June 9, 1942. H. J. KERR 2,285,442

VAPOR GENERATOR

Filed Sept. 22, 1938 4 Sheets-Sheet 1

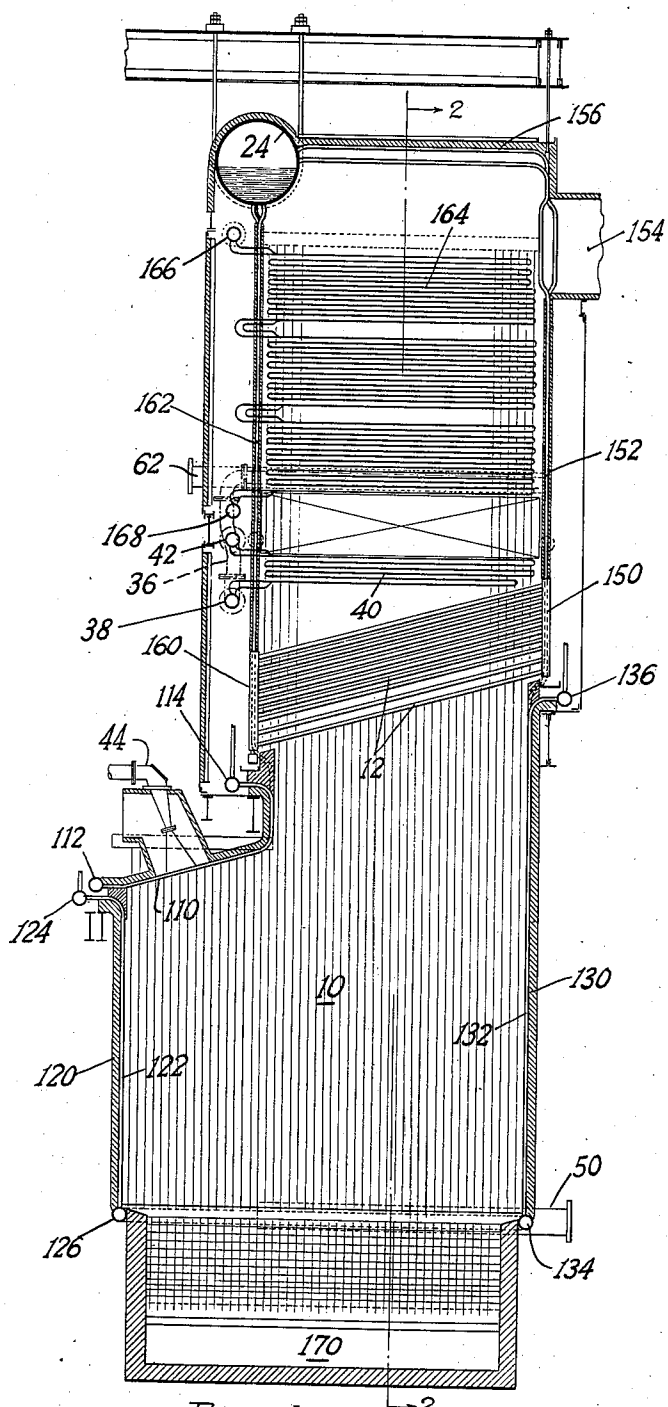

Fig. 1

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Fig. 2

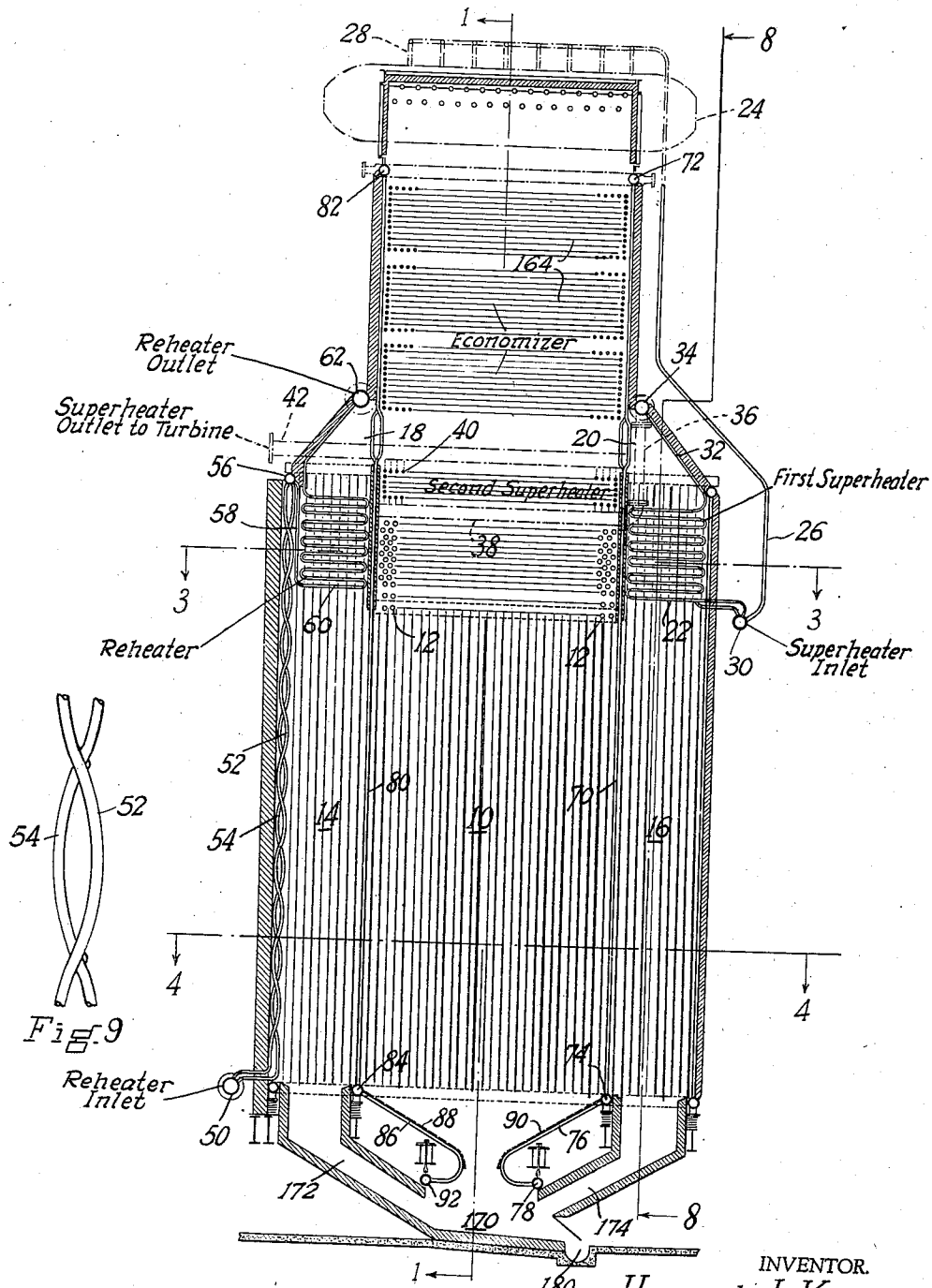

Fig. 9

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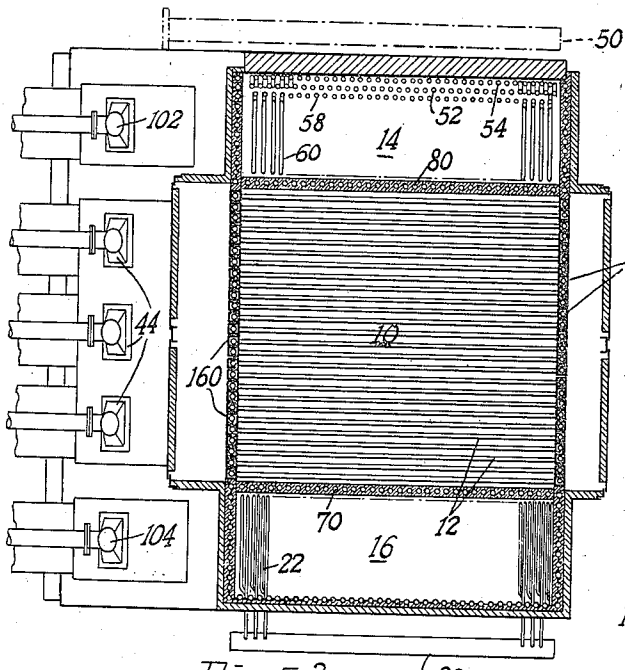

Fig. 3

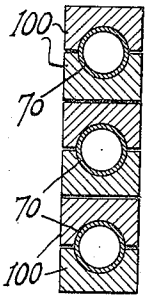

Fig. 5

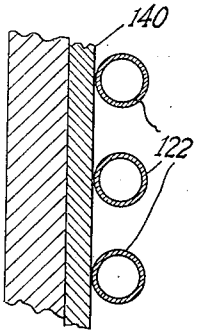

Fig. 7

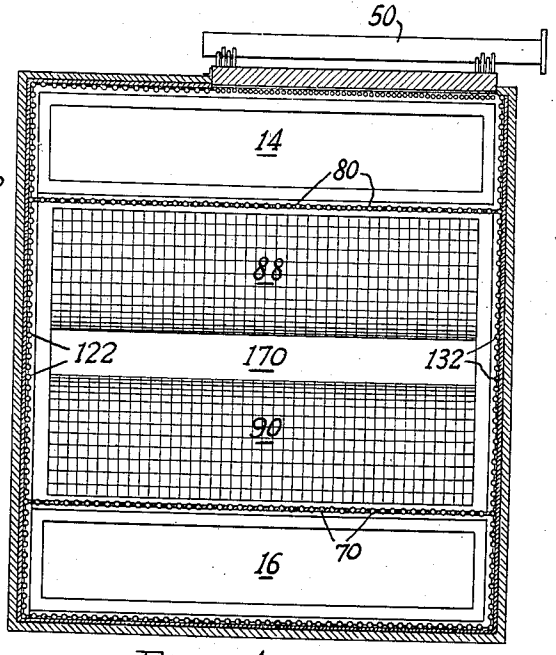

Fig. 4

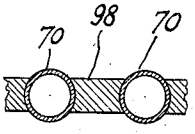

Fig. 6

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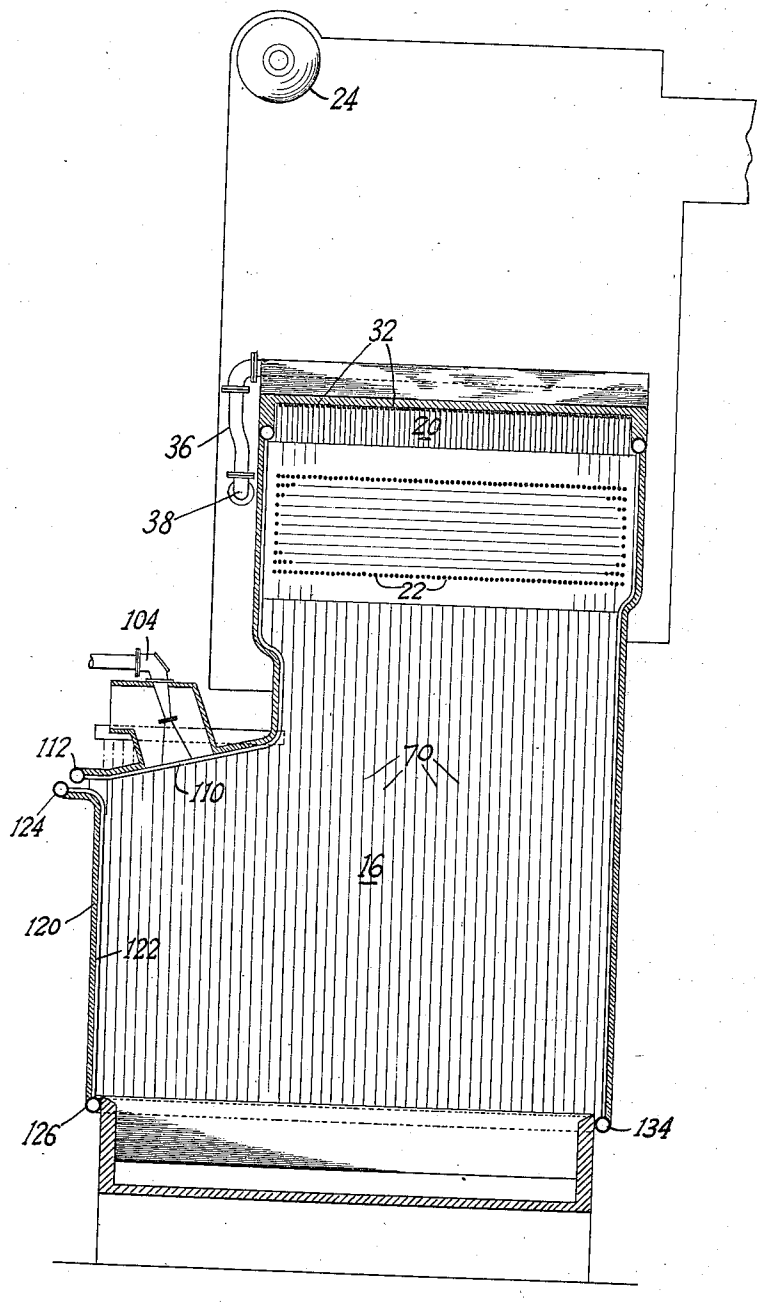
Fig. 8



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2,285,442

UNITED STATES PATENT OFFICE

2,285,442

VAPOR GENERATOR

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Application September 22, 1938, Serial No. 231,124

9 Claims. (Cl. 122—235)

This invention relates to vapor generators.

In the generation of power by steam plants, the operating conditions of boilers as to steam pressure, steam temperature or superheat, feed water temperature, vary widely as do also the hourly steam generating and quality or kind of fuel. At the present time, pressures from low up to more than 2000 lb. per sq. inch are being used, and steam temperatures from saturation values to 950° F. or more, while the temperature of water entering the boiler unit may range from the saturation value down to relatively low values. With such wide ranges of operating conditions, there is a corresponding range for the fraction of heat absorbed per pound of steam to heat the water to saturation temperature, evaporate the water at this temperature and to superheat it. To meet this range of conditions, it is necessary to provide different fractions of the total heating surface in the form of water heating economizer tubes, steam generating tubes and superheater tubes, and different arrangements to insure absorption of such part of the heat of the fuel as corresponds to the desired efficiency. This arrangement is further influenced by the need for burning different fuels, especially coals with different compositions and properties as to combustible and ash.

It has been regarded as necessary to have boiler arrangements in considerable variety to meet these widely varying operating conditions, in spite of recognition of the fact that this practice increases the cost, and makes it impossible or difficult to change a given boiler to meet new operating conditions imposed on it, as to fuel, per cent of heat absorbed in water heating, steam generation, and superheating and as to temperature of superheated steam.

With any one boiler arrangement selected to meet given operating conditions, the results normally vary with load in such a way as to make it necessary to add special control or adjustment features as corrective measures. Steam temperature is one result that varies with load, and it will also vary with the degree of slagging of heating surface, in addition to the rise of superheater metal temperature that takes place in starting when there is no steam flow, or when there is a sudden decrease in load, or a maladjustment of combustion conditions. The temperature of the water entering the drum may also vary with load and this may cause expanded joints of tubes entering the drum to leak, whereas this would not happen if the water temperature was kept uniform.

An object of my invention is to provide a boiler in which such operating conditions may be met by original distribution of its tube heating surface, and in which this disposal may be altered later on to meet new operating conditions, with the least trouble and expense, and in which for any given heating surface distribution, the desired operating results may be maintained in spite of changes of load or other imposed variables such as dirtiness of the surface, changes of fuel, or changes in feed water temperature.

My boiler is characterized by a multiplicity of furnaces each separately fired, one of which is substantially larger than the others, and by a predetermined distribution of the three kinds of tube surface with reference to each furnace and the hot gases flowing from it. Each of the furnaces has fluid cooled walls at least in part and for the large or main furnace these are water walls, while for the smaller or auxiliary furnaces the wall tubes may be wholly water tubes or in part superheater tubes, and the wall tubes for all furnaces may be bare or covered in any one of various satisfactory ways, selected with reference to the effect. When the same sort of fluid cooled walls is used for the main and for the auxiliary furnaces, the former will be hotter than the latter for the same volumetric heat liberation rate because there is less cooling surface per cubic foot of volume, and consequently the gases leaving the main furnace will be hotter than the gases leaving the auxiliary furnace. The relative mean temperatures of the main and auxiliary furnaces and the temperature of their exit gases may however be caused to depart from the values for similar walls and heat liberation rates, by changes in the wall affecting its heat absorption and by changes in the heat liberation rate during operation by combustion control. The gases from the main furnace and all auxiliary furnaces are mixed beyond their respective gas exits, and flow as one stream in a flue toward the stack.

The three kinds of tube surface, water heating or economizer, steam generation, and steam superheating, are of such area and are so distributed between the furnaces as to their walls and the gases leaving them in such a manner as to meet the desired operating conditions, the required overall efficiency and the kind of fuel to be burned.

In all cases steam generating tubes are located in the walls of the main furnace and across the path of gases leaving the main furnace. Also,

in all cases, water heating or economizer tubes are located in the flue conducting the mixed gases from all furnaces toward the stack, and at least part of these tubes are arranged for water flow counter-current to the mixed gas flow. Also in all cases superheater tubes are located in the path of gases leaving one or more of the auxiliary furnaces, or in their walls, or both. All of these tubes are called primary tubes and they are supplemented by other sets called secondary tubes.

Secondary steam generating tubes may be located so as to receive heat from the fuel burned in any of the auxiliary furnaces, secondary economizer tubes may be located so as to receive heat from the fuel burned in the main or any of the auxiliary furnaces, and secondary superheater tubes may be located so as to receive heat from the fuel burned in the main or in any of the other auxiliary furnaces, according to the major operating requirement to be met. When the major operating requirement is changed by circumstances, this distribution of such secondary tubes may be changed without changing the location and distribution of the primary tubes and without changes in the general structure of the boiler, except that the burners and the covering of wall tubes may also be changed.

Accordingly, my boiler comprises, a main furnace and at least one auxiliary furnace, with fluid cooling of the walls, a common flue leading gases to the stack, and tube surface divided into primary and secondary, the primary tube surface including steam generating tubes receiving heat from fuel burned in the main furnace, economizer tubes in the common flue receiving heat from the gases from all furnaces, and superheater tubes receiving heat from the fuel burned in an auxiliary furnace. The remaining surfaces being considered as forming the whole secondary surface.

In the operation of the illustrative installation the rate of steam generation is controlled solely by the rate of burning fuel in the main furnace and the superheat or steam temperature is controlled solely by the rate of burning fuel in an auxiliary furnace, the heat absorption in the economizer being the result of the operation of a plurality of furnaces and the heat absorbed by tubes between them and the economizer. For a given rate of steam generation, or load, the superheat can be held to any desired value by control of combustion in the auxiliary furnace in spite of variations of dirtiness or slagging of the tubes, and also be maintained in spite of change of load. Steam can be raised from cold without damage to the superheater by deferring the operation of the auxiliary furnace. As shown, both furnaces are fired by pulverized coal for dry ash removal from a common collecting chamber, but the auxiliary furnace will normally be colder than the main furnace, and for this reason the main furnace may be made hot enough for wet or molten ash removal while the auxiliary remains cold enough for dry ash removal.

For different operating conditions of pressure and superheat requiring a relatively larger amount of heat of superheat, and a smaller amount of heat of vaporization, some of the steam generating tubes may be omitted and secondary superheater tubes installed in their place. Also if the steam turbine receiving the boiler output of high pressure steam is to be operated in two stages with reheat of steam between them, a second auxiliary furnace may be added to provide the heat and independently control the temperature of the low pressure steam.

It is to be understood that, while the steam generating tubes are shown to be in natural circulation relationship to the boiler drum, this is not a limitation, and forced circulation arrangements including the once through type may replace natural circulation within the scope of my invention.

Objects of my invention, other than those indicated above, will appear as the description proceeds.

The invention will be described with reference to the accompanying drawings in which a preferred embodiment of the invention is disclosed.

In the drawings:

Fig. 1 is a vertical section through a part of a steam generating installation constructed in accordance with the teachings of the invention. This view is taken on the section line 1—1, as it is indicated in Fig. 2;

Fig. 2 is a vertical section taken at right angles to the section plane of Fig. 1. It is taken on the section line 2—2 of Fig. 1;

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

Fig. 4 is another horizontal section taken through the main and auxiliary furnaces on the plane indicated by the section line 4—4 of Fig. 2;

Fig. 5 is a detail view indicating a horizontal section of a furnace wall which may be employed in some parts of the installation;

Fig. 6 is a detail view illustrating a modified form of the furnace wall in horizontal section;

Fig. 7 is a horizontal section of a furnace wall construction which may be employed in parts of the installation;

Fig. 8 is a vertical section taken on the section line 8—8 of Fig. 2; and

Fig. 9 is a fragmentary view of the reheater wall tubes indicating welds to secure these sinuous tubes together at their inter-sections.

Fig. 2 of the drawings indicates a construction in which there are three furnaces. The main furnace 10 is fired in accordance with the demand for steam, its gases passing directly upwardly from the furnace across a bank of steam generating tubes 12.

The main furnace is flanked on either side by auxiliary furnaces 14 and 16. Each of these furnaces is independently fired, the combustion gases from the furnace 14 passing through an outlet 18 and joining the gases of the main furnace at a position beyond the bank of steam generating tubes. The gases from the other auxiliary furnace 16 likewise pass through an outlet 20 and join the gases of the main furnace at a similar position.

In the furnaces 14 and 16 there are types of auxiliary heating equipment which require degrees of heating varying from the heating required by the main furnace 10 which is governed by steam demand.

As indicated in Fig. 2 of the drawings, the auxiliary heating equipment subject only to the heat of the furnace 16 is a superheater having return bend tube coils 22 extending across the path of the furnace gases at a position beneath the furnace gas outlet 20. These coils receive steam from the boiler steam and water drum 24 through the agency of saturated steam supply tubes 26 which have connections 28 leading to the steam space of the drum. These tubes are connected at their other ends to the super-

heater inlet header 30 to which the coils 22 are connected, as shown.

From the coils 22 steam flows through wall tubes 32 to a first intermediate superheater header 34. From this header the steam flows through the upright conduit 36 to a second intermediate superheater header 38. The latter is horizontally disposed, as shown, in order that it may be readily connected to the return bend coils of the second superheater section 40 extending across the path of the furnace gases moving upwardly from the bank of steam generating tubes 12. The superheated steam passes from the superheater section 40 to the superheater outlet header 42 and thence to a steam turbine or other agency utilizing the steam.

The superheater furnace 16, being independently fired by burners similar to the burner 44 shown in Fig. 1 of the drawings, may be operated to control the final temperature or superheat of the steam. Under some load conditions the required superheat may be very nearly attained by the heat of the furnace gases from the main furnace 10 absorbed by the superheater section 40, and in this case the burner for the auxiliary furnace 16 is operated at a very low rating.

The auxiliary heater subject only to the heat of the auxiliary furnace 14 is a reheater useful in connection with the operation of a multiple stage steam turbine receiving steam from the superheater header 42. In this case, the steam exhausted from one stage of the turbine is reheated and then used in another stage.

The steam to be reheated passes to the inlet header 50 and thence through the sinuous wall tubes 52 and 54 to an intermediate header 56 at the top of the furnace. From this header the steam passes through inlet tubes 58 to the coils 60 of a convection section. The return bend sections of these coils extend back and forth across the gas flow from the furnace 14 and discharge into the outlet header 62. From this header the reheated steam is conducted to another stage of the turbine.

The auxiliary furnace 14, like the other auxiliary furnace, is independently fired by a burner which may be similar to the burner 44 shown for the main furnace 10, and the furnace 14 is thus capable of being independently fired solely from the standpoint of the requirements of the auxiliary heater which is subject only to the heat of that furnace.

The furnaces 10 and 16 are separated by wall tubes 70 connected into boiler circulation in a suitable manner. The tubes 70 are connected at their upper ends to the header 72 and at their lower ends to the header 74. From the latter, downwardly inclined tubes 76 extend to the header 78 which may have direct connection with the water space of the drum 24. The furnaces 10 and 14 are separated by similarly arranged tubes 80 connected at their upper ends to the header 82 and at their lower ends to the header 84. From the latter, the downwardly inclined tubes 86 extend toward the outlet of the furnace 10 and form, with the tubes 76 and the refractory blocks 88 and 90, a hopper bottom for the main furnace. The tubes 86 are connected at their lower ends to the header 92 which may have direct connection with the water space of the drum 24.

To form the furnace gas outlet 20 at the top of the auxiliary furnace 16 successive tubes 70 are bent out of their normal plane, as indicated, and the furnace gas outlet 18 for the auxiliary furnace 14 is similarly formed at the opposite side of the installation.

At the lowermost levels in the furnaces the tubes 80 may be spaced and have no blocks or devices for closing the spaces between them, but at a higher level the tubes 70 may support the refractory blocks 98 (see Fig. 6) which close the spaces between the tubes. At a still higher level and between the top of the furnace 10 and the furnaces 14 and 16 the tubes 70 and 80 may be enclosed by refractory elements as indicated in Fig. 5 of the drawings. These refractory elements are shown as the C-tile 100.

Fig. 3 of the drawings shows three of the burners 44 for the main furnace 10, an independently fired burner 102 for the furnace 14, and a similar independently fired burner 104 for the furnace 16. All of these burners are positioned along the roof of lateral extensions of the furnaces as indicated in Fig. 1 of the drawings. The roof of these lateral extensions is defined by water tubes 110 connecting the headers 112 and 114. The latter may be appropriately connected into the boiler circulation.

Fig. 1 also shows the wall 120 of the three furnaces as defined by wall tubes 122 connected at their upper ends with the header 124 and at their lower ends with the header 126. The opposite wall 130 is defined by the wall tubes 132 leading from the lower header 134 to the upper header 136. All of these headers are connected into boiler circulation so that the water tubes connecting them are adequately supplied with water. The wall 120 may be constructed as indicated in Fig. 7 of the drawings, wherein the tubes 122 are bare but are in substantial contact with refractory material 140 which may be secured to the tubes or to a metallic encasement for the furnace.

The upper ends of the steam generating tubes extending across the outlet of the main furnace 10 are connected to a header construction 150 from which risers 152 extend past the flue 154 and along the roof 156 to the steam space of the drum 24. A header construction 160 is in communication with the lower ends of the steam generating tubes, and it receives water from the water space of the drum through the downcomers 162. The risers 152 and the downcomers 162 are of considerable length so as to facilitate boiler circulation and provide adequate space for the economizer 164. The latter consists of return bend tubes connected to and receiving water from the economizer inlet header 166 and discharging the heated feed water into the economizer outlet header 168.

Referring again to the furnace construction indicated in Fig. 2 of the drawings, it will be seen that the three furnaces 10, 14, and 16 communicate with a common ash disposal zone 170. This zone is directly beneath the hopper for the main furnace 10 and it is in communication with the furnaces 14 and 16 by the refractory walled chutes or conduits 172 and 174. Ash from the furnaces may be moved by appropriate devices to the disposal zone 170 and then to the sluiceway 180.

I claim:

1. In a steam boiler, fluid conducting tubes defining walls of a combustion space, spaced tubes connected into the boiler circulation and arranged as walls extending through said combustion space and dividing it into three furnace chambers, independently operable burners associated with said furnace chambers, steam gen-

erating tubes positioned so as to be exposed to the heat of the middle furnace chamber between said walls, a reheater subject to the heat of one of the remaining furnace chambers, and a superheater subject to the heat of a third furnace chamber, the burners for said chambers being independently operated from the standpoint of steam demand, reheat requirements, and superheat requirements, respectively.

2. In a steam boiler, fluid conducting tubes defining the walls of a combustion space, upright tubes connected into the boiler circulation and arranged as walls extending into said combustion space and dividing it into three furnace chambers, steam generating tubes positioned so as to be exposed to the heat of the middle furnace chamber between said walls, a reheater subject to the heat of one of the remaining furnace chambers, a superheater subject to the heat of the third furnace chamber, and independently operable fuel burning means firing the middle furnace in accordance with steam demands while the second and third furnaces have similarly operable fuel burning means firing them to meet the requirements of reheating and superheating respectively.

3. In a steam boiler, a plurality of adjacent furnaces, rows of water tubes extending across the outlet of one of said furnaces and connected into the boiler circulation, and a superheater disposed beyond said tubes relative to gas flow, wall defining water cooled tubes between said furnaces, a steam reheater directly heated by the second of said furnaces, means for firing said first mentioned furnace, and means for independently firing the second of said furnaces to effect reheat control, extensions of said wall defining tubes being disposed at a position beyond said reheater and extending across the path of the gases passing from the second furnace.

4. In a steam boiler, a plurality of adjacent furnaces, rows of water tubes extending across the outlet of one of said furnaces and connected into the boiler circulation, and a superheater disposed beyond said tubes relative to gas flow, wall defining water cooled tubes between said furnaces, a steam reheater of the radiant type directly heated by the second of said furnaces, means for firing said first mentioned furnace, and means for independently firing the second of said furnaces to effect reheat control, extensions of said wall defining tubes being disposed at a position beyond said reheater and across the path of the gases passing from the second furnace.

5. In a steam boiler, a plurality of directly laterally adjacent said similarly constructed furnaces, a bank of water tubes extending across the outlet of one of said furnaces and connected into the boiler circulation, a first superheater section including tubes disposed in a gas pass beyond said bank of tubes, and a partition wall separating said one furnace from a second of said furnaces and including water cooled tubes connected into the boiler circulation, all of said partition wall tubes receiving heat from a plurality of furnaces, a second superheater section heated only by the gases passing from said second furnace, means for connecting said superheater sections in series as to steam flow, means for firing said first mentioned furnace, and means for independently firing the second of said furnaces to effect superheat control.

6. In a water tube steam boiler installation, a plurality of laterally adjacent furnaces of similar construction, similarly arranged means for independently firing the separate furnaces, a bank of convection tubes heated directly from one of said furnaces, a superheater section subject to the heat of the gases of said one furnace at a position beyond said bank of tubes, and a second superheater section subject to the heat of a second of said furnaces and connected to the first superheater section for series flow of steam therethrough, the second furnace having its gases joining those from the first furnace at a position rearwardly of the first superheater section, the second furnace being fired primarily from the standpoint of superheat requirements so as to effect superheat control.

7. In a water tube steam boiler installation a plurality of laterally adjacent similar furnaces, water tubes connected into the boiler circulation and arranged as a wall separating said furnaces, pulverized fuel burners similarly arranged with respect to said furnaces and firing them with downward projection of fuel into the furnaces, a first superheater including tubes heated by the gases rising in one of the furnaces, a second superheater connected to the first superheater for a series flow of steam therethrough and heated by the gases from a second of said furnaces, a reheater heated by the gases rising from a third of said furnaces, and means including convection heat absorbing surfaces positioned in a gas pass leading from a superheater gas outlet and the reheater gas outlet, said water cooled partition tubes having upper parts extending to a position beyond a superheater relative to gas flow.

8. In a water tube steam boiler installation a plurality of adjoining similar furnaces, water tubes connected into the boiler circulation and arranged as a wall separating said furnaces, pulverized fuel burners similarly arranged with respect to said furnaces and firing them with downward projection of fuel into the furnaces, a first superheater including tubes heated by the gases rising in one of the furnaces, a second superheater connected to the first superheater for a series flow of steam therethrough and heated by the gases from a second of said furnaces, and means providing convection heat absorbing surfaces positioned in a gas pass leading from a superheater, said water cooled partition tubes having upper parts extending to a position beyond a superheater relative to gas flow so that gases of the superheater pass between said upper parts.

9. In a steam boiler, a plurality of adjacent furnaces, steam generating tubes extending across the outlet of one of said furnaces and connected into the boiler circulation, and a superheater disposed beyond said tubes relative to gas flow, wall defining water cooled tubes between said furnaces, a steam reheater directly heated by the second of said furnaces, means for firing said first mentioned furnace, means for independently firing the second of said furnaces to effect reheat control, extensions of said wall defining tubes being disposed across the path of the gases from the second furnace at a position beyond said reheater, means providing a single gas pass or flue beyond said furnaces, and means providing auxiliary fluid heating surface in said gas pass, the gases from said furnaces joining at a position forwardly of said surface.

HOWARD J. KERR.

CERTIFICATE OF CORRECTION.

Patent No. 2,285,442. June 9, 1942.

HOWARD J. KERR.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 57, claim 5, for "said" read --and--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of April, A. D. 1943.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.