June 30, 1942. R. M. HARDGROVE ET AL 2,287,798

VAPOR GENERATOR

Filed Aug. 3, 1938 4 Sheets-Sheet 1

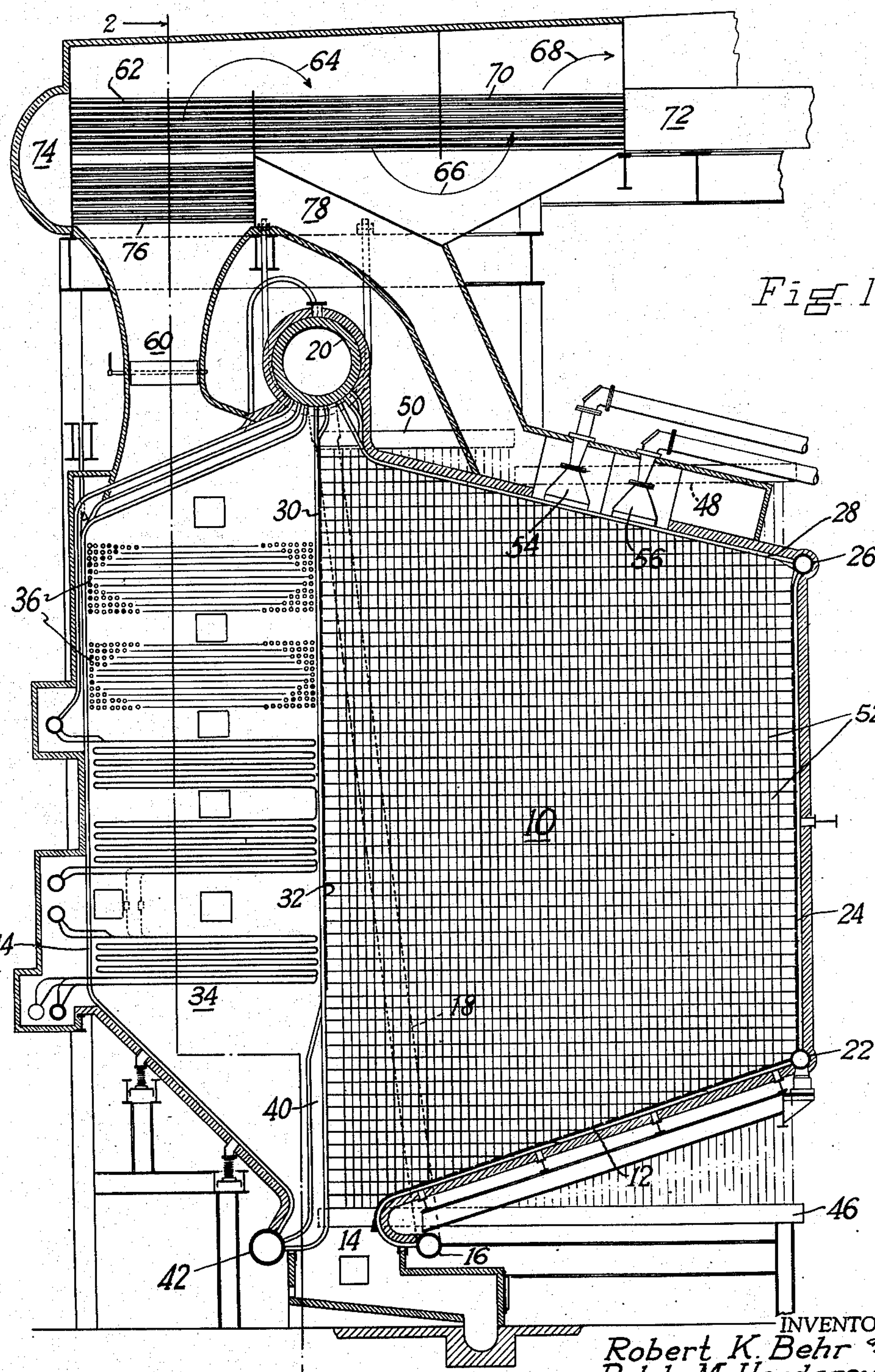

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Fig. 2

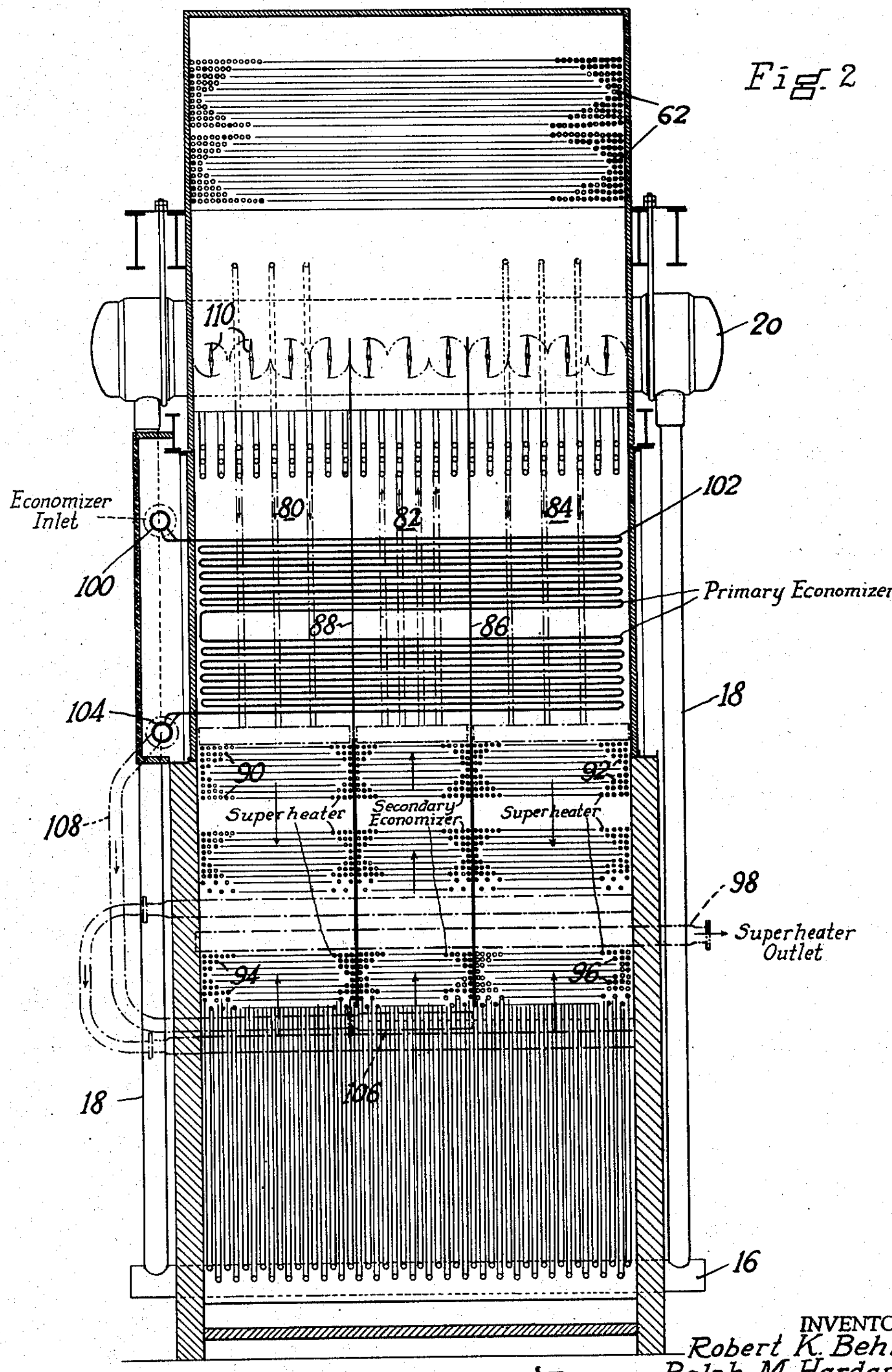

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Fig. 3

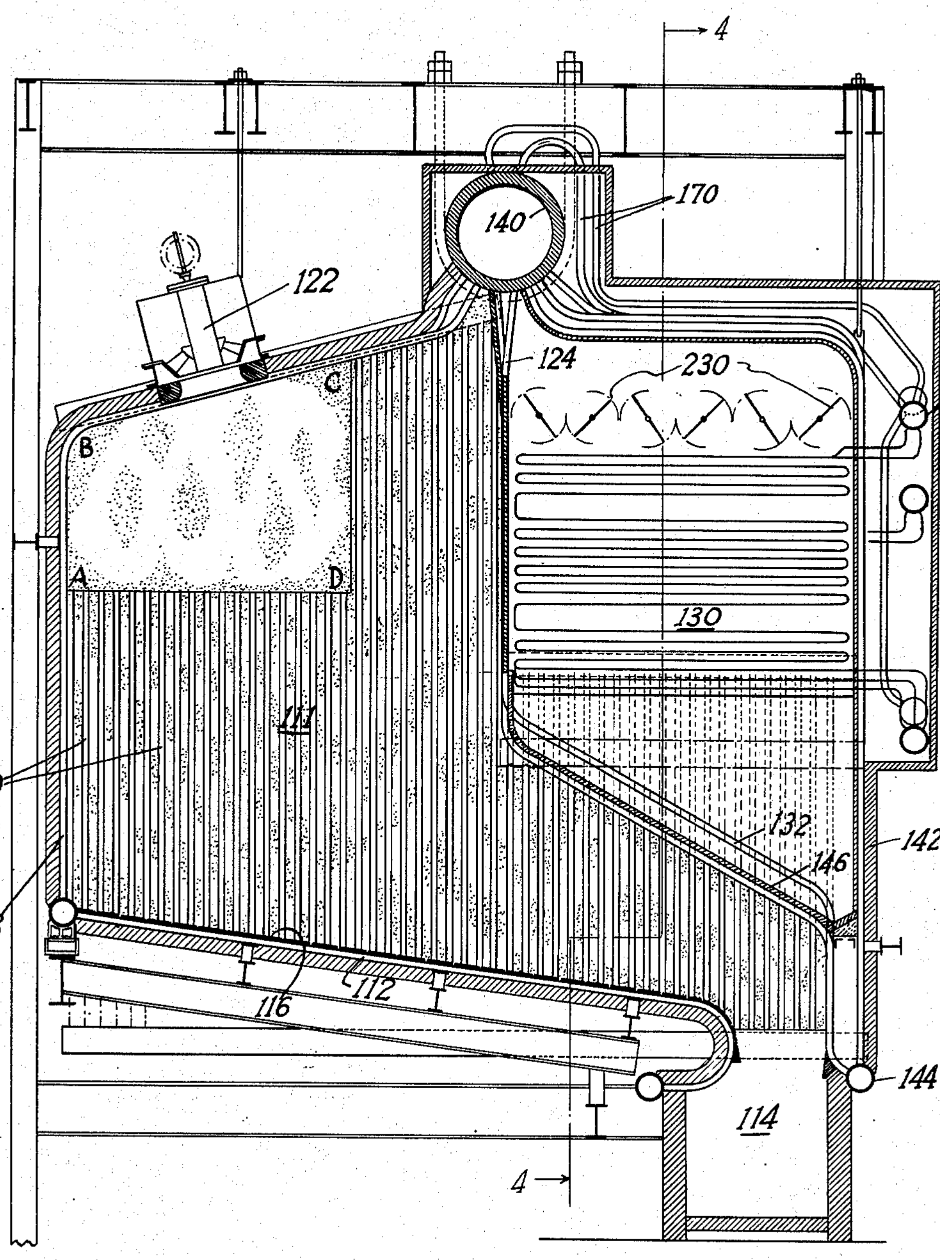

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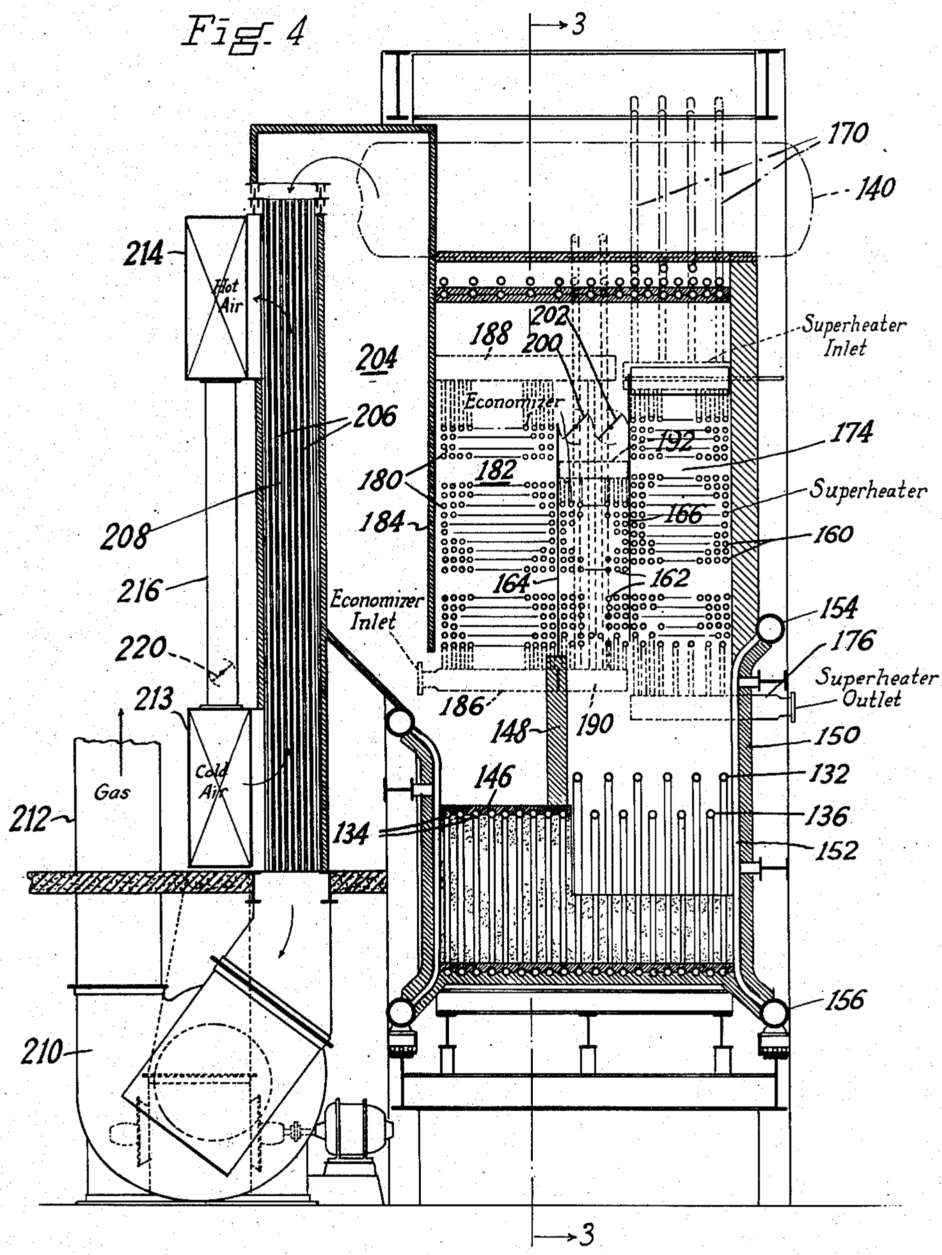
Fig. 4



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VAPOR GENERATOR

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8 Claims. (Cl. 122—235)

This invention relates to fluid heat exchange apparatus, and it will be considered as exemplified herein in a vapor generator.

The invention is more particularly concerned with vapor generators operating at high pressures and high capacities. The vapor generators of the invention also involve the co-ordination of fuel burning and heat exchange apparatus capable of high rates of heat absorption at large temperature differentials between the heat transmitting products of combustion and the heat absorbing media.

In a high capacity steam power plant it is important that high overall efficiencies be attained, and to attain such efficiencies, high pressures and high superheats are advantageous. These conditions are usually accompanied by high furnace gas temperatures.

In the central stations operating under the above conditions and utilizing steam for the development of electrical power, steam turbines are usually employed. The steam, after passing through the turbines, is condensed and returned to the steam generators so that relatively low percentages of make-up water are utilized.

Thus, the steam generators, or boilers, of such central stations are continuously using feed water of low concentration, and a minimum of boiler "outage" due to scaling, tube failures, etc., is experienced.

Conditions are different in industrial installations in that such installations are associated with demands for low pressure steam. These demands are met by utilizing the steam exhausted from the prime mover at pressures above atmospheric. Consequently, the vapor generators used in such industrial installations are supplied with feed water a high percentage of which is "make-up."

The boiler of the present invention is particularly adapted for industrial installations in which boiler feed water is almost 100% make-up, and with such a situation the boiler is required to operate with boiler water having a relatively high concentration. In spite of such conditions it operates at extremely high pressures and high superheats so as to attain high efficiencies. Its steam generating parts are such that they may be readily cleaned, and its furnace gas velocities are low in order that adequate separation of suspended solids may be effected.

The invention is illustrated herein by preferred embodiments shown in the drawings referred to in the following description, and other objects of the invention will appear as the description proceeds.

In the drawings:

Fig. 1 is a vertical section through a vapor generator in which the steam is generated in wall tubes which define a combustion chamber of relatively large volume;

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

Fig. 3 is a vertical section through a boiler constituting another embodiment of the invention; and

Fig. 4 is a vertical section on the line 4—4 of Fig. 3, the plane of the Fig. 4 view being at right angles to the plane of Fig. 3.

The combustion chamber **10** of the Fig. 1 boiler is defined by water tubes connected into the boiler circulation, and the spaces between these water tubes may be closed by refractory material secured to the tubes and forming the furnace faces.

The floor of the combustion chamber **10** is defined by floor tubes **12** which are inclined downwardly toward the ash removal zone **14**. These tubes are reversely bent at their lower portions and have their lower ends connected to a header **16** which receives water through external downcomers **18** connected to the water space of the drum **20**. Water flows upwardly through the tubes **12** to a lower wall header **22** and thence upwardly through the wall tubes **24**. These tubes discharge into the header **26** which is connected to the drum **20** by the furnace roof tubes **28**. The headers, such as the headers **16** and **22**, are all provided with handholes so that tube cleaning tools can be directed into the connected tubes.

The side of the combustion chamber opposite the tubes **24** is defined by the wall tubes **30** which directly communicate with the drum **20** and are suspended therefrom. These tubes, and the refractory material **32** secured thereto, form a division wall separating the combustion chamber **10** from the convection zone **34** in which the economizer **36** and a superheater are located. The wall tubes preferably act as supports for the superheater tubes at one side of the convection section.

The alternate division wall tubes **30** have their lower ends offset or more widely spaced, providing two rows with alternative tubes in staggered relationship, as indicated at **40**, so as to provide an outlet for the furnace gases passing from the combustion chamber **10** to the convection zone **34**. The tubes **30** receive water by reason of their communication with the lower header **42** which is in communication with the water space of the drum **20** by the downcomers **44**.

The side walls of the combustion chamber **10** are defined by wall tubes which directly connect the lower headers **46** with the upper headers **48** and **50**, the spaces between these tubes being closed by the refractory material **52**.

The furnace of the Fig. 1 boiler is fired by down-shot burners herein indicated as the pulverized fuel burners **54** and **56**, and the furnace gases after passing from the combustion chamber **10** to the outlet **40** pass upwardly over the economizer and superheater tubes, through the Venturi connection **60**, and then across the tubes of the air heater **62**. The movement of the furnace gases through the air heater is indicated by the arrows **64**, **66**, and **68**, while the air to be heated passes through the tubes **70** from the inlet **72** to the chamber **74**. From this chamber the air passes through the tubes **76** to the duct **78** and thence to the burners **54** and **56**.

The convection zone beyond the outlet **40** of the combustion chamber is divided into three parallel gas passes **80**, **82**, and **84**. The baffle **86** separates the passes **82** and **84**, while the pass **80** is separated from the pass **82** by the baffle **88**.

In the gas passes **80** and **84** the tubes of a superheater are arranged. In each of these passes there is an upper counter-flow section indicated at **90** and **92**. Steam flowing generally downwardly through the tubes of these sections passes to the lower portions of the parallel flow superheater sections **94** and **96**, and then upwardly to the superheater outlet header **98**.

Feed water for the boiler enters the economizer inlet header **100** and then flows through the coils **102** of the primary economizer across the gases flowing upwardly in the three gas passes **80**, **82**, and **84**. This section of the economizer operates on counter-flow principles, the water flowing through the coils **102** downwardly to the header **104** which is in communication with the header **106** of the secondary economizer. The conduit **108** establishes this communication. This secondary economizer is arranged in the gas pass **82** and between the superheater sections positioned in the adjoining gas passes. It operates on parallel flow principles, discharging water or steam and water directly from its upper portion to the steam and water drum **20**.

The gas pass **82** in which the secondary economizer is located constitutes a gas by-pass for the superheater, the proportioning of the furnace gas flow through this by-pass and over the superheater being accomplished by the manipulation of gas flow controllers **110**, several of which are shown in Fig. 2 at the outlet ends of the parallel gas passes. Adjacent controllers preferably rotate in opposite directions in order to accomplish a better throttling effect, and better control of the superheat.

The Fig. 1 boiler is of high efficiency and is particularly adapted for operation at the high fluid pressures which are required for the most efficient generation of power. Its operating pressure is in excess of 2000 pounds per square inch.

When pulverized coal is used as fuel the limitation of the combustion rate with reference to the area of heat absorbing surface in sight of furnace radiation is such that the ash is deposited on the floor in a dry state. This heat absorbing surface, essentially in the form of water tubes for high pressure boilers, is most effective, and in the present boiler it is desirable to avoid local hot zones which might cause slag to accumulate on the water walls. Such avoidance of local excessive intensity of heating of the furnace water walls in the interest of dry ash removal and most effective cooling of the furnace gases, is additionally important when the boiler operates with boiler water of high concentration of solids.

It is also to be noted that all of the steam generating tubes of the illustrative boiler are located in the walls of the furnace and in the adjoining gas pass. The heating surface thus provided, especially in the furnace walls which are of sufficient area to insure dry ash, is as a whole also sufficient to generate substantially all of the steam that the furnace gases can superheat to the required degree at the contemplated pressure. The economizer is located in the gas pass beyond the superheater, preheating the feed water and possibly generating some steam. There is no bank of convection steam generating tubes such as has been usually considered standard in water tube steam boilers.

It is also to be understood that at the very high pressures used and at the pertinent superheat, the latent heat of vaporization is smaller in relation to the heat of liquid heating and steam superheating than at low pressures. It is enough smaller to make it possible to reduce the steam generating surface and to concentrate all of it in the furnace walls, especially when these walls have sufficient effective cooling area to cause congealing of the molten ash and its deposit, or separation, in dry form.

In the illustrative boiler the disposition of the steam generating surface in the walls of the furnace makes it unnecessary to provide such setting walls as have been a problem in the use of water tube steam boilers.

The arrangement of the superheater and economizer in the gas pass is such as to provide for the control of superheat without loss of efficiency. One section of the economizer extends across the whole width of the gas flow through the entire convection section. It has an advantageous downflow of water, while a second section of the economizer, with an upflow of water, extends between two vertical baffles at the level of the superheater. The middle part of the gas pass containing a part of the economizer is also a superheater by-pass to regulate superheat by damper gas control at the top of the gas pass.

In the embodiment of the invention illustrated in Fig. 3 of the drawings a combustion chamber indicated generally by the numeral **111** has its boundaries defined by steam generating tubes in a manner somewhat similar to that of the modification previously described. The floor tubes **112** slope downwardly toward the ash pit **114** and are covered on their furnace sides with refractory material **116**. The upright wall tubes **118** and **120** may have the spaces between them filled with ceramic refractory material held in place by metallic extensions welded to the tubes. These tubes are preferably bare on their furnace sides so as to promote a high degree of furnace gas cooling, and in an ignition zone adjacent the burner **122** the tubes are entirely covered by ceramic refractory material to promote high ignition temperatures. The ceramic refractory covering on one wall in the ignition zone is indicated in Fig. 3 by the area ABCD.

With reference to the Fig. 3 embodiment, it is to be noted that the ash pit **114** is beneath the convection zone **130** and that the extensions **132**, 134, and 136 (Fig. 4) of the tubes 124 of the division wall separating the combustion chamber from the convection zone extend downwardly from the drum 140 to a position intermediate the roof and the wall of the furnace. From that position they extend laterally toward the remote wall 142 of the convection zone, and thence downwardly to the top of the ash pit where they are connected to the header 144. As indicated in Fig. 4 of the drawings, the downwardly inclined portions of the tubes 124 are covered on their upper sides by refractory material 146 so that the gases from the furnace enter the convection zone only over a part of the width of the installation. This is indicated by the distance between the baffle 148 and the wall 150 in Fig. 4 of the drawings, the baffle extending above one edge of the refractory material 146 and the wall 150 being defined by wall tubes 152 connecting the upper header 154 with the lower header 156. In the space between the wall 150 and the baffle 148 the gases pass over a screen formed by the downwardly inclined parts of the tubes 132 and 136. They then pass upwardly over the tubes of the superheater 160 and the tubes of the economizer 162 located in the superheater gas pass defined by the baffles 164 and 166.

The tubes of the superheater are in the form of flat coils partially supported by the division wall tubes 124.

Steam from the drum 140 passes through the saturated steam supply tubes 170 to the superheater inlet header 172 and thence generally downwardly through the flue 174 to the superheater outlet header 176.

The economizer may be considered as arranged in two sections. The first section 180 is a counter-flow section located in the flue 182 formed by the baffle 164 and the wall 184. In this section the feed water enters the economizer inlet header 186 and proceeds upwardly through the tubes of the economizer section 180 to the intermediate header 188. From this header the feed water passes downwardly to the inlet header 190 of the parallel flow economizer section in the gas pass between the walls 164 and 166. From that header the fluid within the tubes passes upwardly to the economizer outlet header 192 and thence to the drum 140.

Superheat control is attained by the operation of the dampers 200 and 202 positioned at the top of the superheater by-pass. These dampers are preferably simultaneously rotated in opposite directions in order to accomplish a better throttling effect.

The furnace gases after passing over the tubes of the counter-flow economizer section pass around the lower end of the wall 184 upwardly through the idle pass 204 and then downwardly through the tubes 206 of the air heater 208. Thence they pass through the exhaust fan 210 and through a flue 212 to a stack.

In the operation of the air heater, cold air passes from the inlet 213 over the tubes 206 to the hot air outlet 214, and in order to prevent corrosion of the air heater tubes by condensation of the combustion products at low loads, some of the cold air from the inlet is permitted to pass directly to the outlet 214 through the conduit 216, the amount of air thus by-passing the air heater tubes 206 being determined by the operation of the controller 220. When the quantity of air passing over the tubes is reduced, the exit gas temperature from the air heater is higher and condensation is avoided.

In addition to the damper control of gas flow through the superheater by-pass, Fig. 3 indicates a plurality of dampers 230 arranged across the top of the superheater so as to directly control the gas flow thereover. Adjacent dampers 230 are arranged to move in opposite directions when they are operated for the reason above referred to in describing the operation of the dampers 200 and 202.

We claim:

1. In a water tube steam boiler, a furnace presenting a combustion chamber the sides of which are defined by wall tubes which enable the boiler to generate sufficient steam without the inclusion of a natural circulation bank of steam generating tubes, a convection section including a superheater, means forming an ash disposal zone beneath the convection section, means causing the gases to turn upwardly in passing from the combustion chamber and over said zone to the convection section, means for dividing the convection section into a plurality of gas passes two of which lead upwardly in parallel from said zone to the entrance of the third gas pass, horizontally inclined tube sections extending over said zone at a position beneath said gas passes, some of said tube sections acting as a gas mixing slag screen across the entrances of the parallel gas passes, refractory material closing the spaces between others of the tube sections to close off the third gas pass and form a baffle directing the gases laterally toward the parallel gas passes, one of said parallel gas passes forming a superheater by-pass, superheater elements in the other of the parallel passes, gas flow regulators controlling the gas mass flow through the parallel passes to control superheat, and means causing the gases to pass from said parallel passes into said other gas pass.

2. In a water tube steam boiler, fluid heating and steam generating tubes defining the walls and other boundaries of a combustion chamber, means for burning fuel in said chamber, substantially all of the steam generated by the boiler being generated as a result of the radiant transmission of heat to said tubes, other tubes connected into the boiler circulation and co-operating with some of the first mentioned tubes to define a convection heating zone to and through which furnace gases pass from the combustion chamber, economizer and superheater elements supported by the tubes defining the convection zone, said elements extending across the furnace gas flow, and means forming an ash collection zone common to the combustion chamber and the convection zone for the disposal of the solid residues of combustion, some of said tubes defining floor surfaces of the combustion chamber and the convection zone downwardly inclined toward the common collection zone and others of the tubes constituting a gas mixing screen at a position above the collection zone and between the combustion chamber and the convection zone.

3. In fluid heat exchange apparatus, fluid heating tubes defining a combustion chamber having a gas outlet at the lower part thereof, means forming a gas pass in which the furnace gases pass upwardly from said outlet, some of said tubes extending across the furnace gas inlet of said gas pass, means dividing said gas pass into two parallel gas passes immediately beyond said inlet, a secondary economizer in one of said parallel passes, a superheater in the other of said parallel passes, means for controlling the division of the total furnace gas flow between the

parallel passes to control superheat, and a primary economizer subjected to all of the furnace gases beyond said parallel passes.

4. In a steam generator, a boiler setting, furnace wall tubes defining a combustion chamber having a furnace gas outlet at the lower part thereof, a steam and water drum in communication with said wall tubes, other wall tubes in communication with the drum and defining a wall of a second stage furnace gas chamber receiving the furnace gases from said outlet, some of said first mentioned wall tubes having parts defining a wall dividing the combustion chamber from the second stage chamber and other parts constituting a screen extending across said outlet, fuel burning means associated with the combustion chamber, means providing a plurality of gas passes arranged in parallel in the second stage chamber, said gas passes receiving the furnace gases from the combustion chamber, steam generator auxiliary in the respective parallel passes, means for controlling the division of the furnace gases between said passes to regulate the effect of at least one of said auxiliaries, and means forming a reverse gas pass within the setting, said reverse gas pass being arranged to receive furnace gases discharged from both of said parallel passes.

5. In a steam generator, a combustion chamber, a convection section in which spaced tubes extend across the path of the furnace gases from the combustion chamber, spaced tubes connected into the fluid system of the generator and defining a division wall between the combustion chamber and the convection section, said tubes having lower portions disposed beneath the convection section, the lower portions of some of the tubes being arranged in wall alignment while the remainder are arranged as a screen across the furnace gas inlet of the convection section, refractory material filling the spaces between the tubes which are in wall alignment, and a baffle construction, extending upwardly from said wall aligned tubes and into the convection section to direct the furnace gases over the tubes of the convection section above the screen.

6. In a steam generator, a boiler setting of rectangular section, a furnace, walls of which are defined by steam generating tubes, down-shot pulverized fuel burners firing the furnace, a convection section laterally adjacent the furnace, some of the steam generating tubes defining a division wall common to the gas pass of the convection section and the furnace and having their lower ends bent so as to extend in screen formation across the gas entrance to the convection section, fluid heating tubular elements extending transversely of gas flow in the convection section, the said heating elements being partly supported by the division wall tubes, means providing water cooled floor surface for the bottom of the furnace area and extending beneath the convection section for the disposal of ash particles thereof, the furnace wall tubes and the partition tubes being connected to an upper steam and water drum extending transversely at a position across the central portion of the setting.

7. In a steam generator, a boiler setting of rectangular section, a furnace, walls of which are defined by steam generating tubes, down-shot pulverized fuel burners firing the furnace, a convection section laterally adjacent the furnace, some of the steam generating tubes defining a wall directly dividing the gas pass of the convection section from the furnace and having their lower ends bent so as to extend in screen formation across the gas entrance to the convection section, superheater elements extending transversely of gas flow in the convection section, the said superheater elements being partly supported by the division wall tubes, means providing water cooled surface for the bottom of the furnace area and extending beneath the convection section to form the wall of an ash disposal zone, the furnace wall tubes and the partition tubes being connected to an upper steam and water drum extending transversely at a position across the central portion of the setting, means connecting the steam space of the drum with the superheater elements, the superheater elements being U-shaped straight portions extending throughout the major portions of their length and transversely of the gas flow.

8. In a steam generator, a boiler setting of rectangular section, a furnace, walls of which are defined by steam generating tubes, down-shot pulverized fuel burners firing the furnace, a convection section laterally adjacent the furnace, some of the steam generating tubes defining a partition wall directly dividing the gas pass of the convection section from the furnace and having their lower ends bent so as to extend in screen formation across the gas entrance to the convection section, superheater elements extending transversely of gas flow in the convection section, the said superheater elements being partly supported by the division wall tubes, means providing water cooled surface for the bottom of the furnace area and extending beneath the convection section for the disposal of ash particles thereof, the furnace wall tubes and the partition tubes being connected to an upper steam and water drum extending transversely at a position across the central portion of the setting, means connecting the steam space of the drum with the superheater elements, the superheater elements being U-shaped with straight portions extending throughout the major portions of their length and transversely of the gas flow, the screen extensions of the partition wall tubes having their lower ends extending vertically along a downward extension of a wall of the convection section.

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CERTIFICATE OF CORRECTION.

Patent No. 2,287,798. June 30, 1942.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 51, for the word "alternative" read --alternate--; page 4, first column, line 21, claim 4, for "auxiliary" read --auxiliaries--; line 43, claim 5, strike out the comma after "construction"; and second column, line 28, claim 7, before "straight" insert --with--; 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 15th day of August, A. D. 1944.

Leslie Frazer

(Seal) Acting Commissioner of Patents.