

May 30, 1933.

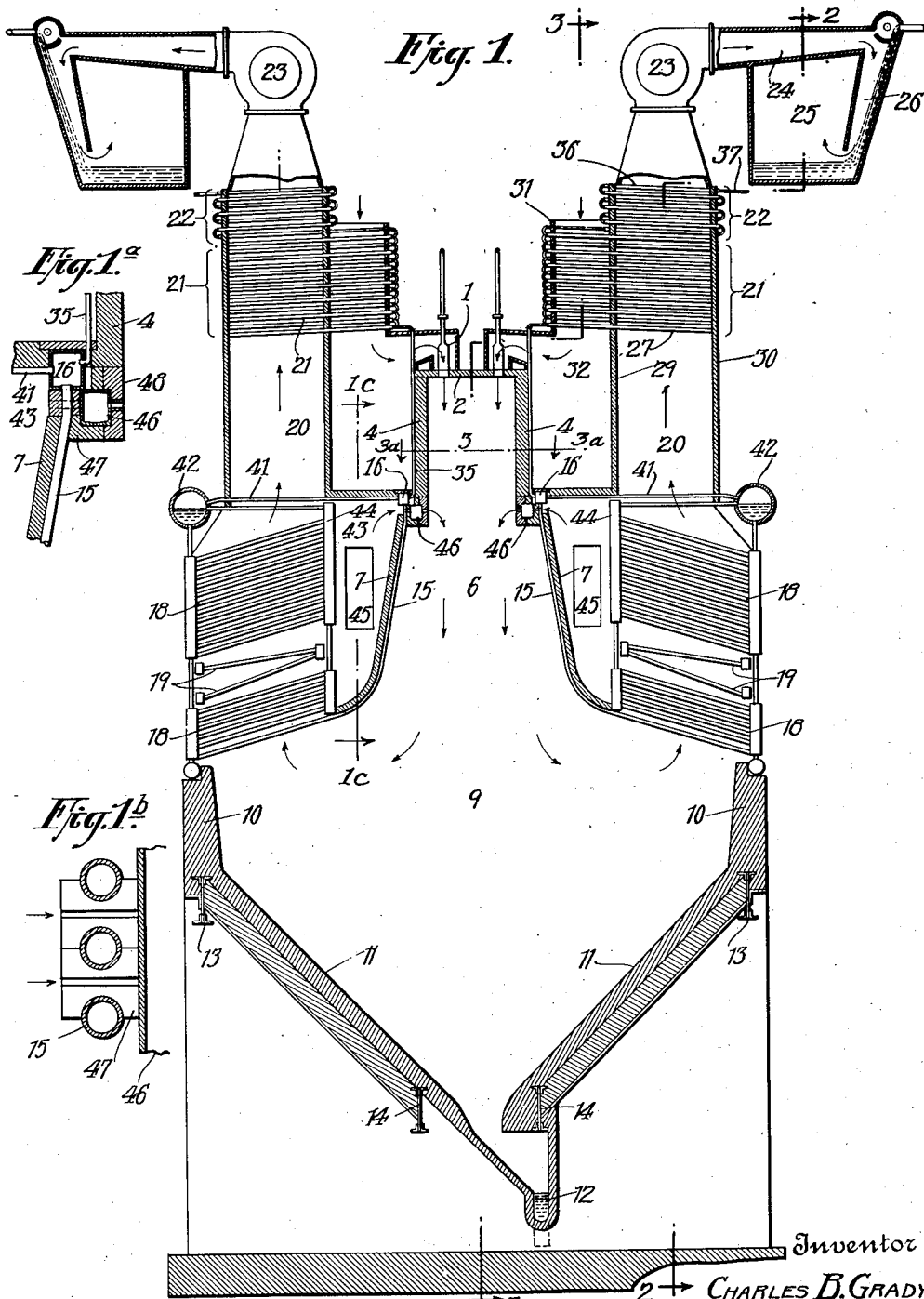
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1,911,501

STEAM GENERATING APPARATUS AND METHOD

Filed Sept. 28, 1923

4 Sheets-Sheet 1



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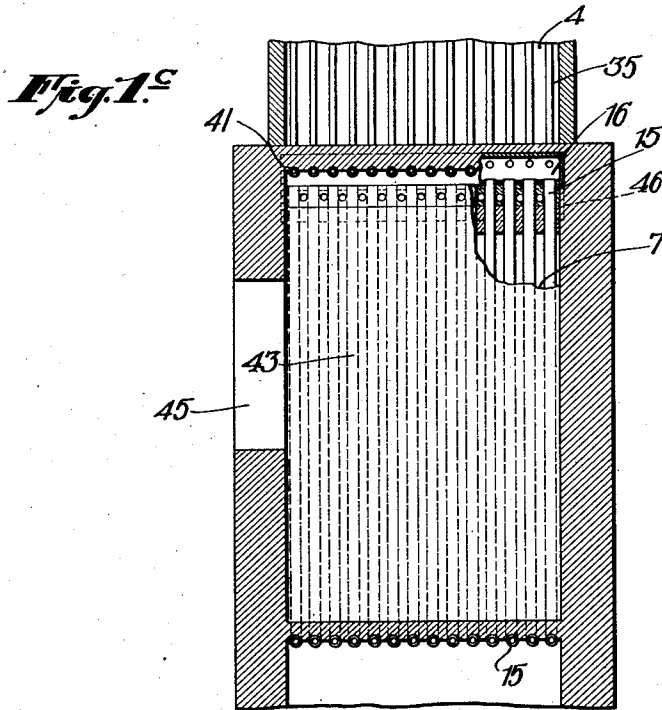
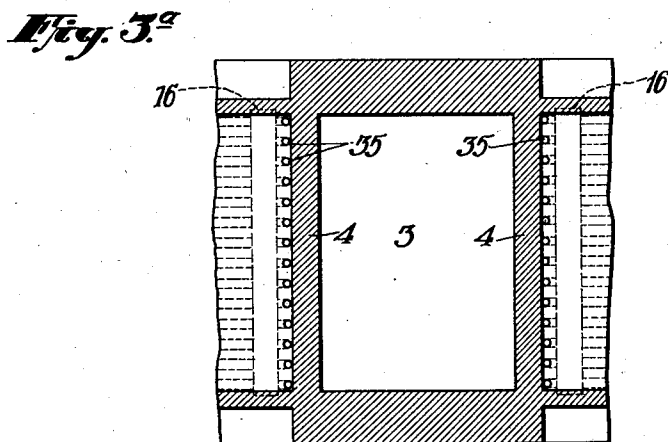
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STEAM GENERATING APPARATUS AND METHOD

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4 Sheets-Sheet 2



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STEAM GENERATING APPARATUS AND METHOD

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4 Sheets-Sheet 3

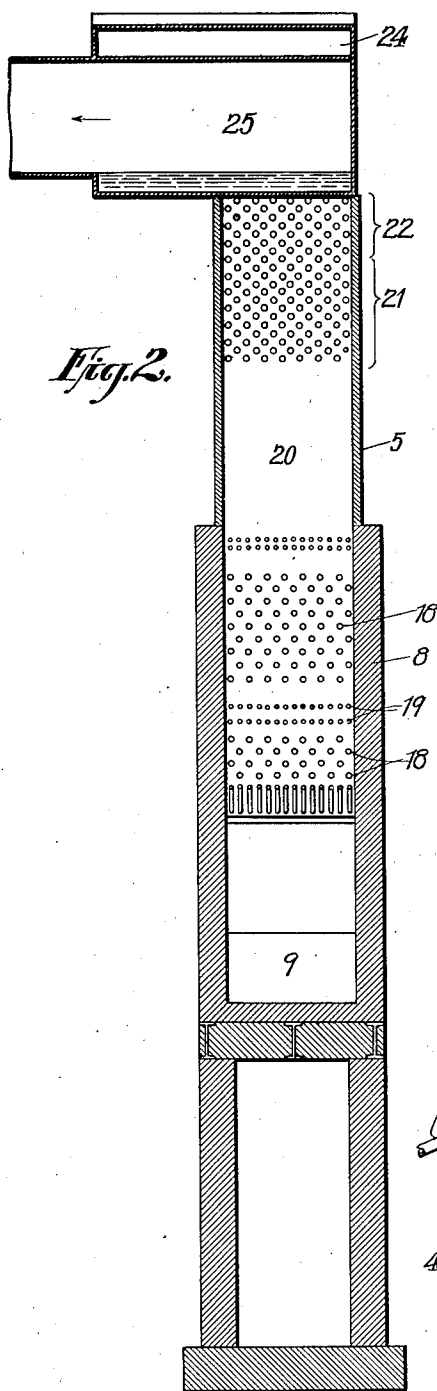


Fig. 2.

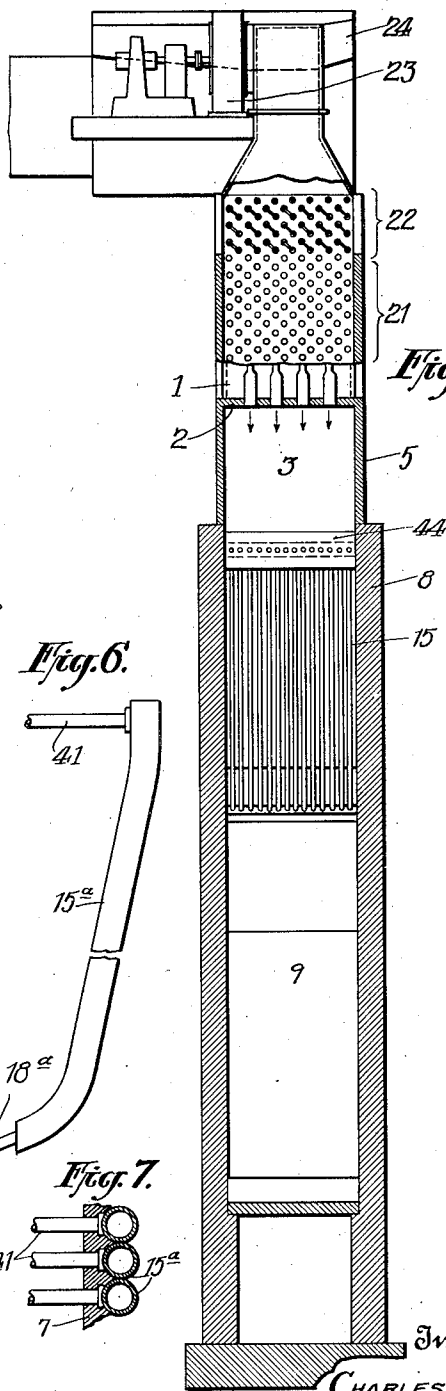


Fig. 3.

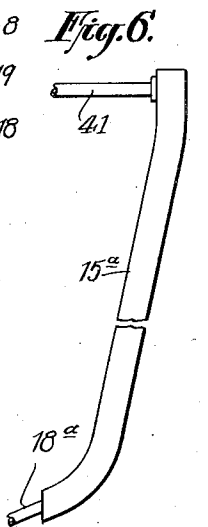


Fig. 6.

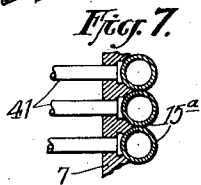


Fig. 7.

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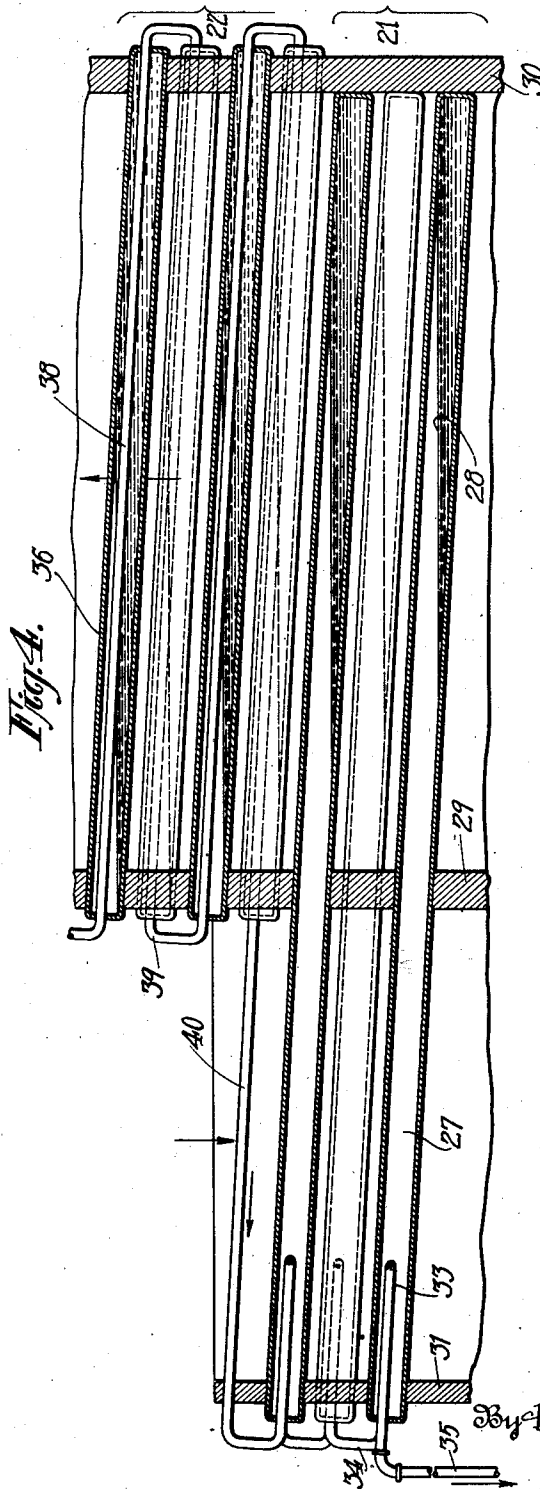
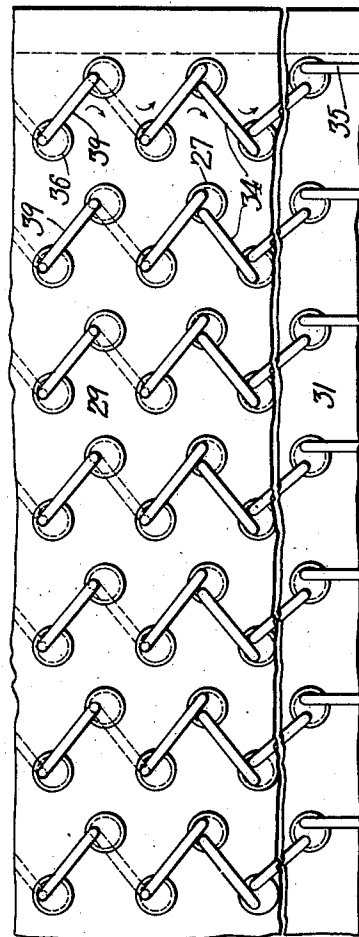
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STEAM GENERATING APPARATUS AND METHOD

Filed Sept. 28, 1923

4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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STEAM GENERATING APPARATUS AND METHOD

Application filed September 28, 1923. Serial No. 665,266.

My invention aims to provide a steam generating unit particularly, though not exclusively, adapted for the burning of pulverized fuel, having various advantageous features 5 referred to in detail hereinafter.

Fig. 1 is a longitudinal vertical section;

Figs. 1^a and 1^b are vertical and horizontal sections of an enlarged detail; Fig. 1^c is a detail section on line 1^c—1^c of Fig. 1;

10 Figs. 2 and 3 are vertical cross-sections taken respectively along the lines 2—2 and 3—3 of Fig. 1; Fig. 3^a is a horizontal section on line 3^a—3^a of Fig. 1;

Fig. 4 is a longitudinal section on an enlarged scale of parts of the heat exchangers;

Fig. 5 is a partial end view of the same; Figs. 6 and 7 are an elevation and plan of a modified detail.

Referring to the embodiment of the invention illustrated, the powdered coal or other fuel passes downwardly through nozzles 1 in a top wall 2 into a chamber 3 which I call an oven. This is bounded by end walls 4 and side walls 5, Fig. 3. The bottom of the oven 3 is open and communicates with a downwardly flaring chamber 6 which I call a pre-furnace, having flaring end walls 7 and parallel side walls 8, the latter extending continuously to the bottom of the structure as shown in Fig. 3. The end walls 7 of the pre-furnace are rounded outwardly at their lower ends, where the chamber 6 communicates with a chamber 9 which is of very much enlarged size in the endwise direction, and which I call a main furnace. This is bounded by the side walls 8, above referred to, and by end walls 10 at the outer ends of the structure. The walls 10 connect at their bottom ends with downwardly tapering walls 11 forming a sort of hopper which conducts the unburned solid particles to a trough 12 from which they are removed by a current of water or any other suitable ash conveyor. The walls described are constructed of fire-brick or other usual or suitable material and may be supported by beams 13 and 14. The trough 12 is preferably offset from the opening through which the ashes are discharged into it, so as to minimize the absorption of heat from the furnace.

In the oven 3, the fuel will be dried and ignited so as to give it a good start toward combustion.

The two end walls 7 of the pre-furnace carry on their exposed faces tubes 15 which 55 communicate at their upper ends with cross-boxes or headers 16, which receive the feed water as hereinafter described.

By lining the pre-furnace 6 in this way, I provide extra evaporating surfaces exposed 60 to the radiant heat of the burning mixture, and at the same time I protect the walls from the action of the burning gases by cooling them. The tubes 15 communicate at their lower ends with boilers 18, one at each end of the furnace 9 and which carry interposed superheaters 19. The gases entering the main furnace 9 are divided into two streams which pass upwardly through the boilers and superheaters. The gases from each boiler 70 pass upwardly through vertical passages 20 through a first heat exchanger 21, thence through a second heat exchanger 22, being drawn therefrom by a fan 23 which discharges them through a horizontal duct 24 75 into a gas washer 25 comprising a vertical duct 26 with an inclined wall down which a film of water is passing and thence over a body of water accumulated in the bottom of the washer. 80

The heat exchanger referred to is of a peculiar design adapted for use not only in this connection, but in various other situations. For example, it may be used as an air cooler 85 for cooling quantities of air that are to be used to absorb the heat from the windings of electric generators and similar apparatus. Or it may be applied to the cooling of automobile or aeroplane engines. In fact, its application as a cooler or as a heat exchanger 90 may be widely varied.

The heat exchangers are shown enlarged in Figs. 4 and 5. A plurality of tubes 27 in parallel inclined positions are sealed at their 95 ends and carry a certain quantity of water or other suitable liquid 28 at their lower ends, these being the ends over which the hot gases from the boiler fuel pass. Preferably air is exhausted from the tubes 27 to facilitate 100

evaporation and condensation of the liquid therein.

The lower ends of the tubes (or other containers which may be substituted therefor) serve as coolers for the gas passing around them. The upper ends will generally carry vapor of the liquid contained in the tubes, and serve as a heater for the water or air, or both, as hereinafter described. The tubes 27 may be connected to a vacuum pump by which they could be kept free of air either continually or intermittently as circumstances require.

The first heat exchanger comprises tubes 27 which extend beyond the inner wall 29 of the flue for the combustion gases. The smaller tubes 36 of the second heat exchanger 22 terminate at this wall. The difference in use between these two exchangers is that the lower or first one is used for heating both the feed water and the air which is supplied for combustion; and the upper or second exchanger, since it takes gas at a lower temperature, is used only for warming the feed water preparatory to the additional transference of heat thereto in the first exchanger. This difference is illustrated in Figs. 1, 4 and 5.

The long tubes 27 of the first exchanger abut against the outer wall 30 of the gas flue and pass through the inner wall 29 thereof to a secondary supporting wall 31. The space between the walls 29 and 31 is enclosed to form a flue 32, Fig. 1, for the air supply. The air passes down over the upper ends of the tubes and thence by suitable lateral passages, as indicated by the arrows, to the nozzles 1 for mixture with the fuel.

The ends of the long tubes 27 extend through the wall 31 and receive certain loops of the feed water pipe. Such loops are indicated at 33, Fig. 4. They lie within the upper ends of the tubes 27 and are exposed to the heat of the vapor generated in said tubes by the hot gases from the boiler. The loops 33 at their outer ends are connected serially by connecting tubes 34, the lowest loop in each series discharging into a vertical pipe 35 which conveys it to the boiler as hereinafter described.

After the burnt gases have passed over the tubes 27 of the first exchanger, there is very little heat remaining to be extracted from the gas. Consequently the second exchanger 22 is composed of the shorter tubes 36. These tubes, however, are inclined and provided with more or less volatile liquid in their lower ends, the same as for the tubes 27 of the first exchanger. Their upper sealed ends project through the wall 29 of the gas flue. In order to secure the maximum extraction of heat from these tubes for the feed water, the feed water pipe 37 (Fig. 1) for each line enters the upper tube of a series at one end and has a portion 38 (Fig. 4) passing through the upper zone in the tube 36 and

out at the other end to a connection 39 which leads to a length of pipe 38 passing in the opposite direction through the next lower tube; and so on to the lowermost tube, from which the line passes by a length 40 of pipe into the top tube 27 of the first exchanger.

I prefer to use about twenty high of the long tubes for the first exchanger and ten high of the short tubes for the second under ordinary steam-generating conditions. The number and the sizes of the tubes, may, however, be varied according to the temperature and volume of the hot gases, the air or water or other medium to be heated, and other considerations. I prefer also to use increasing volumes of liquid in the successively higher tubes, as shown in Fig. 5; but the volume and character of the liquid used may also be varied according to circumstances. For some cases it will be advantageous to use, for example, carbon tetrachloride which boils at a lower temperature than water and which has suitable latent and specific heat characteristics, and which also is non-inflammable; and though generally these tubes will be exhausted of air above the liquid, this will not always be necessary. Instead of using loops for the water in one exchanger, and lengths of pipe passing from end to end through the other, I may use either one of these arrangements for both exchangers. Likewise, I may use for either or both exchangers a parallel flow of water with the pipes connected to a common header or headers instead of being connected by bends in the serial arrangement illustrated. Also I may use either of the styles of exchanger shown alone. In this connection it is to be observed that the second exchanger which cools the gases and transfers the heat therefrom to feed water alone is similar in purpose to the ordinary economizer.

In experiments which I made on a heat exchanger of this type with tubes of steel and with tubes of glass, I have secured a much higher heat transfer in British thermal units per degree difference in temperature per hour from the hot surface of the tubes to the air, and also from the vapor to the water in the pipes exposed thereto, than has been obtained in the air heaters and economizers now generally in service. The data obtained indicate that the more nearly complete the air exhaustion, the better the heat transfer. They also indicate that the pressure in the tubes will not rise to an amount that will distort them past the elastic limit, or burst them. With 20% of the space within the sealed tube filled with water and the remainder with water vapor and a small amount of air and other foreign matters, the maximum pressure in the tube will not exceed about 500 pounds per square inch when the gases striking the lower tubes are at

about 900 degrees Fahrenheit, (which is above the usual maximum temperature).

The feed water pipes 35 pass down through or alongside of the walls to the cross-boxes or headers 16, previously referred to, communicating with the tubes 15 and with the tubes 41 which are connected with the drums 42 of the boilers.

The complete steam generating unit described is particularly adapted to the burning of pulverized fuel for the following reasons. The oven 3 provides heat for driving off moisture from the coal and igniting it and giving it an initial start toward complete combustion. The pre-furnace 6 provides for progressive combustion, with increasing volume, and at the same time provides an increased heating surface of the boiler, which increases its steaming capacity. In this pre-furnace the combustion is continuing and the exposed boiler surface is absorbing heat at a reasonable rate, while also protecting the walls from excessive heating. The length of the oven and pre-furnace may be made such that the combustion will be nearly complete at or near the top of the main furnace 9, and there will be no danger of secondary combustion or an excessive amount of carbon monoxide in the gases passing through the boiler at high rates. The amount of air primarily admitted at or near the nozzles may be varied to suit the characteristics of the fuel used. A secondary supply of air may be admitted at various points in the course of the fuel and gases.

For example, (as shown in the enlarged details, Figs. 1^a and 1^b) air may be admitted from chambers 43 between the pre-furnace walls 15 and the inside boiler walls 44 (these chambers being provided with openings 45) into steel boxes 46, which support walls 4, and partially support cross-boxes 16, and the air passing thence through suitable perforations into the upper end of the pre-furnace 6. The air thus admitted serves also to cool the steel supporting boxes 46. It also serves to cool the blocks 47 and 48 which surround the box 46 and thus to preserve them from excessive heat and consequent destruction as well as the lower edges of the walls 4 of the oven and the upper edges of the walls 15 of the pre-furnace.

Below the point described, it will not generally be advisable to provide further air admission, for the reasons above stated. The large volume of cross-section of the main furnace 9 provides space for a final complete mixture of the products of combustion, and thus provides for complete combustion and the throwing out of the ash and slag. The velocity of the products of combustion entering the main furnace may be relatively high because of the comparative restriction in cross-section of the pre-furnace, and this also will aid in the mixing together of

the elements in the stream and will aid in the throwing down of the solid particles. The temperature at the lower portion of the main furnace will be low compared with that in furnaces now generally in use, because of the absorption of heat by the boiler surface exposed in the pre-furnace. The proportional length of the latter, therefore, as well as its diminished cross-section, has an important bearing on the temperature of the gases in the main furnace. For example, increased length in the pre-furnace will mean increased heat absorption by the boiler surface exposed therein, and consequently reduced temperature of the gases in the main furnace, which will mean less trouble from slag and less deterioration of the walls of the main furnace.

The upward turn of the gases before they pass over the principal water-carrying elements of the boiler, also aids in the thorough mixing of the gases. After these have turned upward they have a straight clean cut path through the single pass boiler, the superheater and the heat exchangers; which means low resistance and low power consumption by the induced draft fan. This arrangement also permits the maintenance of high gas velocities without excessive drop in pressure, as well as a comparatively great length of travel of the products of combustion before they strike the principal elements of the boiler. We thus insure almost perfect combustion. We are thus permitted to make the velocity of the gases greater than in present practice, and to cut down the furnace volume per ton of coal burned. Also the ash and slag thrown out will contain practically no combustible matter, combustion being complete when the gas streams turn upward.

One of the principal objections to the use of powdered fuel is the nuisance from dust. In most plants now in operation over half of the ash in the coal is carried out of the stack in the form of a fine dust. This is avoided in my steam generating unit by the interposition of an efficient gas washer as illustrated.

In the unit illustrated two boilers are used and the enlargement of the several combustion chambers is in the endwise direction only, the transverse direction being uniform throughout the height as indicated in Figs. 2 and 3. This is a very convenient form structurally, and gives easy access to all the parts. The functional advantages of the invention, however, may be secured using any desired number of boilers in a unit supplied with a single furnace and preliminary combustion chambers, the boilers being disposed about the said chambers in various ways.

The tubes or containers of the heat exchangers are not necessarily inclined as shown. Those of the second exchanger, for example, may be arranged horizontally with

advantage in view of the passing of the water pipes through them.

The tubes exposed within the pre-furnace may be on the end walls only, as shown, or they may be also extended over the side walls. Also they may be made larger, as at 15^a, Figs. 6 and 7, so as to practically cover and entirely shield the wall 7 on which they are carried. The tubes 18^a from the lower part of the boiler would then be expanded into or otherwise connected to the lower ends of the larger tubes 15^a. The cross-box at the top may then be eliminated and the circulating tubes 41 be connected directly to the tubes 15^a.

Though I have described with great particularity of detail certain embodiments of my invention, yet it is not to be understood therefrom that the invention is restricted to the particular embodiments disclosed. Various modifications thereof in detail and in the arrangement of the parts may be made and the several features of improvement may be used in other combinations by those skilled in the art without departure from the invention as defined in the following claims.

What I claim is:

1. A single steam generating unit comprising a plurality of boilers, a common furnace therefor having its greatest width below said boilers, and means for directing gases of combustion into said furnace and causing them to turn at the zone of greatest width into separate streams through said boilers, said means including water-cooled heat-absorbing surfaces along which the gases flow to the place where they turn.

2. A single steam generating unit comprising a plurality of boilers, a common furnace therefor, and a pre-furnace having additional heating surfaces disposed along a plurality of walls thereof in which the gases of combustion are formed and from which they pass to the main furnace, said main furnace having a width substantially greater than said pre-furnace.

3. A single steam generating unit comprising a plurality of boilers, a common furnace therefor, and a pre-furnace in which gases of combustion are formed and from which they pass to the main furnace and an oven in which the fuel and air are mixed before entering said pre-furnace, said main furnace having a width substantially greater than said pre-furnace.

4. A single steam generating unit comprising a pair of oppositely arranged boilers, a common furnace therefor having its greatest width below said boilers and means for directing the gases of combustion downward into said furnace and causing them to turn upward below said boilers into separate streams through said boilers, said means including water-cooled heat-absorbing surfaces

along which the gases flow to the place where they turn.

5. A boiler having at least two sets of water carrying elements, a furnace having a wall alongside of the principal water carrying elements of the boiler, the other water carrying elements being on the opposite side of said wall and exposed within said furnace, and a means for directing gases of combustion downwardly through said furnace and causing them to change direction and expand and to pass upward through said principal water carrying elements.

6. A water tube boiler having radiant heat absorbing tubes and convection heat absorbing tubes, a furnace in advance of said convection heat absorbing tubes, a pre-furnace in advance of said furnace, one wall of said pre-furnace being lined with said radiant heat absorbing tubes and said pre-furnace having an unrestricted outlet leading to said furnace and an oven in advance of said pre-furnace in which fuel and air are admitted and combined.

7. The method of producing steam which comprises creating an ignited stream of fuel and air, exposing water to the radiant heat of combustion, thereafter permitting the hot gases of combustion to expand without substantial change in direction of flow, subdividing the stream into lesser streams, changing the direction of flow of said lesser streams and passing said lesser streams separately in heat exchange relationship with water after combustion in said streams has substantially ceased.

8. The method of producing steam which comprises creating an ignited stream of fuel and air, causing the stream to flow past hot radiating surface to assist in ignition and combustion thereof, passing the stream thereafter in heat exchange relationship with water while combustion in the stream continues to a substantial extent, permitting the stream to expand without substantial change of direction and thereafter revert, and then passing the stream in heat exchange relationship with water after combustion in said stream is substantially complete.

9. A single steam generating unit comprising the combination of a plurality of separate boilers, a single main furnace therefor, a pre-furnace disposed above the main furnace and having a cross-sectional area considerably less than that of the main furnace, certain of the defining walls of said pre-furnace being lined with water-cooled heat-absorbing elements, and means for leading ignited fuel and air through the pre-furnace in a single stream into the main furnace and thence in separate streams to said boilers.

10. In a steam generating unit, the combination of a plurality of boilers, a single main furnace communicating with said boilers, a pre-furnace disposed above the main

furnace and having a cross-sectional area considerably less than that of the main furnace, certain of the defining walls of said pre-furnace being lined with water-cooled heat-absorbing elements, and means for leading ignited fuel and air downwardly through the pre-furnace and into the main furnace and thence upwardly in separate streams to said boilers.

11. In a steam generating unit, the combination of a plurality of boilers, a single main furnace serving said boilers and disposed below them, a pre-furnace disposed above the main furnace and having a cross-sectional area considerably less than that of the main furnace, certain of the defining walls of said pre-furnace being lined with water-cooled heat-absorbing elements, and means for leading an ignited stream of fuel and air downwardly through the pre-furnace into the main furnace, subdividing said stream into lesser streams and changing the direction of flow thereof in said main furnace, and leading said lesser streams upwardly and independently to single boilers.

12. A furnace comprising an entrance throat leading to a main chamber of substantially greater cross-sectional area than said entrance throat, water carrying tubes forming a part of the defining walls of said throat and extending into said main chamber and being spaced apart therein, said tubes extending across an outlet from said chamber, thus forming a water cooled outlet, and said throat being provided with a refractory entrance preceding said water carrying tubes, and means for directing fuel and air into said throat and discharging the products of combustion through said water cooled outlet.

13. A furnace comprising an entrance throat leading to a main chamber of substantially greater cross-sectional area than said entrance throat, water carrying tubes forming a part of the defining walls of said throat and extending into said main chamber and being spaced apart therein said tubes extending across an outlet from said chamber, thus forming water cooled outlets, and means for directing fuel and air into said throat and discharging the products of combustion through said water cooled outlets.

14. A furnace comprising an entrance throat leading to a main chamber of substantially greater cross-sectional area than said entrance throat, water carrying tubes forming a part of the defining walls of said throat and extending into said main chamber and being spaced apart therein said tubes extending across an outlet from said chamber, thus forming water cooled outlets, and said throat being provided with a refractory entrance preceding said water carrying tubes, and means for directing fuel and air into said throat and discharging the products of com-

bustion through said water cooled outlets.

15. A furnace comprising an entrance throat leading to a main chamber of substantially greater cross-sectional area than said entrance throat, water carrying tubes forming a part of the defining walls of said throat and extending into said main chamber and being spaced apart therein said tubes extending across an outlet from said chamber, thus forming a water cooled outlet, and said throat being provided with a refractory entrance preceding said water carrying tubes, one of the defining walls of said refractory entrance being provided with other water carrying tubes set behind the face of said wall, and means for directing fuel and air into said throat and discharging the products of combustion through said water cooled outlet.

16. In a steam generating unit the combination of a plurality of boilers, a common furnace therefor disposed below said boilers, and a pre-furnace above said common furnace and having additional water-cooled heat-absorbing surfaces disposed along a plurality of walls thereof, and means for introducing an ignited combustible mixture into the pre-furnace whereby radiant heat of combustion is absorbed by the surfaces therein, and causing the gases of combustion to flow from the pre-furnace to the common furnace and thence upwardly and to said boilers.

17. A steam generating unit comprising the combination of a furnace having refractory walls defining a portion of a passage for gases and other defining walls beyond said refractory walls in the direction of gas flow and defining the remainder of the passage, said passage being substantially straight and said other defining walls being provided with water carrying tubes exposed directly to said gases, a boiler having a bank of tubes beyond said other walls, means for supplying fuel for ignition and preliminary combustion in said passage, and means for leading the gases of combustion along said other walls and through said bank of tubes.

18. A steam generating unit comprising a refractory-lined passage, means for introducing a combustible mixture into said passage for ignition and preliminary combustion therein, diverging defining walls beyond said passage for directing the flow of gases issuing from said passage and permitting the gradual expansion of said gases, water-carrying elements on said defining walls exposed directly to said gases, a chamber beyond said defining walls to which the gases are led, an outlet from said chamber, a bank of tubes beyond the outlet, and means for drawing gases of combustion from said passage along said defining walls and through said chamber and said bank of tubes.

19. A steam generating unit comprising the combination of a plurality of boilers having their tube banks in end-to-end alignment, a

common furnace therefor having its greatest dimension parallel to the axes of the said tube banks, a pre-furnace having water-cooled walls disposed above said furnace in communication therewith, and means for directing the gases of combustion through said pre-furnace downwardly into said furnace, causing them to turn upward at the zone of greatest dimension to flow in separate streams through said boilers.

20. In a furnace for burning powdered fuel, the combination of a boiler having heating surfaces so arranged as to provide a lower combustion compartment, walls extending above the boiler and arranged inwardly of the boiler heating surfaces to provide an upper combustion compartment in vertical alignment with the lower compartment, the upper and lower compartments forming a vertically disposed combustion chamber, and means for feeding powdered fuel and air into the upper compartment.

In witness whereof, I have hereunto signed my name.

CHARLES B. GRADY.