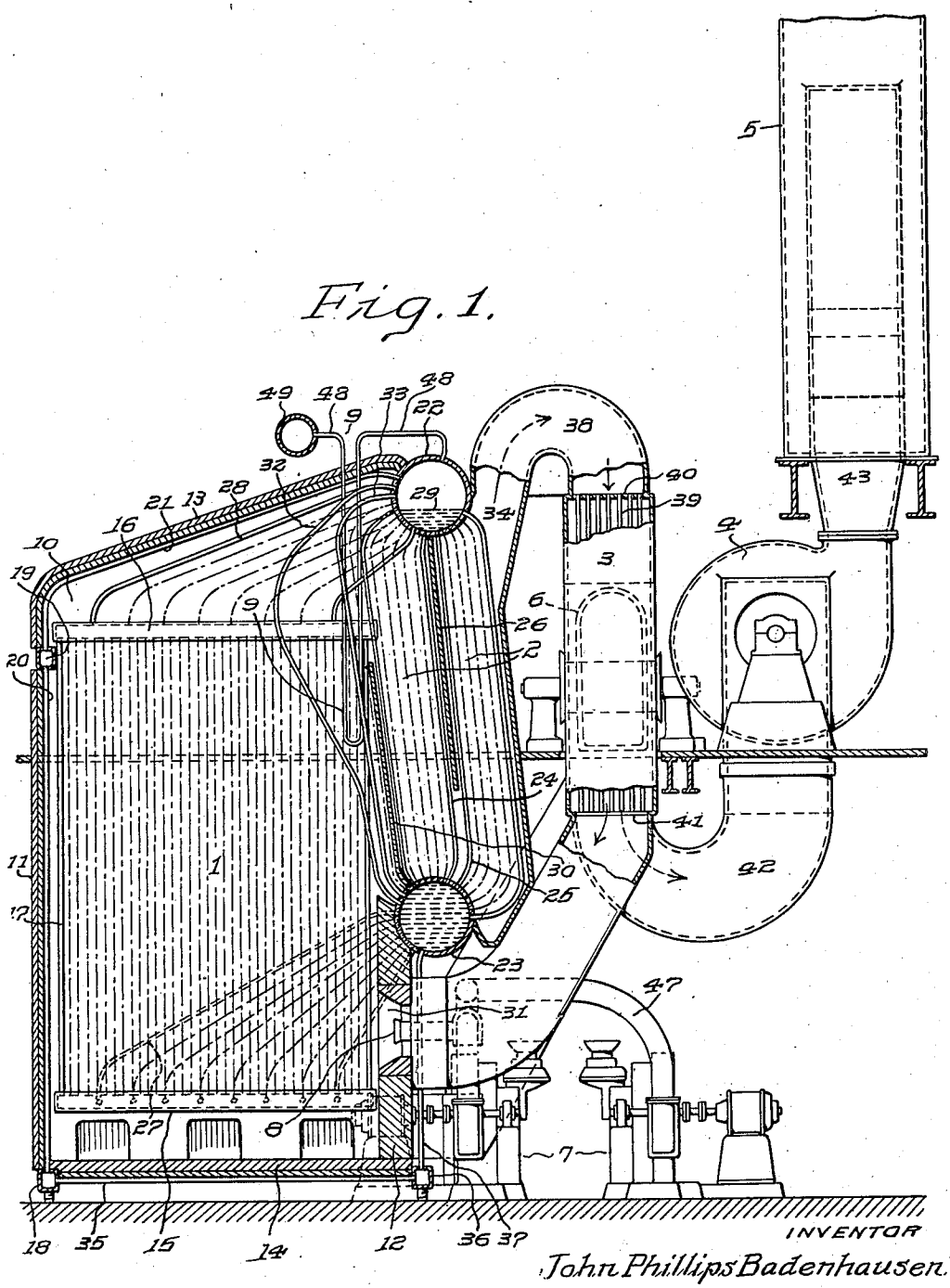
Feb. 1, 1938. J. P. BADENHAUSEN 2,107,022

STEAM GENERATOR

Filed April 8, 1935 3 Sheets-Sheet 1

Fig. 1.



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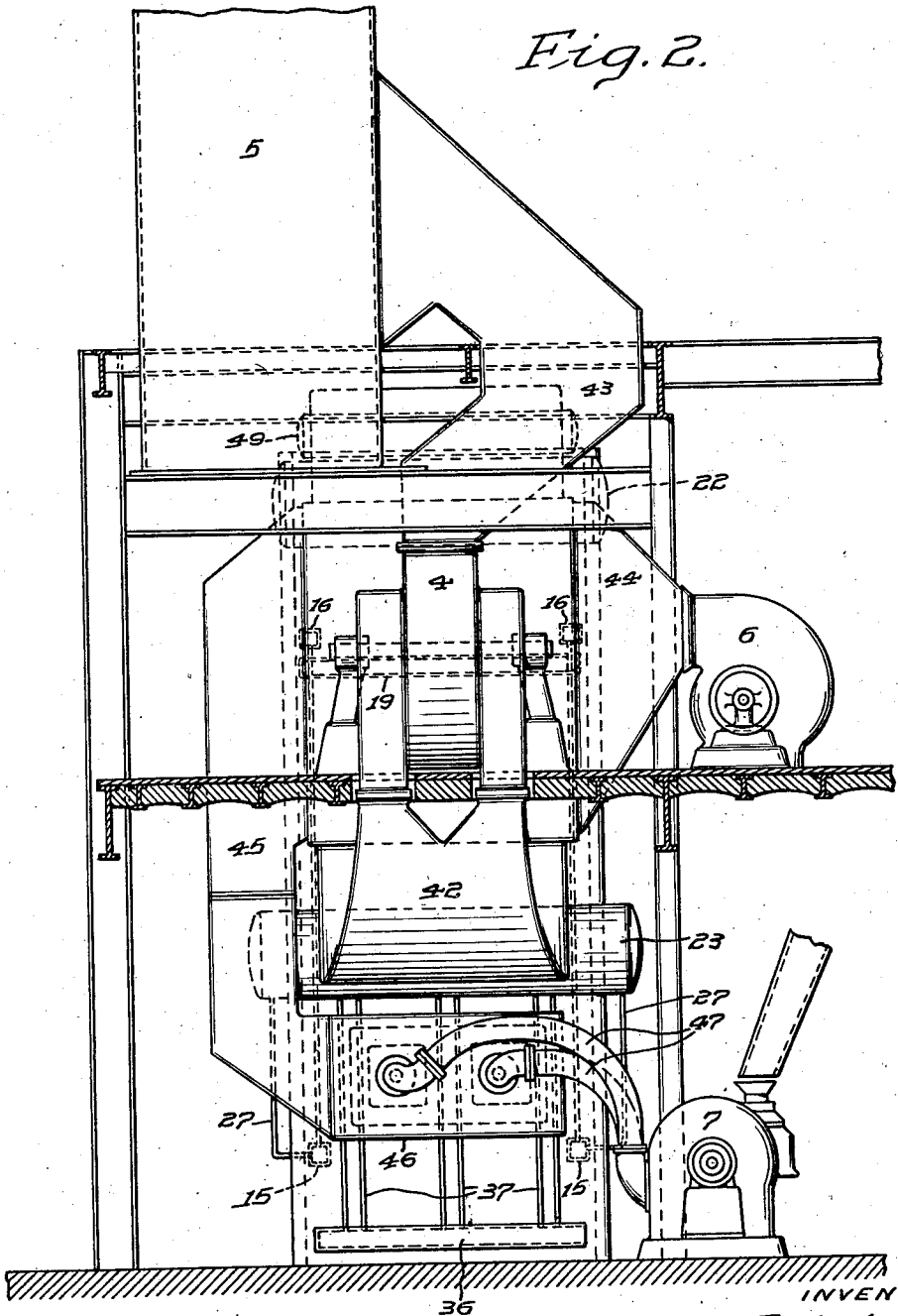
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STEAM GENERATOR

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Fig. 2.



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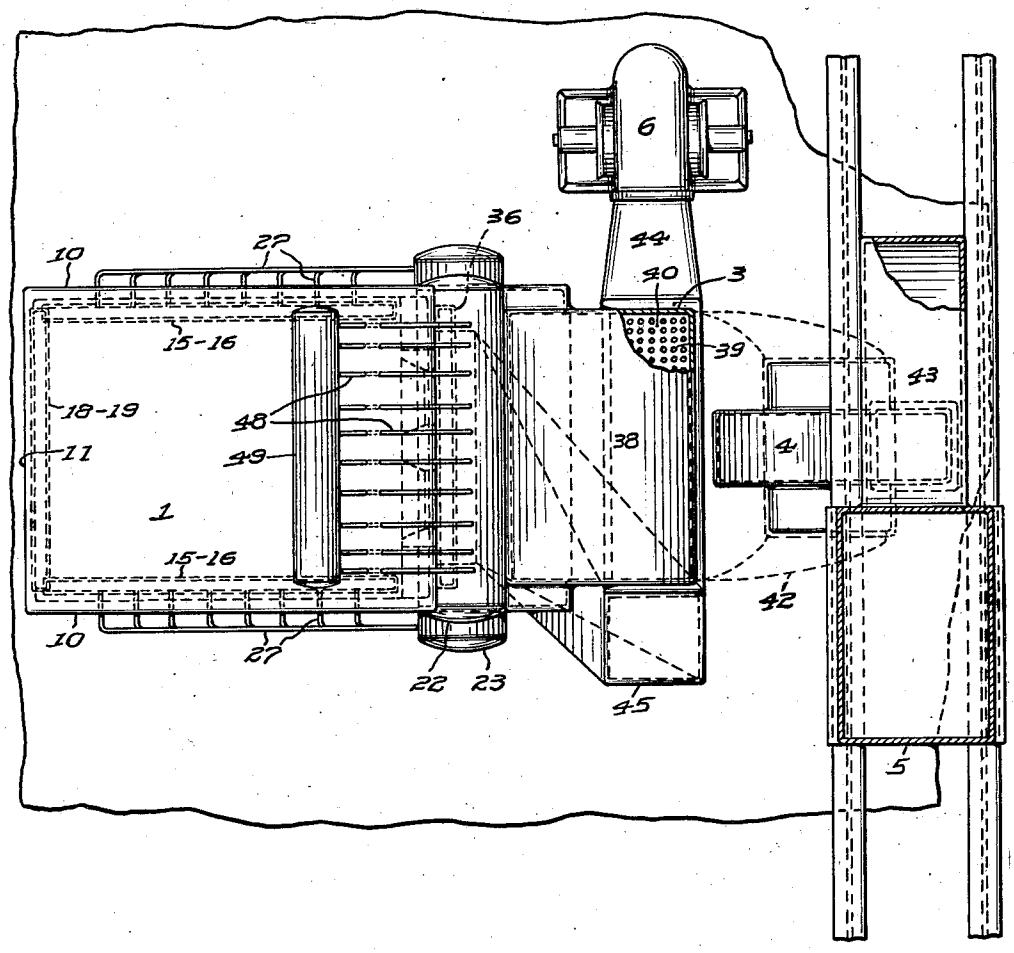
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STEAM GENERATOR

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Fig. 3.



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UNITED STATES PATENT OFFICE

2,107,022

STEAM GENERATOR

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Application April 8, 1935, Serial No. 15,211

4 Claims. (Cl. 122—235)

My invention relates to the generation of steam, and more particularly to a complete steam generating unit in which the various submechanisms or accessory mechanisms are constructed and arranged with respect to each other so that each directly contributes to the efficient operation of the others and to the unit as a whole.

Among the objects of the present invention are to provide a highly efficient steam generator plant of the water-tube boiler type, of large capacity, and arranged within a relatively small space, by providing ample combustion chambers wherein a substantially complete combustion of the fuel is effected within the combustion chamber; to utilize substantially all of the radiant heat of combustion for the purpose of generating steam by providing the four side walls and the top wall of the combustion chamber each with a bank of water-tubes connected to the water circulatory system of the generator for the transfer thereto of a great proportion of the radiant heat of combustion; to reduce the height of the generator as a whole by positioning a relatively small water-tube boiler section, comprising a pair of parallel horizontal drums vertically disposed one over the other and connected by banks of downcomer and riser tubes, at the front side of the combustion chamber with the upper steam-and-water drum substantially on the level at which the gases of combustion leave the combustion chamber and providing the boiler section with baffles whereby the gases of combustion on entering the boiler section pass downwardly to a point near the lower drum and then are conducted upwardly through the bank of downcomer tubes before passing out of the boiler section; to provide a generator unit, by reason of the features last described, which as a whole is not substantially higher or taller than the combustion chamber; to provide the boiler section of the generator with a transverse bank of riser tubes positioned in the path of the gases of combustion as they leave the combustion chamber and prior to their passage to the boiler section of the generator and operative to prevent the passage of dust, slag or unburned particles of fuel therethrough into the boiler section and to substantially throw said particles back into the combustion chamber thereby preventing an accumulation of scot, slag and ash in and on the water-tubes of the boiler section; to first admit the gases of combustion to the boiler section at the top of the boiler section and to deflect the stream of gases so delivered downwardly through a rear bank of riser tubes of the boiler section and to then deflect them upwardly through a front bank of downcomer tubes, and thereafter delivering the gases of combustion after they have traversed the said boiler section to an air heater at a temperature sufficiently high to elevate the temperature of the air delivered from the air heater to the combustion chamber with the fuel to a temperature at or above that necessary to ignite the fuel; to attach the downcomer tubes of the boiler section and the wall cooling tubes to the upper steam-and-water drum at points well below the water level of the boiler and the riser tubes of the same thereto at points above the normal level of the water in the boiler to provide a circulation of water in the boiler substantially irrespective of the quantity of water in the boiler; to permit the gases of combustion that traverse the boiler section to leave the boiler section at a relatively high temperature and immediately transferring the heat thereof to the air to be supplied to the combustion chamber with the fuel, and to thereby provide facile means for raising the temperature of the air delivered to the combustion chamber to a point higher than that necessary to ignite the fuel, and to thereby accelerate the combustion of the fuel without substantially reducing the temperature of the combustion chamber; to provide a water circulatory system, including the boiler tubes and the banks of tubes for cooling the walls of the combustion chamber whereby the generator or steam generator may be safely operated even when the level of the water in the generator is six or more feet below the normal water level for which the generator is designed, and without interfering with the free circulation of water through the said parts; and to project the fuel into the combustion chamber, in the form of minute particles (liquid fuel or solid pulverized coal) suspended in a fluid medium (hot air), the height of the combustion chamber being sufficient to permit of the complete combustion of the particles within the combustion chamber and prior to the passage for the gases of combustion from the combustion chamber to the boiler section proper.

Other objects of my invention will appear in the specification and claims below.

Referring to the drawings forming a part of this specification and in which the same reference characters are used throughout the various views to designate the same parts,

Fig. 1 is a side elevational view of my improved generating unit, but with the furnace or combustion chamber and the boiler section of the generator in vertical cross-section and with the clo-

sure or casing of the air heater broken away at the ends for the purpose of indicating the direction of the passage of the air and of the products of combustion therethrough;

Fig. 2 is an end elevational view of the construction shown in Fig. 1 and taken from the right-hand side of Fig. 1;

Fig. 3 is a plan view of the construction shown in Fig. 1.

The essential elements which together form my improved steam generating unit comprises a furnace or combustion chamber 1; a water-tube boiler section 2; an air heater 3; an induced draft fan 4 for drawing the products of combustion through the boiler section and through the air heater 3 and for delivering the products of combustion to the stack 5; a forced draft fan 6 to supply air to the furnace with the fuel for the combustion of the fuel; a mechanism 7 for finely dividing the fuel into minute particles to be projected into the combustion chamber; a set of burners 8 through which the finely divided fuel is projected into the combustion chamber; and the superheater 9. While all of these elements singly and broadly may have been previously used in different combinations in steam generating plants, I have arranged and disposed the same in such a manner, with respect to each other, that for a given capacity, the unit occupies relatively little space and its efficiency and output is substantially higher than that which has been heretofore attained in boiler construction and design. These improvements will now be referred to, more specifically, as follows:

The combustion chamber 1 comprises two side walls 10—10, a rear wall 11, a front wall 12, a top wall 13, and a bottom wall 14. Each side wall 10 is provided near the bottom thereof with a lower header 15 and an upper header 16 connected by a bank of tubes 17 which are exposed to the radiant heat of the burning gases in the combustion chamber. The rear wall is also provided with a lower header 18 and an upper header 19 connected by a bank of tubes 20 also exposed to the radiant heat of combustion. The lower header 18 of the rear wall is, however, below the bottom wall 14 of the furnace or combustion chamber. From the upper header 19 a bank of tubes 21 extends upwardly close to the top wall 13 and such tubes are also exposed to the interior of the combustion chamber and to the radiant heat thereof.

The boiler section of the steam-generating unit comprises an upper steam-and-water drum 22 and a lower water drum 23 preferably vertically beneath the upper drum 22 and connected by two banks of tubes 24 and 25, the tubes 24 being the tubes nearest the combustion chamber 1 and the tubes 25 being more remote from the combustion chamber 1, said banks 24 and 25 being separated by a baffle 26 extending downwardly longitudinally of the tubes and between the banks thereof from the upper drum 22 to a point adjacent but spaced from the lower drum 23.

The lower headers 15 of the side walls of the combustion chamber 1 are supplied with water from the lower drum 23 through a series of tubes 27 preferably arranged outside of the side walls 10, or at least where they are not exposed to the radiant heat of the combustion chamber, and constitute downcomer tubes through which the water of the boiler circulates downwardly from the lower water drum 23 to the lower headers 15 of the side walls. The upper headers 16 of the side walls are preferably connected by a bank of riser tubes 28, the upper ends of which communicate with the steam-and-water drum 22 of the boiler section. As many of these tubes of the bank of tubes 28 as possible are attached to the steam-and-water drum 22 at points above the normal water level 29 of the boiler section. The bank of tubes 21 of the top wall are preferably also in communication with the steam-and-water drum 22 at points above the level of the water in the boiler section.

Since the hot gases of combustion traverse the bank of tubes 24 of the boiler section immediately upon their exit from the combustion chamber 1 and since they are cooler when they subsequently traverse the front bank 25 of the boiler section the forward bank 25 will substantially comprise a set or bank of downcomer tubes while the bank 24 will substantially be a bank of riser tubes of the boiler section. To more completely separate the rear bank 24 of boiler tubes from the combustion chamber, I preferably provide a baffle 30 constituting substantially an upward extension of the front wall 12 whereby the gases of combustion are forced to travel upwardly through the combustion chamber to a point beyond or above the baffle 30 between which and the top wall 13 the said gases leave the combustion chamber and enter the boiler section 2.

The upper steam-and-water drum 22 of the boiler section is at the upper side of the passage between the top wall 13 and the upper end of the baffle 30, while the lower drum 23 is directly vertically below the drum 22 and is only a little above the opening 31 through which the fuel is projected into the boiler as will be referred to again below. Thus it is that the boiler section 2 is not substantially higher than the highest portion of the combustion chamber and the boiler section 2 as a whole is relatively smaller and is vertically positioned in front of the front wall 12 of the furnace and its extension formed by the baffle 30, the baffle 30 lying substantially in the vertical plane of the front wall 12.

Heretofore it has been common in this type of steam-generator to place the boiler section above and over the combustion chamber so that the gases of combustion after passing out of the combustion chamber continue to travel upwardly through the steam-boiler section. This greatly increases the vertical height of the unit as the power or capacity of the generator is increased, that is to say, the larger the generator, the larger the combustion chamber and the higher the entire generator unit. My improvement consists in making the entire generator plant no higher than that of the combustion chamber, the combustion chamber being large and high enough to afford time for the complete combustion of the fuel prior to its departure from the combustion chamber and then passing the hot gases of combustion through a steam-generating unit or boiler section which is positioned in front of the ignition chamber rather than over it thereby producing a steam-generating unit of the smallest vertical dimension.

In addition to the banks 24 and 25 of boiler tubes, I preferably connect the upper and lower drums 22 and 23 of the boiler section 2 by two banks of tubes 32 and 33 both of which are behind the baffle 30 and are within the combustion chamber 1 and are therefore exposed to the radiant heat of the combustion chamber. The first bank 32 is deflected rearwardly out into the combustion chamber and their upper ends are connected to the upper drum 22 at a point above the normal water level 29. In them the water circulating be-

tween the upper and lower drums is converted into steam, due to the high temperature to which the bank of tubes are subjected, which discharges into the upper part of the steam-and-water drum 22. These tubes 32 and 33 are preferably arranged in close banks, extending across the full width of the combustion chamber 1 and substantially receive the blast of burning gases just prior to their exit from the combustion chamber. These tubes 32 disposed in the main at an angle to the vertical, are engaged by the burning gases just as the gases are about to leave the combustion chamber and any slag, ash or unburned fuel impacting against these tubes 32, will be arrested in their travel and will be thrown back to the combustion chamber. The function of this bank of tubes 32 is, then, to prevent any accumulation of ash, slag or soot on the banks 24 and 25 of the boiler section thereby keeping said banks clean of accumulations and efficient. The second bank 33 of tubes is preferably also connected at their upper ends to the upper steam-and-water drum at a point above the water level 29 and, being exposed to the high temperature of the ignition chamber also constituting steam generating tubes which facilitate the circulation of the water in the downcomer bank 25 and the upward flow or circulation of the water in the boiler in the riser bank 24. They also function to cool the baffle 30 which, as above stated, substantially forms a part of or extension of the front wall 12.

It is to be observed that the boiler section 2 of the generator is relatively small. The gases of combustion traverse it but twice, first through the bank of riser tubes and then through the bank of downcomer tubes 25. It is the purpose of my invention to thus make this boiler section of the generator relatively small so that the gases of combustion leaving the boiler section through the opening or port 34 are still very hot for the purposes to be hereinafter described.

But returning to the combustion chamber 1 the lower header 18 of the rear wall is supplied with water from the boiler conducted thereto through the pipes 35 below the lower or bottom wall 14 of the combustion chamber, said pipes 35 being protected from the radiant heat of combustion of the boiler by the bottom wall 14. The forward end of the pipes 35 are connected to a header 36 extending transversely to the boiler and supplied with water from the boiler drum 23 through downcomer pipes 37, it being understood that the lower drum 23 is practically at the coolest portion of the circulatory system of the boiler. The cool water conducted therefrom through the pipes 37, headers 36 and pipes 35 to the lower header 18 of the rear wall, rises in the banks 20, due to the generation of steam therein, and moving upwardly through the upper header 19 and the bank of tubes 21 discharges into the upper drum 22 of the boiler section above the water level 29.

Adjacent the boiler section 2 is the air heater 3, the upper end of which is connected to the port 34 by a conduit 38. This air heater 3 is an enclosed box-like structure filled with vertical tubes 39 passing through the upper wall 40 of the air heater 3 and in communication with the duct 38. These tubes 39 extend through the air heater 3 and through the bottom wall 41 thereof, to discharge the hot gases of combustion passing therethrough directly into a duct 42 connected with an induction draft fan 4 which in turn discharges the gases of combustion drawn therethrough to a duct 43 leading into the stack 5.

To effect a transference of heat from the hot gases of combustion in the air heater 3 to the air to be supplied to the burners 8 for combustion purposes, I provide the forced draft fan 6 (see Fig. 2) which communicates through a duct 44 with one side of the air heater 3 delivering air from the fan 6 to the space in the air heater outside of and between the pipes or tubes 39. On the opposite side of the air heater 3 I provide a duct 45 leading downwardly from the side thereof and discharging the hot air into the air box 46 covering the doors or openings 31 through which the fuel is projected into the combustion chamber by the burners 8.

The fuel for which these steam generator units are supplied preferably consists of fine particles suspended or floating in a gaseous medium, such as air. In the drawings is more or less diagrammatically indicated a system whereby pulverized solid fuel is thus projected into the ignition chamber, but it is to be understood that a liquid fuel may be similarly fed into and discharged into the combustion chamber where a liquid fuel is obtainable and is preferred. In either case the fuel is projected as a cloud or spray of finely divided separate particles floating in air. In order that this finely divided fuel may be substantially immediately ignited upon its entrance into the combustion chamber, I prefer to suspend it in an atmosphere the temperature of which is as high or higher than the temperature necessary to ignite it. It is for this purpose that the products of combustion leaving the boiler section 2 of my steam-generator are preferably very hot and are immediately conducted to the air heater where the heat of the spent gases is effectively transferred to the air which is immediately delivered to the burners 8 projecting into the doors 31 of the front furnace wall 12.

In the drawings I have shown merely in elevation, a pair of coal pulverizers 7 connected by pipes 47 with the burners 8 whereby the pulverized coal delivered to the burners 8 is immediately commingled with the hot air from the air box 46 and discharged as a cloud into the combustion chamber.

I preferably provide the boiler with a suitable superheater 9 comprising a bank of tubes 48 extending from the top of the upper drum 22 rearwardly and forming the superheater loop 9 in the combustion chamber 1 across the outlet between the baffle 30 and the top wall 13. This superheater 9 communicates with the superheater drum 49 located in any desirable place and preferably above the top wall 13 whence the superheated steam may be conducted by suitable piping to the point where it is to be utilized.

It will thus be apparent that I have provided an exceedingly compact and efficient unit wherein the air admitted into the combustion chamber with the finely divided fuel is at a high temperature and that this heat for the air for combustion is transferred thereto from the gases of combustion leaving the boiler section of the generator at a temperature sufficiently high to heat the air supplied to the combustion chamber to a temperature as high or higher than that at which the fuel will ignite.

Moreover, by the above arrangement the water level 29 in the boiler may be allowed to fall considerably because the riser pipes or tubes of the banks 32 and 33 and some of the riser tubes of the bank 24 of the boiler section normally discharge steam and water into the drum 22 comparatively near the top thereof and what water

is so discharged with the steam will be conducted immediately into the downcomer tubes 25 of the boiler and to the lower drum 23. From the lower drum 23 the water will flow to the headers 15 of the side walls and to the headers 36 and 18 to the rear wall. The steam generated in the boiler tubes 24 and in the water cooled walls and in the top wall will be discharged with a certain amount of water entrained therewith into the upper drum 22, thereby insuring a continuous circulation of water throughout the boiler section and through the water cooled walls of the boiler even when the water level of the boiler is relatively very low.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States is:

1. In a steam generating unit, the combination of a combustion chamber and a boiler section, the walls of said combustion chamber being lined with water tubes exposed to the radiant heat of the burning fuel in said chamber, and forming a substantial part of the steam generating section of said unit, said boiler section comprising a transverse steam-and-water drum at the upper end of said boiler section, a transverse water drum substantially vertically below said first mentioned drum, a bank of riser tubes connecting said lower drum with said upper drum at points above the normal water level of said boiler, a bank of downcomer tubes connecting said upper drum below the water level thereof with the lower drum, and a baffle extending between said banks downwardly from said upper drum to a point adjacent but spaced from said lower drum to provide a passage for the gases of combustion from said riser bank to said downcomer bank of said boiler, a wall extending from said lower drum upwardly between said combustion chamber and said boiler section and providing at the top thereof a passage from the top of said combustion chamber to the top of said boiler section for the passage of gases of combustion, an additional bank of riser tubes extending from said lower to said upper drum and arranged to the rear of said wall, the heat absorptive capacity of said boiler section being relatively small whereby the temperature of the gases of combustion leaving said boiler section after traversing the tubes thereof is higher than the temperature required to ignite the fuel in said combustion chamber, burners for impelling fuel in a finely divided condition into said combustion chamber, and means to supply air to said burners and means to transfer the heat of the gases, immediately they leave said boiler, to said air on its passage to said burners to raise the temperature of the air so supplied to substantially the temperature at which said fuel ignites.

2. In a steam generating unit, the combination of a combustion chamber of a size sufficiently large to provide for the complete combustion of a finely divided fuel therein and a boiler section mounted on one side of said combustion chamber, the top of said boiler section being substantially level with the top of said combustion chamber, said boiler section comprising an upper drum, a lower drum, and banks of tubes extending therebetween, and a baffle extending from said upper drum downwardly and terminating short of said lower drum to form a passage between said lower end thereof and said lower drum for the passage of gases, a wall extending from said lower drum upwardly between said combustion chamber and said boiler section and providing at the top thereof a passage from the top of said combustion chamber to the top of said boiler for the passage of gases of combustion, said banks of tubes including banks of riser tubes in the passage between said wall and one side of said baffle and banks of downcomer tubes in the space on the other side of said baffle, a bank of riser tubes connecting said lower and upper drum and positioned within said combustion chamber relatively close to said upwardly extending wall to cool said wall, exposed to the radiant heat of said combustion chamber, and operative to supplement the steam generating capacity of the unit, and an additional bank of riser tubes connecting said lower and upper drum and spaced from said last named bank, said additional bank of tubes having inclined angularly disposed portions extending within the combustion chamber and away from said wall for preventing the entrainment of solid particles with the gases of combustion passing into the boiler section.

3. In a steam generating unit, the combination of a combustion chamber and a boiler section, the walls of said combustion chamber being lined with water tubes exposed to the radiant heat of the burning fuel in said chamber, and forming a substantial part of the steam generating section of said unit, said boiler section comprising a transverse steam-and-water drum at the upper end of said boiler section and at the front of said combustion chamber, a transverse water drum substantially vertically below said first mentioned drum, a bank of riser tubes connecting said lower drum with said upper drum at points above the normal water level of said boiler, a bank of downcomer tubes connecting said upper drum below the water level thereof with the lower drum, and a baffle extending between said banks downwardly from said upper drum to a point adjacent but spaced from said lower drum to provide a passage for the gases of combustion from said riser bank to said downcomer bank of said boiler, a wall extending from said lower drum upwardly between said combustion chamber and said boiler section and providing at the top thereof a passage from the top of said combustion chamber to the top of said boiler section for the passage of gases of combustion, an additional bank of riser tubes extending from said lower to said upper drum and arranged to the rear of said wall, the heat absorptive capacity of said boiler section being relatively small whereby the temperature of the gases of combustion leaving said boiler section after traversing the tubes thereof is higher than the temperature required to ignite the fuel in said combustion chamber, burners in the front wall of said combustion chamber for impelling fuel in a finely divided condition into said combustion chamber, means to supply heated air to said burners including an air heater in front of said combustion chamber to transfer the heat of the gases, immediately they leave said boiler, to said air on its passage to said burners to raise the temperature of the air so supplied to substantially the temperature at which said fuel ignites.

4. In a steam generating unit, the combination of a combustion chamber and a boiler section, the walls of said combustion chamber being lined with water tubes exposed to the radiant heat of the burning fuel in said chamber, and forming a substantial part of the steam generating section of said unit, said boiler section comprising a transverse steam-and-water drum at the upper end of said boiler section and at the

front of said combustion chamber, a transverse water drum substantially vertically below said first mentioned drum, a bank of riser tubes connecting said lower drum with said upper drum at points above the normal water level of said boiler, a bank of downcomer tubes connecting said upper drum below the water level thereof with the lower drum, and a baffle extending between said banks downwardly from said upper drum to a point adjacent but spaced from said lower drum to provide a passage for the gases of combustion from said riser bank to said downcomer bank of said boiler, a wall extending from said lower drum upwardly between said combustion chamber and said boiler section and providing at the top thereof a passage from the top of said combustion chamber to the top of said boiler section for the passage of gases of combustion, an additional bank of riser tubes extending from said lower to said upper drum and arranged to the rear of said wall, the heat absorptive capacity of said boiler section being relatively small whereby the temperature of the gases of combustion leaving said boiler section after traversing the tubes thereof is higher than the temperature required to ignite the fuel in said combustion chamber, burners for impelling fuel in a finely divided condition into said combustion chamber, and means to supply heated air to said burners including an air heater in front of said combustion chamber, a duct through which the gases of combustion leaving said boiler section are immediately delivered to said air heater, a conduit connecting the upper end of said boiler section to the top of said air heater and a conduit to conduct said gases of combustion from said air heater to the stack, and an induction fan to draw said gases of combustion through said air heater and to deliver the same to said stack, a conduit from said air heater to the burners of said combustion chamber, and a forced draft fan to drive the heated air directly to the burners.

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