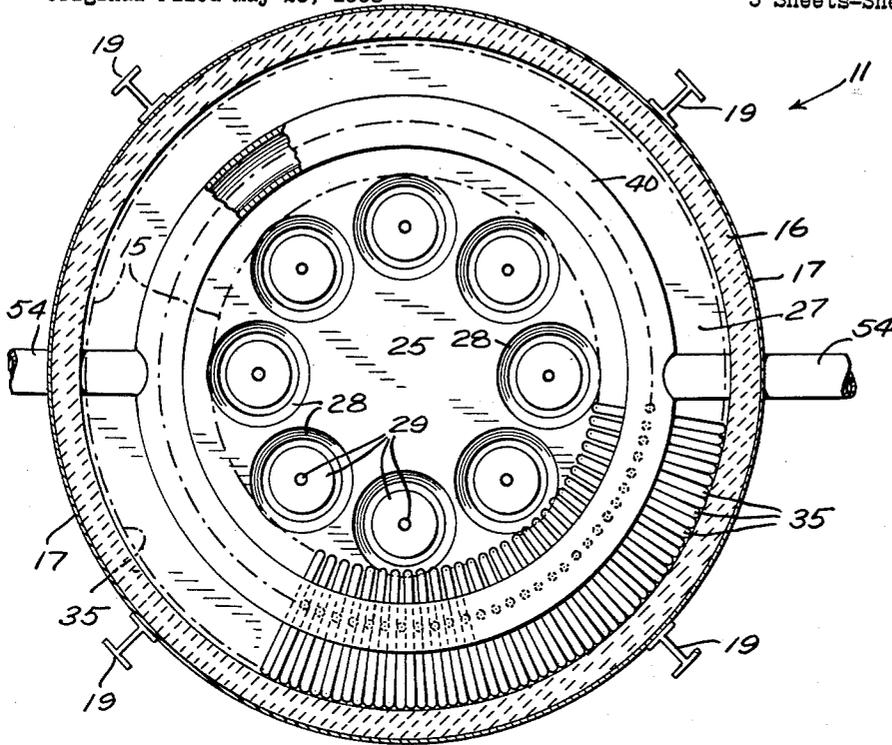


Fig. 5.

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3,072,109

SUPERCHARGED VAPOR GENERATOR

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 Original application May 28, 1958, Ser. No. 738,385, now Patent No. 2,946,187, dated July 26, 1960. Divided and this application Apr. 29, 1960, Ser. No. 25,722
 2 Claims. (Cl. 122-478)

This invention relates to vapor generators and more particularly pertains to supercharged vapor generators.

The present application is a divisional application of applicants' pending U.S. patent application Serial No. 738,385, filed May 28, 1958, now Patent No. 2,946,187.

In conventional type steam generators, internal gas pressures are substantially at atmospheric pressure, while in supercharged vapor generators the internal gas pressures are relatively high, as for example, 75 p.s.i.g. In order to withstand the relatively high internal pressures, the setting of supercharged vapor generators are generally cylindrical in shape. Heretofore supercharged vapor generators having cylindrical settings have been provided with superheater and/or reheater units of complicated and expensive helically formed tube banks. Such superheater and reheater constructions also present problems of maintenance and repair. The present invention overcomes the aforesaid problems by providing a rectangular convection gas passage in the upper part of the setting which permits installation of superheater and reheater units of simple, inexpensive construction. The problem of maintenance and repair is solved in the present invention by the novel arrangement of the reheater and superheater tubes and by providing an access opening in the setting of such size that removal and replacement of the superheater and/or reheater unit from the setting can be easily accomplished without the necessity of disturbing other pressure parts.

It is therefore an object of the present invention to provide a supercharged vapor generator having a cylindrical setting which is capable of receiving convection superheater and/or convection reheater units of simple, inexpensive construction and at the same time provide for maximum heat transfer surface in the convection section. Another object of this invention is to provide a supercharged vapor generator wherein convection superheater and/or convection reheater units may be removed from the setting and replaced in the setting quickly and easily.

Accordingly, the present invention provides a novel supercharged vapor generator comprising an elongated cylindrical shell or setting suitably supported to extend vertically. The shell is closed at the bottom by a wall while the top is open to provide a large access opening which is closed by a removable cover member. The lower portion of the vapor generator forms a circular radiant furnace section which is provided with burners for the generation of products of combustion therein. The upper portion of the vapor generator is provided with suitable contiguous walls to define a convection section of rectilinear configuration, which convection section communicates with the upper part of the radiant furnace section to receive products of combustion from the latter. An outlet is provided adjacent the top of the setting which communicates with the upper portion of the convection section and a flue to respectively receive and pass combustion products from the setting to the flue. The radiant furnace section is lined with vapor generating tubes which communicate with a steam and water drum disposed above and exteriorly of the setting to receive water from the latter and to pass saturated steam to the drum. Each of the walls of the convection sec-

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tion are lined with vertically extending vapor generating tubes which are in communication with the steam and water drum to receive water from the latter and to pass saturated steam to the drum.

In the convection section between the walls thereof, is disposed, one above the other, a superheater unit and a reheater unit. The superheater unit communicates with the steam and water drum to receive steam from the latter and pass the steam in indirect heat exchange relationship with the products of combustion flowing through the convection section to superheat the steam. The superheater unit is connected to deliver the superheated steam to a place of use, such as a turbine. The reheater unit communicates with a source of steam to be reheated, such as a turbine, and passes the steam in indirect heat exchange relation with the products of combustion flowing through the convection section to reheat the steam. The reheater unit is suitably connected to pass the reheated steam to a place of use, such as a low pressure turbine. The superheater and reheater units each comprises a plurality of horizontally spaced rows of tubes with each tube having a plurality of vertically spaced straight portions serially connected together. The superheater unit and reheater unit are dimensioned so as to pass through the access opening at the top of the setting. The superheater tubes and reheater tubes are also constructed and arranged with respect to each other so that either the reheater unit or superheater unit may be removed in its entirety from the convection section through the access opening at the top of the setting without disturbing the other unit and the vapor generating tubes which line the walls of the convection section.

The invention will be more fully understood from the following detailed description thereof when considered in connection with the accompanying drawings and in which:

FIG. 1 is a perspective view in elevation of supercharged vapor generators of the present invention;

FIG. 2 is a longitudinal view in section of the upper part of one of the supercharged vapor generators;

FIG. 2A is a longitudinal sectional view of the lower part of the supercharged vapor generator shown in FIG. 2 and joined to FIG. 2 on line a-a.

FIG. 3 is a transverse sectional view taken along line 3-3 of FIG. 2;

FIG. 4 is a transverse sectional view taken along line 4-4 of FIG. 2; and

FIG. 5 is a transverse view, in section, taken along line 5-5 of FIG. 2A.

Referring to the drawings and more particularly to FIGS. 1, 2 and 2A, reference numerals 11 and 12 generally designate supercharged vapor generators according to this invention. Although in FIG. 1 two vapor generators are shown as part of a power plant, the invention is not limited thereto. It is contemplated that a power plant may be provided with one supercharged vapor generator according to this invention and, therefore, only supercharged vapor generator 11 will be described in detail.

Vapor generator 11 comprises an elongated cylindrical shell or setting consisting of a refractory wall 16 covered by a fluid-tight metal casing 17. The setting is supported to extend vertically and in spaced relationship with a foundation 18 by a plurality of spaced vertically extending support columns 19 and horizontal beams (not shown) which extend between and are connected to support columns 19. The vapor generator shell is provided with a bottom 21 (FIG. 2A) and a slightly reduced top portion 22 (FIG. 2) which is provided with a relatively large circular access opening 23. Access opening 23 is closed by a closure cap 24 which is secured to the top portion 22 of the shell in a fluid-tight manner.

The interior of vapor generator 11 is divided into two

sections, the lower portion being a radiant furnace section 25 (FIG. 2A) and the upper portion a convection section 26 (FIG. 2).

As best shown in FIG. 2A, radiant furnace section 25 is provided with a horizontal floor 27 which is disposed in relatively close spaced relationship to bottom 21. Floor 27 has a plurality of circumferentially arranged burner ports 28 through which fuel burners 29 emit fuel for combustion in furnace chamber 25. A metallic casing 30, forming a plenum chamber 31 therein, is disposed between bottom 21 and floor 27. Casing 30 is provided with openings 32 which register with burner ports 28 in floor 27. Fuel is supplied to each of the burners 29 by a feed pipe 33 which extends through bottom 21 of the vapor generator setting. A combustion air feed pipe 34 communicates with plenum chamber 31 through setting bottom 21, to supply combustion air under relatively high pressure, as for example 75 p.s.i.g., to plenum chamber 31. The combustion air passes, from plenum chamber 31 through openings 32 and burner ports 28, into admixture with the fuel emitted from burners 29 into furnace chamber 25. Since there would be a pressure differential across floor 27 if combustion air was introduced into the space between floor 27 and bottom 21, floor 27 would have to be of reinforced construction to withstand that differential pressure. However, casing 30 eliminates the requirement for a reinforced floor construction by absorbing and relieving the floor of that pressure differential.

Refractory wall 16 in furnace chamber 25 is lined by tangentially disposed vapor generating tubes 35. Tubes 35 extend vertically from a ring-shaped inlet header 36 which is disposed below floor 27 to a ring-shaped outlet header 37 disposed in the upper part of radiant furnace chamber 25. As shown in FIG. 1, water is supplied to inlet header 36 from the vapor and liquid drum 13, by a pair of downcomers 38 (see FIG. 1) and distribution pipes 39 which extend through setting bottom 21 and are connected at one end to the lower portions of downcomers 38 and at the opposite end to inlet header 36. Saturated steam generated in tubes 35 flows from outlet header 37 into a plurality of riser pipes 40. Riser pipes 40 project through the vapor generator setting and extend upwardly exteriorly of the setting and are connected to liquid and vapor drum 13.

As shown in FIGS. 2, 3 and 4, four refractory walls, 41, 42, 43 and 44 are disposed within the setting of vapor generator 11 in convection section 26. Walls 41, 42, 43 and 44 are secured together in a fluid-tight manner at right angles to each other to define therebetween a rectilinear convection passageway 45 which communicates at one end with furnace chamber 25. Each of the walls extend from a point in spaced relationship with outlet header 37 (FIG. 2A) upwardly to a point in spaced relationship to upper portion 22 of the setting or shell. Wall 41 adjacent its upper end is provided with an opening in which is secured a combustion gas outlet duct 46 which duct 46 extends through an opening 47 in the setting or shell of the vapor generator and is connected to the vertically extending portion of combustion gas duct 15.

Walls 41, 42, 43 and 44 are lined by a bank of vapor generating tubes 48, 49, 50 and 51, respectively. Each of the tubes 48 is connected at one end to an inlet header 52, which header is disposed below wall 41 and extends horizontally and parallel thereto. The opposite ends of tubes 48 are connected to a horizontally disposed outlet header 53, which header is positioned below duct 46 and between wall 48 and the refractory wall 16 of the setting. Tubes 49 are connected at one end to an inlet header 54 which inlet header is disposed below wall 42 opposite from inlet header 52 and at the opposite end are connected to an outlet header 55. Tubes 48 at their lower ends extend from header 52 upwardly and inwardly toward the center line of convection passageway 45 and then away from the center line of the latter to wall 48 while tubes 49 at their lower ends extend from header 54 upwardly and inward-

ly toward the center line of the convection passageway 45 and then away from the center line of the latter to wall 49 whereby tubes 48 and 49 provide a slag screen 56. Tubes 50 and 51, adjacent walls 43 and 44, are connected to inlet headers 57 and 58, respectively, which headers are horizontally disposed below and parallel to walls 43 and 44. Tubes 50 and 51 extend upwardly from headers 57 and 58 along the respective walls 43 and 44 and are connected to outlet headers 59 and 60, respectively, which headers are arranged in the same horizontal plane as outlet header 55. As shown in FIG. 2, water is supplied to inlet headers 52, 54, 57 and 58 by a plurality of distribution lines 61 which are connected to downcomers 38 and to inlet headers 52, 54, 57 and 58. A plurality of riser lines 62 are connected to outlet headers 53, 55, 59 and 60 and project through wall 16 and casing 17 of the setting and are connected to the vapor and liquid drum 13 (see FIG. 1) to conduct saturated steam and water mixture from outlet headers 53, 55, 59 and 60 to the former. The vapor generating tubes 48, 49, 50 and 51, lining refractory walls 41, 42, 43 and 44, respectively, function to protect the walls from direct exposure to the relatively high temperature combustion gases flowing through the convection section, which direct exposure would cause flaking, cracking and other damage to the walls. In addition, the use of vapor generating tubes 48, 49, 50 and 51 within the convection section increases the capacity of the vapor generator without increasing overall size of the vapor generator by fully utilizing the heat in the products of combustion flowing through the convection section.

Within convection passageway 45 is disposed a reheater 63, and below the reheater, a superheater 64. Reheater 63 comprises a plurality of horizontally spaced parallel rows of tubes 65 which are connected to an outlet header 66. Header 66 is disposed above outlet gas duct 46 adjacent wall 41. Tubes 65 extend from outlet header 66, through wall 41, downwardly across the top of convection passageway 45 and thence downwardly parallel to wall 42 to a point slightly below the level of outlet gas duct 46. The tubes are then formed into a plurality of horizontally extending, vertically spaced, straight portions serially connected together by return bend portions. The lower portions of reheater tubes 65 extend downwardly parallel to wall 42, between tubes 49, and then through wall 42, to an inlet header 67. Steam to be reheated is supplied to reheater inlet header 67 by means of a pipe 68 while reheater outlet header 66 is connected by a suitable line 74 (FIG. 2) to a place of use, such as a steam turbine.

Superheater 64 comprises a plurality of horizontally spaced rows of tubes 69 which are connected at their ends to an inlet header 70 which is disposed above reheater outlet header 66. Superheater tubes 69 project from inlet header 70 downwardly across convection passageway 45 parallel to reheater tubes 65 to wall 42 and thence parallel to wall 42 between the rows of reheater tubes 65. Below the lowermost horizontal straight portions of reheater tubes 65, superheater tubes 69 are formed into a plurality of horizontally extending, vertically spaced, straight portions which are connected together by return bends. From the lowermost straight portion of superheater tubes 69, the tubes project downwardly parallel to wall 41 and thence through wall 41 to a superheater outlet header 71. Steam is conducted from vapor and liquid drum 13 to superheater inlet header 70 by a feed pipe 72 which is connected to drum 13 to receive steam from the vapor space of the latter and to inlet header 70 to deliver steam thereto. As shown in FIG. 2, superheater outlet header 71 is connected to a pipe 73 which communicates at one end with outlet header 71 and at the opposite end with an inlet header of a convection superheater disposed in vapor generator 12 or to a place of use, such as a steam turbine, where the power plant has only one vapor generator. Pipe 73 is provided with a U-bend portion 77 which allows for differential expansion and contraction between vapor generator 11 and vapor generator 12.

Reheater 63 and superheater 64 are of such size that they may be readily withdrawn from vapor generator 11 through access aperture 23 in the setting for inspection and replacement. To accomplish removal and replacement of reheater 63 and superheater 64 as a unit, a novel arrangement of the superheater tubes 69 with respect to the reheater tubes 65 is provided. As best shown in FIG. 4, the tubes 65 of a reheater 63 are horizontally spaced from each other and vapor generating tubes 50 and 51 a distance slightly greater than the outside diameter of tubes 69 of superheater 64 so that the vertically extending portions of superheater tubes 69 can extend from inlet header 70 downwardly between horizontally extending portions and U-bend portions of adjacent reheater tubes 65. The arrangement also permits the vertically extending portions of reheater tubes 65 to project upwardly from inlet header 67 between the horizontally extending portions and U-bend portions of adjacent superheater tubes 69. This horizontal offset relationship of the superheater tubes and the reheater tubes in addition to permitting maximum utilization of the convection passageway flow area also provides spaces in which the tubes of the reheater or superheater may be passed between the tubes of the other unit for withdrawal from the vapor generator and replacement in the vapor generator without the necessity of removing or otherwise disturbing the tubes of the vapor heating unit (reheater or superheater) which is not to be removed and the vapor generating tubes 48, 49, 50 and 51. To remove either the superheater or reheater from the vapor generator 11, as above described, the tubes of the unit to be removed must first be severed from their inlet and outlet headers by cutting the tubes adjacent the headers. To replace the superheater or reheater which has been removed, the unit, after being properly positioned in the convection passageway is reconnected to the inlet and outlet headers thereof by welding the tubes to the ends of stubs which were left on the headers when the tubes were cut from the headers.

As shown, the upper inclined portion of superheater tubes 69 form a roof 78 across the top of convection passageway 45. Roof 78 also includes a refractory surface 79 which is joined to the top of wall 42 and extends between opposite walls 43 and 44 and along the top of superheater tubes 69 to a point short of wall 41. Adjacent the lower ends of walls 41, 42, 43 and 44 are disposed sealing walls 80 which extend between the walls and the inner periphery of setting wall 16 (see FIGS. 2 and 3). Sealing walls 80 prevent combustion gas, flowing from furnace chamber 25, from bypassing convection passageway 45 and insure flow of combustion gas through the latter.

Vapor generator 12 is of essentially the same construction as herein described for vapor generator 11 and, therefore, will not be described in detail. However, in FIG. 1 the parts of vapor generator 12 which correspond to similar parts of vapor generator 11 are designated by the same reference numeral except that the reference numeral has a suffix A added thereto. Vapor generator 12 only differs from vapor generator 11 in that there is no reheater and only a superheater (not shown) is disposed within the convection passageway. The superheater in vapor generator 12 will be hereinafter referred to as a secondary superheater, the primary superheater being superheater 64 in vapor generator 11. The secondary superheater of vapor generator 12 comprises an inlet header (not shown) and a plurality of tubes extending upwardly from the inlet header. Each of the tubes have a plurality of straight horizontal portions serially connected together by return bends in a manner similar to tubes 69 of primary superheater 64 of vapor generator 11. The secondary superheater is dimensioned so that it may be removed and replaced as a unit through the access opening at the top of vapor generator 11, the access opening being closed by a cover member 24A.

In the twin vapor generators 11 and 12 of this inven-

tion, feed water is supplied to vapor and liquid drum 13 from an economizer unit (not shown) via feed water lines (not shown). Water flows from vapor and liquid drum 13 by way of the pairs of downcomers 38 and 38A. A portion of the water in downcomers 38 and 38A passes into distribution pipes 39 and 39A, respectively, and then into ring-shaped inlet header 36 and a similar header, not shown, in vapor generator 12. The water then flows upwardly in vapor generating tubes 35 of vapor generator 11 in indirect heat exchange relationship with combustion gas produced in furnace chamber 25 by combustion of fuel emitted therein by burners 29. Saturated steam generated in tubes 35 pass into outlet header 37 and thence via riser pipes 40 into vapor and liquid drum 13. Similarly, the saturated steam generated in the vapor generating tubes in the furnace chamber of vapor generator 12 flows via riser pipes 40A into vapor-liquid drum 13. Simultaneously, with the circulation of water into and through vapor generating tubes of the furnace chambers of vapor generators 11 and 12, another portion of the water flowing from drum 13 via downcomers 38 and 38A passes into distribution pipes 61 and 61A. From pipes 61 and 61A, the water flows into inlet headers 52, 54, 57 and 58 (FIGS. 2 and 3) and into similar inlet headers (not shown) in vapor generator 12. The water then rises upwardly through vapor generating tubes 48, 49, 50 and 51 of vapor generator 11 and upwardly through similar vapor generating tubes (not shown) of vapor generator 12 in indirect heat exchange relationship with combustion gas flowing through the respective convection gas passages 45 of vapor generators 11 and 12 and into their respective outlet headers 53, 55, 59 and 60 of vapor generator 11 and similar outlet headers (not shown) of vapor generator 12. From each of the aforementioned outlet headers, saturated steam flows to the vapor and liquid drum 13 by way of riser lines 62 and 62A.

Saturated steam from drum 13 passes into the inlet header 70 of primary superheater 64, via line 72. The steam then passes into and downwardly through superheater tubes 69 to outlet header 71 in indirect heat exchange relationship with combustion gases flowing through convection passageway 45. The heated steam passes from outlet header 71 into pipe 73 and into the inlet header (not shown) of the secondary superheater of vapor generator 12 (FIG. 2). Thereafter, steam is further heated by flowing upwardly in superheater tubes 81 in indirect heat exchange relationship with combustion gases flowing through convection passageway (not shown) of vapor generator 12. Steam heated to a predetermined desired temperature in the secondary superheater passes into an outlet header (not shown) and thence to a place of use, as for example a steam turbine. Downward temperature control of final superheated steam temperature is achieved by injecting water, which may be feed-water or condensate, into the superheated steam flowing from the primary superheater 64, by means of a liquid injection apparatus 86 (FIG. 2) disposed in line 73, which line interconnects primary superheater 64 with the secondary superheater of vapor generator 12.

Steam to be reheated flows from a source of steam, such as a steam turbine, through line 68 into reheater inlet header 67 and thence upwardly through reheater tubes 65 to outlet header 66 in indirect heat exchange relationship with combustion gas flowing through convection passageway 45. From outlet header 66, the reheated steam passes to a place of use, such as a low pressure steam turbine, by way of line 74.

Although flow of steam through reheater 63 has been described as flowing parallel to the combustion gas flow through convection gas passageway 45, it is within the contemplation of the present invention to provide flow of steam to be reheated in a direction countercurrent to the flow of combustion gas. Likewise flow of steam to be superheated may be provided parallel to the flow of com-

bustion gas in convection gas passageway 45 of vapor generator 11 while flow of steam to be superheated may be countercurrent to flow of combustion gas through convection gas passageway of vapor generator 12 without departing from the spirit and scope of the present invention.

Combustion of fuel in vapor generators 11 and 12 is effected by supplying fuel to burners 29, from a suitable source of fuel, by way of feed lines 33. Combustion air under relatively high pressure is conducted from a suitable source of compressed air, such as a gas turbine and compressor assembly (not shown), via ducts 34 and 34A to the burners of the respective vapor generators 11 and 12. The products of combustion flow upwardly, through the furnace chambers of each of the vapor generators and through the convection passageways to gas outlet duct 46 (FIG. 2) and a similar gas outlet in the vapor generator 12. The combustion gas from convection passageway 45 and convection passageway of vapor generator 12 flow through respective outlet ducts into combustion gas duct 15 and into admixture with each other.

It is readily apparent from the foregoing description that a supercharged vapor generator has been provided having a novel convection section of rectilinear configuration within a cylindrical setting which enables the arrangement of convection reheater and superheater units of relatively simple and inexpensive construction to utilize the maximum flow area of the convection section. The invention also provides a novel arrangement of the reheater and superheater units with respect to each other whereby one or the other may be removed from the convection zone and replaced as a unit without disturbing the other unit or other pressure parts of the vapor generator. Furthermore, the vapor generator provides increased steam generating capacity without increased size by lining the convection section with vapor generating tubes, which tubes also protect the walls of the convection section from exposure to the relatively high temperature combustion products flowing through the convection section.

Although but one embodiment of the invention has been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the spirit and scope of the invention, as the same will now be understood by those skilled in the art.

What is claimed is:

1. A supercharged vapor generator comprising a closed cylindrical vertical setting having a shell, a floor, a top, a lower portion and an upper portion, the lower portion defining a radiant furnace section, a source of fuel, a plurality of burners communicating with the source of fuel, the burners penetrating the floor and communicating with the radiant furnace section to inject streams of flame therein, means for supplying combustion air at super-atmospheric pressures to the burners, four contiguous planar walls supported in the upper portion of the setting and defining therebetween a convection passage, the convection passage having a rectangular plan section and communicating with the radiant furnace section to receive combustion gases therefrom, the upper portion of the setting defining an outlet in the vicinity of the top,

the convection passage communicating with the outlet to exhaust combustion gases therethrough so that the course of combustion gases passing through the convection passage is upward, means defining a liquid space, means defining a vapor space, a first vapor generating means disposed in the radiant furnace section and communicating with the liquid space to receive liquid to be heated by combustion gases on the radiant furnace section, the first vapor generating means communicating with the vapor space to deliver vapor thereto, a first source of vapor, a first heat transfer tube bank comprising horizontal tube portions disposed in the convection passage and communicating with the first source of vapor to be heated by combustion gases flowing through the convection passage, first delivery means for exhausting heated vapor from the first heat transfer tube bank, the shell defining an access opening in the top, the access opening larger than the plan section of the convection passage, the first heat transfer tube bank defining a plurality of first parallel vertical planes, a second source of vapor, a second heat transfer tube bank disposed in the convection passage and communicating with the second source of vapor to be heated by combustion gases flowing through the convection passage, second delivery means for exhausting heated vapor from the second heat transfer tube bank, the second heat transfer tube bank defining a plurality of second planes parallel to each other and parallel to and alternating with the first planes, the first planes spaced from the second planes so that the first heat transfer tube bank is movable relative to the second heat transfer tube bank for removal through the access opening and so that the second heat transfer tube bank is movable relative to the first heat transfer tube bank for removal through the access opening.

2. The vapor generator of claim 1 with a lower ceramic lining connected to the shell and embracing the radiant furnace section, the setting having an intermediate portion between the radiant furnace section and the convection section, an upper ceramic lining connected about the inside of the convection passage, the first vapor generating means comprising water filled tubes disposed inside the lining along the inner surface thereof, a second vapor generating means communicating with the liquid space to receive liquid to be heated by combustion gases in the convection section, the second vapor generating means communicating with the vapor space to deliver vapor thereto, the second vapor generating means comprising water filled tubes bent inwardly in the intermediate portion to define a slag screen transverse to the convection passage for protecting the first and second heat transfer tube banks in the convection section, the second vapor generating means extending upward and disposed inside the upper ceramic lining along the inner surface thereof.

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