H. L. DOHERTY.

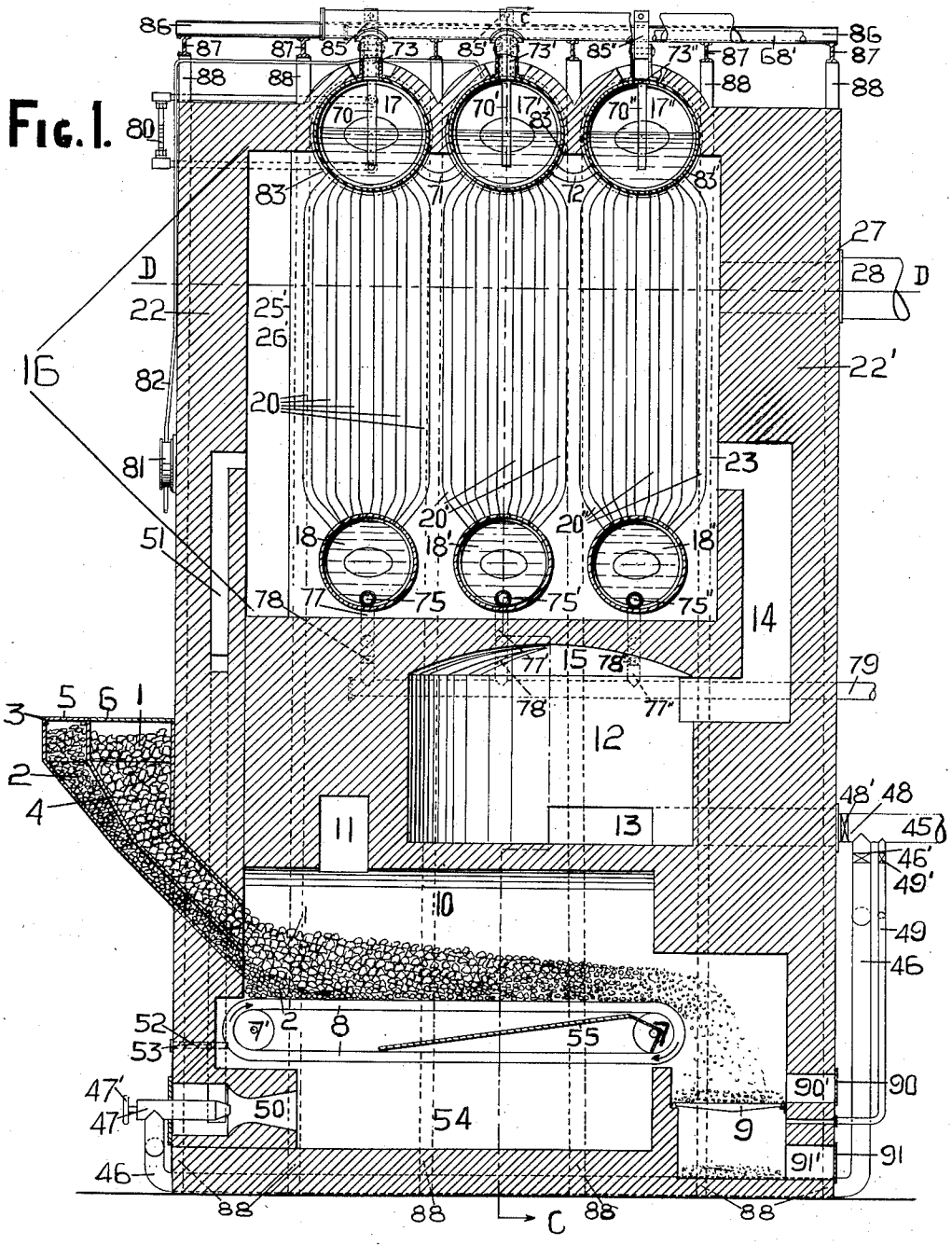
STEAM BOILER.

APPLICATION FILED JAN. 20, 1911.

1,034,218. **Patented July 30, 1912.**

4 SHEETS—SHEET 1.

FIG. 1.



Witnesses:

Frank L. Blackmer

Henry L. Doherty, Inventor

By his Attorney Frank S. Young

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4 SHEETS—SHEET 2.

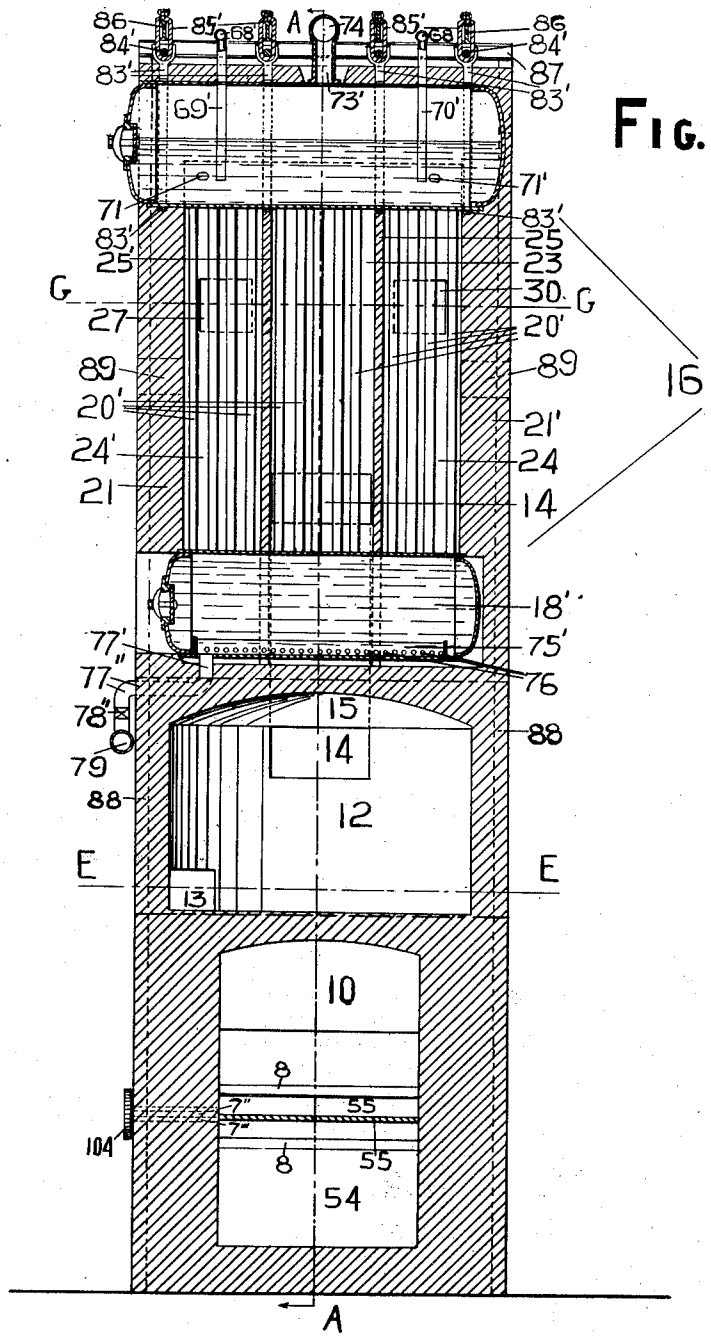

FIG. 2.

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4 SHEETS—SHEET 3.

FIG. 3.

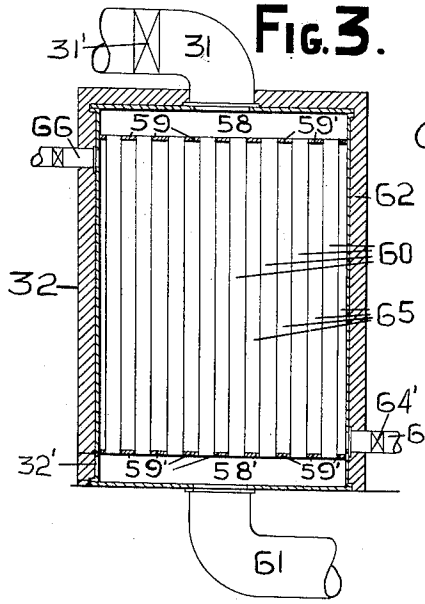


FIG. 4.

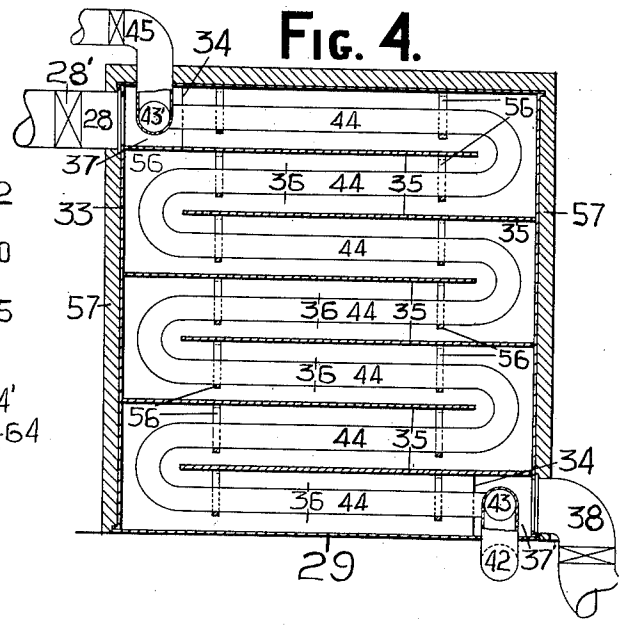
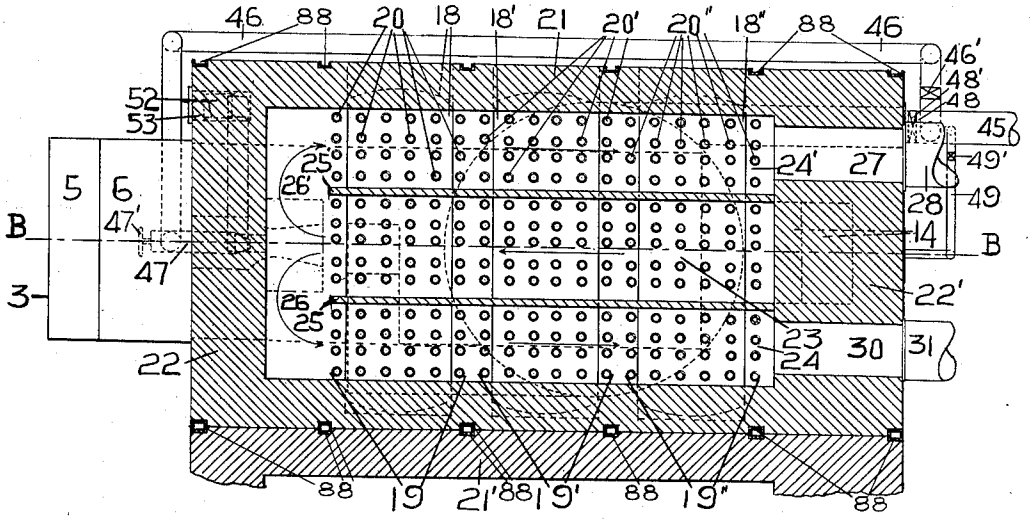


FIG. 5.



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STEAM BOILER.

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1,034,218.

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4 SHEETS—SHEET 4.

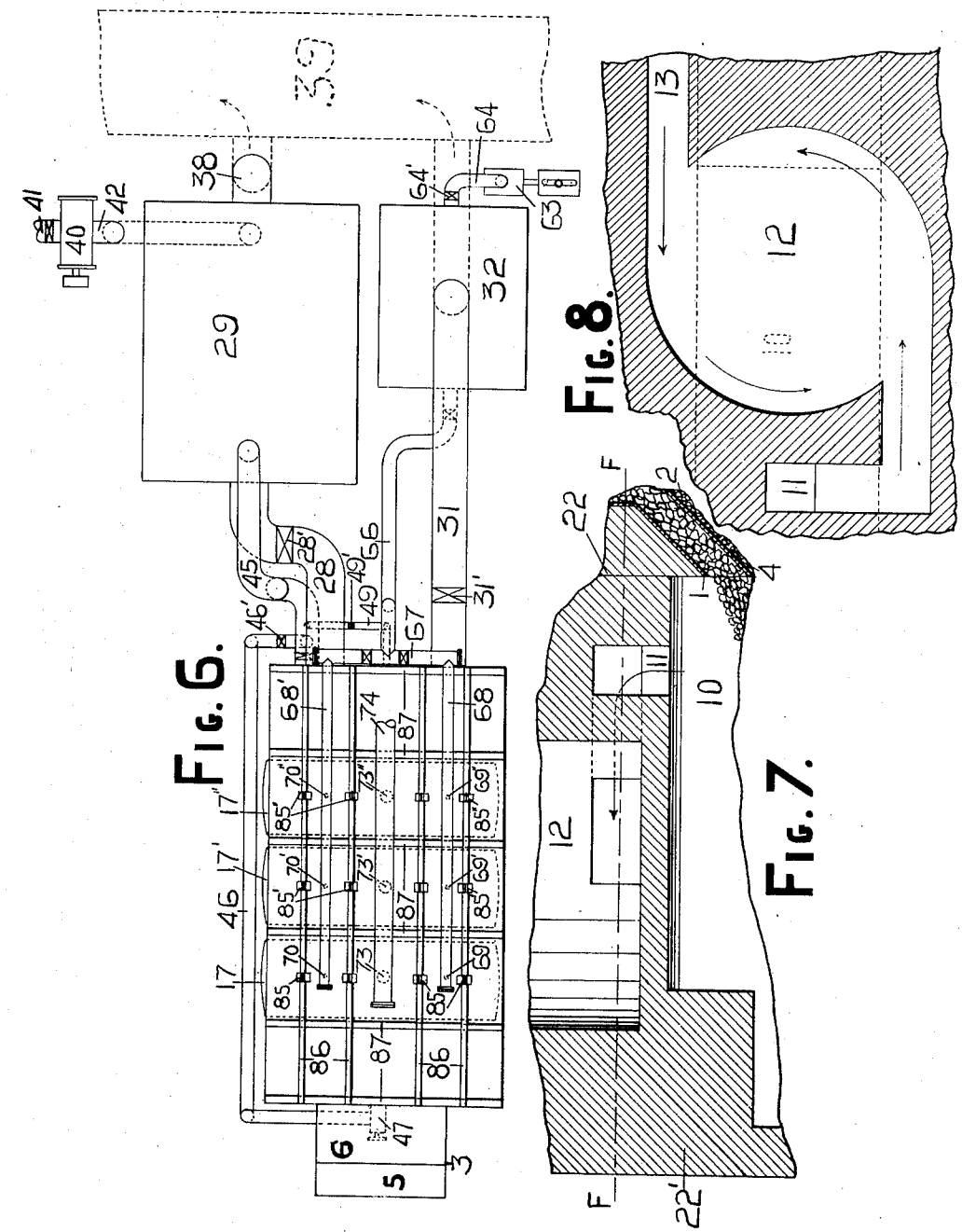

FIG. 6.

FIG. 8.

FIG. 7.

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UNITED STATES PATENT OFFICE.

HENRY L. DOHERTY, OF NEW YORK, N. Y.

STEAM-BOILER.

1,034,218. Specification of Letters Patent. Patented July 30, 1912.

Application filed January 20, 1911. Serial No. 603,771.

To all whom it may concern:

Be it known that I, HENRY L. DOHERTY, a citizen of the United States, and a resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Steam-Boilers, of which the following is a specification.

This invention relates to steam boilers and, in particular, to a steam boiler fired with producer gas from a self-contained gas producer.

The object of my invention is the furnishing of a steam boiler of such construction, and having a method of operation such, that a very rapid rate of circulation of the water is secured, thus effecting the maximum rate of heat conductance from the gaseous products of the combustion of the water, and the maximum possible utilization of the heat of the fuel secured.

Briefly, my invention consists of a steam boiler comprising in combination, a gas producer having a movable grate, a combustion chamber, a steam generating chamber divided by vertical partitions into three compartments, a plurality of steam drums and coöperating mud drums, a plurality of tubes connecting each pair of coöperating drums, a water heater of novel construction and a recuperator for heating the air used in the combustion of the fuel, as well as various other features which will be fully set forth later. The arrangement is such that the gas formed in the gas producer of the apparatus is burned in the open combustion chamber in such a way as to secure complete combustion with the minimum supply of air, the extremely hot products of this combustion pass through the middle compartment of the steam generating chamber in contact with the middle group of water tubes, thence divide and return through the two side compartments of the steam generating chamber, after which one stream passes to the water heater and the other stream to the air recuperator. By subjecting the water in the middle group of water tubes to the action of the extremely hot combustion gases, the tubes, themselves, being of comparatively small cross-section, I convert the bulk of the water in the tubes to steam. The tubes of the middle group are thus filled with a foamy mass of steam and water. The generation of steam in the two side groups of tubes is much slower, owing to the fact that the combustion gases have been greatly reduced in temperature by the time they have reached the side compartments. The fluid filling of the tubes of the side groups is therefore much heavier than the column of fluid in the tubes of the middle group. There is, therefore, a considerable hydrostatic pressure exerted by the fluid in the side tubes, through the connecting mud drums, upon the fluid in the middle tubes. The result is that the velocity of flow of the fluid through the middle tubes is very high, and the rate of heat transmission high in consequence.

In the accompanying drawings, I have shown the preferred form of my invention, in which the same numerals are used to denote the corresponding parts in all the figures.

Figure 1 is a vertical longitudinal section of the apparatus along the line A A of Fig. 2 and B B of Fig. 5. Fig. 2 is a vertical transverse section along the line C C of Fig. 1. Fig. 3 shows the feed-water heater in vertical section and Fig. 4 shows the recuperator. Fig. 5 is a horizontal cross-section of the steam generating chamber along the lines D D of Fig. 1 and G G of Fig. 2 showing clearly the chamber filled with the water tubes and the vertical partitions which cause the gases to flow in the direction of the arrows. Fig. 6 is a diagrammatic plan view of the apparatus. Fig. 7 is a part vertical section of the lower portion of the combustion chamber along the line A A of Fig. 2 but looking in the opposite direction from which Fig. 1 was taken, showing the connection for the producer gas, from the producer to the combustion chamber. Fig. 8 is a part horizontal section of the combustion chamber along the lines E E′ of Fig. 2 and F F′ of Fig. 7 showing the relative positions of the tangential inlets for the combustion gas and secondary air.

A clear understanding of my invention can now be had from the following description:

Coal, 1, and clinkers, 2, are fed into a hopper, 3, which has a partition, 4, so as to keep the clinkers and coal from intermingling while in the hopper.

5 and 6 are suitable covers for the clinker and coal compartments of the hopper 3.

As the sprocket-wheel 7 is made to slowly rotate in the direction of the arrow, by any suitable driving gear, it causes the upper part of the chain grate 8, to assume a motion toward the opposite end of the producer, from that where the fuel is fed, the rate of such motion depending upon the rate of gasification of the fuel, 1, on the grate, 8, and being so regulated that by the time the fuel fed in at the front end of the producer has been practically completely burned, it will be discharged from the grate at the rear end of the producer.

9 is a fixed grate onto which the clinker and any unburned fuel left on the traveling grate is discharged.

The clinker being fed into the producer under the fuel, will form a layer of non-combustible material upon the grate 8 and thus protect it from excessive heat during gasification. The gas formed in the producer 10 is led to the combustion chamber 12 through the flue 11, as shown in Fig. 7. As the gas enters the lower part of the combustion chamber 12, it is mixed with air entering through the flue 13 on the opposite side of the chamber. The height of the combustion chamber is such as to allow several convolutions of the gaseous stream, thus obtaining a thorough mixture and complete combustion before leaving the combustion chamber through the flue 14. The combustion chamber is of circular cross-section and preferably having an arched roof, 15. The air and gas are entered tangentially at opposite sides, thus forming a helical flame. By this device I have found that I can secure a very complete and rapid combustion of the producer gas with the minimum supply of air, thus insuring a very high flame temperature. This method of combustion and form of combustion chamber I do not herein claim, as it is claimed in my application Ser. No. 356414, filed Feb. 8th, 1907.

The steam generating chamber 16 is inclosed by the side walls 21 and 21′ and the end walls 22 and 22′ and is divided into three heating compartments, 23, 24 and 24′, by the vertical partitions or baffle walls 25 and 25′ which extend the entire height of the chamber, but they do not traverse the entire length of the chamber but leave spaces 26 and 26′ so as to connect the middle compartment 23 with the lateral compartments 24 and 24′.

A plurality of steam drums, 17, 17′ and 17″, are set transversely of the steam generating chamber. A corresponding number of mud drums occupy the lower part of the said chamber, each being set directly under its coöperating steam drum. A large number of tubes, the ones occupying the middle compartment 23, at least, being preferably of comparatively small cross-section, join each steam drum with its coöperating mud drum.

The hot combustion gases pass from the combustion chamber 12, through the flue 14, and enter the middle compartment 23 of steam generating chamber 16. This central compartment, 23, is of such cross-section relative to the cross-sections of two lateral compartments 24 and 24′, that the gases flowing through it have a much higher relative velocity than in the lateral compartments 24 and 24′. The object of this feature will be explained in more detail farther on.

If the inlet to the steam generating chamber is at the rear of the chamber, as is shown in the drawings, the current of combustion gases will move toward the front of the chamber in the central compartment and will divide into two currents at the front end of the chamber, one current following the direction of the arrow through the passage 26′ and assuming a direction toward the rear end of the chamber in the compartment 24′. In the rear wall 22′ is the flue 27, through which flue and pipe 28 the combustion gases, after heating the water tubes in the compartment 24′, are led to a recuperator, 29. The other current will follow the direction of the arrow through the passage 26 and will also assume a direction toward the rear of the chamber in the compartment 24, heating the tubes in this compartment and leaving the compartment through the flue 30. The pipe 31 leads this second current of combustion gases to a water heater, 32, where a further portion of its sensible heat is used to heat the feed water supplied to the boiler.

As stated before, the current of combustion gases leaving the compartment 24′ of the steam generating chamber 16, is led to the recuperator 29 by the conduit 28. A valve, 28′, on the conduit 28 regulates the flow of gas through the recuperator 29. The recuperator 29 may be of any suitable type, the one shown comprising a plurality of parallel, serpentine, combustion gas flues enveloping a corresponding number of air flues. The main current of combustion gases is divided, as it enters the top of the recuperator, between the several combustion gas flues, the several currents again uniting in the transverse flue 37′. 33 is the casing of the recuperator. The recuperator is divided into several parallel vertical compartments by the partitions 34, which partitions extend the entire height and length of the recuperator except at the points of distribution and collection, thereby forming a distributing and a collecting flue respectively. The horizontal partitions 35 extend alternately from the front and back of the recuperator to a short distance from the opposite end and are joined to the vertical partitions, thus forming the continuous ser-

pentine flues 36. 37 is the distributing gas-flue and 37′ the collecting gas-flue. The current of combustion gases entering the recuperator by the conduit 28 flows through the cross-flue 37 and is distributed to the plurality of serpentine flues 36, one of which is shown in Fig. 4. Flowing downward through the flues 36 the gases unite in the collecting flue 37′ and are led from the recuperator, after giving up the larger part of their sensible heat to the air flowing in the opposite direction therethrough, by the conduit 38 to the large underground flue 39 which leads all waste gases to the chimney. 40 is a blower forcing air through the pipe 42 to the distributing air pipe 43 placed in the collecting gas flue 37′. The air is thus divided into the same number of parallel currents as the combustion gas. The air pipes, 44, are placed substantially in the centers of the gas flues 36.

In the distributing gas flue 37 is placed the collecting air pipe 43′, to which collecting pipe is attached the off-take air pipe 45 which leads the heated air from the recuperator. 56 are hangers for supporting the air pipes 44 in the recuperator 29, and 57 is the lagging covering said recuperator. The current of heated air flowing through the main pipe 45 is divided into three currents, one current flowing through the pipe 46 to the injector 47 furnishes the primary air for supporting the combustion in the gas producer. The secondary air supplied for the combustion of the producer gas in the combustion chamber 12, is led to that chamber by the pipe 48 (in the drawings shown, this is an extension of the pipe 45) and thence through the flue 13. A small part of the main current is taken off by the pipe 49 and led under the stationary grate 9, for the purpose of burning whatever carbon may have escaped combustion in the producer 10. Valves, 46′, 48′ and 49′, on the respective pipes 46, 48 and 49, serve to regulate the currents of air flowing through them.

The primary air flowing through the injector 47 and injector throat 50 induces a current of hot combustion gases from the steam generating chamber 16 through the flue 51 in the front wall 22. The volume of this current of combustion gas is regulated by a damper, 52, placed in the opening 53, and by varying the volume and pressure of the air on the nozzle by means of the valve 47′. As the primary air enters the space 54 below the movable grate 8, it is distributed along the length of the grate in proportion to the amount of combustible fuel along the grate. That is to say, a greater amount of air is caused to pass through the front end of the grate, where the fuel bed is thicker, than through the rear end of the grate, where the fuel bed is thinner, due to the contraction of the mass on the grate as the carbon is burned out. This distribution is accomplished by placing a partition or baffle plate, 55, between the upper and lower parts of the movable grate 8 and in a direction inclining downward toward the front of the grate. The plate extends clear across the chamber, extending into the two side walls. The upper rear end is so constructed as to substantially prevent any air from passing through the grate at that end. The effect of this baffle is to continuously diminish the passage open to the air under the grate 8, from the front to the rear end of the grate. The distance of the baffle below the grate should be so regulated that the resistance which it offers to the flow of the air along the grate shall be sufficient to cause the major portion of the air to pass through the mass on the front of the grate, and continually diminishing portions through the successive sections of the grate from the front to the rear end thereof. This is an important feature of my invention, as it is evident that for economical working the air must be distributed along the length of the fuel bed in proportion to the quantity of combustible thereon. This proper distribution of the air through the fuel bed is regulated by the inclination and length of the baffle plate 55, as described above. The gas formed in the producer 10 by the combustion of the fuel and the air, leaves the producer by the large flue 11 and enters the combustion chamber 12 tangentially, as already stated. The second current of combustion gases, after passing through the compartment 24 and flue 30, enters the conduit 31, leading to the water heater 32. The water heater may also be of any preferred type, but I prefer to use one of the form shown in Fig. 3. This is of a novel construction, so arranged that there is no circulation of the water passing therethrough. I have not claimed this specific invention herein, but reserve the right to claim it in a later application. The hot gases enter at the top of the water heater through a pipe, 31, into an open distributing gas space, 58. This space is formed by the top of the water heater, the upper ends of the inclosing walls and the upper header 59. This header, as well as a similar lower header, 59′, contains numerous openings for the insertion of the vertical gas tubes 60 which connect the distributing space 58 with the collecting space 58′. The hot gases are distributed among the several rows of tubes 60 (only one row of which is shown in Fig. 3) and flow downward through the tubes 60, giving up their sensible heat to the feed water, which flows in the opposite direction through the intertubular space of the water heater, as explained later. After passing through the space 58′ the gases are led away from the water-heater through the conduit 61 to the

underground flue 39 and thence to the chimney. 32′ is a means of access to the gas space 58′ for cleaning purposes. The water heater is preferably insulated with some suitable lagging, 62.

The water to be fed to the boiler is forced through the pipe 64 by the pump 63 and enters the lower part of the intertubular space of the water heater just above the lower collecting gas space 58′. It completely fills the space 65 between the tubes 60, entirely surrounding them and flows upward through the heater, its temperature rising, due to the absorption of the heat given up by the opposite flowing hot combustion gases through the tube 60. By this device of causing the heating gases to travel downward through the heater while the water is caused to travel upward, it is apparent that the greatest heating effect is at the surface of the water in the heater and diminishes toward the bottom of the heater. There is thus very little tendency to set up convection currents, the water moving slowly from the bottom to the top of the water heater as a mass, with very little local circulation. By this arrangement the lower ends of the tubes 60 are surrounded with water which is at substantially the temperature of the water entering through 64. The conditions are therefore very favorable for the recuperation of the heat of the combustion gases flowing through the water heater, and these leave the heater at a comparatively low temperature. The heated water leaves the water heater by the pipe 66, which is placed just below the distributing gas space 58. The flow of gas and water to the water heater may be controlled by the respective valves 31′ and 64′ placed respectively on the pipes 31 and 64. The heated water is now led to the several water spaces of the steam drums 17, 17′ and 17″, and this may be done in any convenient manner. In the accompanying drawings is shown a pipe, 67, connected with the feed water pipe 66. The water leaving pipe 66 divides into two currents, one flowing through 67 to the pipe 68 and the other through 67 to the pipe 68′. This arrangement of the feed water pipes is shown clearly in Fig. 6. The pipes 68 and 68′ traverse, respectively, opposite ends of all the steam drums. The water is then led from the pipes 68 and 68′ to the steam drums through the respective feed pipes 69, 69′ and 69″ and 70, 70′ and 70″. It will be noted that the water is fed into the several drums at two points, these points being over the lateral compartments of the steam generating chamber 16, and are thus fed into the cooler portions of the drums, thus increasing the rapid circulation at which I aim. The upper drums communicate with each other through the curved pipes 71, 71′ and 72, 72′, which are also placed over the lateral compartments 24′ and 24, respectively. These pipes connect the water spaces and thus maintain equal water levels in all the drums.

The steam liberated from the water in the drums 17, 17′ and 17″ is led out through their respective connections 73, 73′ and 73″ into the main steam pipe 74, which carries the steam from all the drums to where it is to be used, and also serves for equalizing the pressure in the several drums. The lower, or mud drums, may be made much smaller than the steam drums, and each contains a device for collecting the sediment precipitated from the impure feed water. I have shown perforated pipes, 75, 75′ and 75″, placed longitudinally in each mud drum for this purpose. The sediment collects at the lowest point of the boiler and is forced through the perforations 76 which are placed along the sides of the pipes and near their lower surfaces and is blown out by the blow-off pipes 77, 77′ and 77″, by opening the valves 78, 78′ and 78″, respectively, and carried away by the waste pipe 79. 80 is the water gage and 81 the steam gage. The steam gage is connected to the steam space of one of the steam drums by the pipe 82.

The drums, tubes and contained water are supported in any suitable manner, but I prefer the support to be independent of the brickwork, and I have shown each of the steam drums, 17, 17′ and 17″, suspended by their respective straps, 83, 83′ and 83″, from suitable guides. Bolts, 84, 84′ and 84″, pass through the upper ends respectively of the straps 83, 83′ and 83″, and other straps or hangers, 85, 85′ and 85″, pass under the respective bolts 84, 84′ and 85″ and are supported by the uppermost I-beam, 86, which are supported transversely over the drums by the supporting beams 87, which are placed at right angles to the beams 86 and are in turn supported at their ends by the beams or standards 88, which are placed along the sides of the boiler setting and also serve as buckstaves to prevent the walls from buckling. It is to be understood that the above described system of beams is one way of supporting the drums, tubes and contained water, but I do not limit myself to that particular method of support. The lower mud drums are supported from the upper drums by the water tubes. This may be done in this case, as the large number of tubes connecting each pair of drums make the strain brought on any individual tube negligible.

Openings, 89, give access to the interior of the steam generating chamber 16. The brick setting is for the purpose of inclosing the chamber and does not support any part of the boiler proper.

90 and 91 are doors to the openings 90′ and 91′, respectively, through which the

ash and clinker discharged from the grate 8 are withdrawn.

It is apparent that, by regulating the distribution of air, for combustion of the fuel on the movable grate, along the length of that grate in proportion to the quantity of carbon on the different sections of the grate, I will obtain a gas of normal quality. This air distribution may be regulated, as already explained, by some suitable means placed below the fuel bed, such as the inclined baffle 55, or a horizontal plate provided with vertical baffles at intervals and extending across the producer and below the lower part of the grate with suitably graduated openings.

It is desirable to have a means of protecting the grate and this I accomplish by feeding clinker, as explained before, below the fuel.

In the ordinary methods of operating power plants there is always a considerable proportion of the fuel used lost, due to the falling through the grate of portions of unburned carbon. In the present apparatus practically all of the carbon of the fuel is burned in the producer. This is insured by allowing the ashes, which may contain a certain amount of unburned carbon, to fall upon a secondary grate, and allowing a small amount of air to pass through this secondary grate and burn whatever combustible material may have escaped combustion in the producer proper. In this way the proportion of the carbon of the fuel which is wasted is reduced to a minimum.

In the drawings is shown a combustion chamber connected with the producer where the gas led from the producer is burned with the necessary amount of air. This combustion chamber is circular in cross-section and has a spherical top or dome and is lined entirely with fire-brick. As already explained, the gas and air enter the bottom of this chamber tangentially at a comparatively high velocity. There is therefore produced a helical flame having several complete convolutions in contact with each other.

One of the important features of this invention is the method used to secure a rapid circulation of both the heating gases and the water in the tubes, so that the evaporation in the tubes and drums will be a maximum. It is the aim in all types of boilers to obtain a rapid circulation of the water through the tubes and drums and thus obtain a rapid generation of steam since, as is well known, the rate of heat transmission varies about as the sq. root of the velocity of the circulation.

As explained before, the hot combustion gases enter the steam generating chamber in the center of one of its ends and pass through this chamber by a middle compartment which contains the middle group of water tubes. The cross-section of this middle compartment, depending upon the distance between the division walls 25 and 25', is such as to cause the hot gases flowing through it to have relative velocity. The high velocity of the hot gases in contact with the water tubes in the compartment causes a rapid rate heat transmission from the gases to the water in the tubes. This is due to the fact that the rate of heat transmission from fluids to metal depends upon the velocity of flow of the gases in contact with the metal, as already explained. The time of contact of the gases and tubes is of course shortened, but the heat transmitted by the higher velocity of the gases more than balances the lower amount of heat transmitted through the tubes by the shorter interval of contact of gases with the tubes.

After passing through the length of the steam generating chamber and giving up a greater part of its heat to the water in the central group of tubes, the gases are split and flow through the side compartments to the other end of the chamber, heating the tubes contained in said side compartments which connect the end portions of the steam drums with their respective mud drums. The cross-sections of these outer compartments is such as to reduce the velocity of flow of the gases passing through them relatively to the velocity they had while heating the central group of tubes. We have therefore, that the gases heating the end tubes in the lateral or side compartments are traveling at a lower velocity and are at a lower temperature than the gases heating the central tubes contained in the central compartment. There is consequently a rapid heating and rising of the water in the central groups of all the banks of tubes and a corresponding rapid downward motion of the water in the two end groups of each bank of tubes, to take the place of the water rising in the central groups. There is thus a rapid circulation from the center of each steam drum to the ends thereof and down the end groups of tubes to the centers of the mud drums and up the central groups again. The circulation in each pair of coöperating steam and mud drums is independent of the circulation in the other pairs of drums, the connections between the steam drums serving to equalize the water level in them.

The feed water is entered in the coolest parts of the drums above the tubes in which the circulation is downward, and so immediately passes vertically through these tubes, liberating itself of most of its impurities while passing through these tubes and the mud drums. The sediment naturally falls to the bottom of the mud drums, from where it is readily blown off when necessary.

The waste gases leaving the boiler at

about 500° to 600° F. are not allowed to escape directly to the atmosphere through a chimney, but their sensible heat is utilized to raise the temperature of the feed water and the air used for combustion of the fuel on the grate and of the gas in the combustion chamber. This is accomplished as already explained. It has been also explained how a part of the hot combustion gases are mixed directly with the already preheated air while passing through the injector throat below the fuel gate. The carbon dioxid of this portion of the combustion gases is mostly broken down by reaction with the carbon of the fuel to carbon monoxid. As this reaction causes the absorption of a large amount of heat from the fuel bed, it enables the temperature thereof to be kept at a point below the clinkering temperature of the ash, whereby the grate is kept free from obstructive masses and the fuel bed in a condition easily permeable by the draft current.

With these methods of recuperation, above described, together with the preliminary drying and continual slow feeding of the coal, which does away with the necessity of opening doors and allowing an inrush of cold air when intermittent firing is resorted to, I obtain the recovery of the maximum amount of heat units of the fuel in useful work.

I have not herein claimed specifically the form of gas-producer and traveling grate shown, but reserve the right to claim these specifically in another application.

Having described my invention, what I claim is:

1. In a steam boiler, a chamber divided into forward-flow and return-flow passages for the heating gases, an upper steam-drum and a lower mud-drum each of said drums being set so as to traverse all of said passages and to lie cross-wise to the direction of flow of the heating gases through said passages and a plurality of water-tubes connecting said drums.

2. In a steam boiler, a chamber divided into forward-flow and return-flow passages for the heating gases, said passages being so arranged that the flow of gases therethrough is substantially horizontal, a plurality of steam-drums set transversely of all of said passages in the upper part thereof, and a plurality of mud-drums set transversely of said passages in the lower part thereof, and a plurality of water-tubes connecting said drums.

3. In a steam boiler, a chamber divided into forward-flow and return-flow passages for the heating gases, a plurality of steam-drums set transversely of all of said passages in the upper part thereof, and a plurality of mud-drums set transversely of all of said passages in the lower part thereof, each of said mud-drums being set substantially vertically under one of said steam-drums and coöperating with said steam-drum, and a plurality of water-tubes connecting each of said steam-drums with its coöperating mud-drums.

4. In a steam boiler, a chamber divided into forward-flow and return-flow passages for the heating gases by substantially vertical partitions, a plurality of steam-drums set transversely of said passages in the upper part thereof, and a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums coöperating with one of said steam-drums, and a plurality of water tubes connecting each of said steam-drums with its coöperating mud-drum.

5. In a steam boiler, a chamber divided into forward-flow and return-flow passages for the heating gases, a plurality of steam-drums set transversely of all of said passages in the upper part thereof, and a plurality of mud-drums set transversely of all of said passages in the lower part thereof, each of said mud-drums coöperating with one of said steam-drums, a plurality of water-tubes connecting each of said steam-drums with its coöperating mud-drum, and a plurality of tubes cross-connecting said steam-drums.

6. In a steam boiler, a chamber divided into forward-flow and return-flow passages for the heating gases by substantially vertical partitions, passages around one end of said partitions establishing communication between said forward flow and said return flow passages, a plurality of steam-drums set transversely of said passages in the upper part thereof, and a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums coöperating with one of said steam-drums, a plurality of water-tubes connecting each of said steam-drums with its coöperating mud-drum, and a plurality of tubes connecting the water spaces of said steam-drums.

7. In a steam-boiler, in combination, a chamber divided into forward-flow and return-flow passages for the heating gases by substantially vertical partitions, passages around one end of said partitions establishing communication between said forward flow and said return flow passages, a plurality of steam-drums set transversely of said passages in the upper part thereof, and a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums coöperating with one of said steam-drums, a plurality of tubes connecting each of said steam-drums with its coöperating mud-drum and a plurality of

steam tubes establishing communication between the steam spaces of the said steam-drums.

8. In a steam-boiler, in combination, a chamber divided into a plurality of passages for the heating gases by substantially vertical partitions, said partitions extending substantially from the bottom to the top of said chamber, a plurality of steam drums in the upper part of said passages, a plurality of mud-drums in the lower part of said passages, each of said mud-drums coöperating with one of said steam-drums, a plurality of tubes connecting the vapor space of each of said steam-drums with the adjacent drum or drums, and a plurality of tubes connecting the water space of said steam drums with the water space of the adjacent steam-drum or drums.

9. In a steam-boiler, in combination, a chamber divided into a plurality of passages for the heating gases by means of a plurality of substantially vertical partitions, passages around one end of said partitions establishing communication between said passages for heating gases, a substantially horizontal steam-drum set in the upper part of said passages, a substantially horizontal mud-drum set in the power part of said passages, and a plurality of water-tubes connecting said steam-drum with said mud-drum.

10. In a steam-boiler, in combination, a chamber divided into a middle and two side passages for the heating gases by means of two substantially vertical partitions, said partitions extending substantially from the bottom to the top of said chamber, a substantially horizontal steam-drum set transversely of said passages in the upper part thereof, a substantially horizontal mud-drum set transversely of said passages in the lower part thereof, and a plurality of water-tubes connecting said steam-drum with said mud-drum.

11. In a steam-boiler, in combination, a chamber divided into a middle and two side passages for the heating gases by means of two substantially vertical partitions, a plurality of substantially horizontal steam-drums, each of said steam drums being set transversely of all of said passages in the upper part thereof, a plurality of substantially horizontal mud-drums set transversely of said passages in the lower part thereof, and a plurality of water-tubes connecting the said steam-drums with the said mud-drums.

12. In a steam-boiler, in combination, a heating chamber, a plurality of substantially vertical partitions, said partitions extending substantially from the bottom to the top of said heating chamber and dividing said chamber into a middle and two side passages for the heating gases, a plurality of steam-drums set transversely of said passages in the upper part thereof, a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums being located substantially vertically underneath one of said steam-drums and coöperating therewith, and a plurality of water-tubes connecting each steam-drum with its coöperating mud-drum.

13. In a steam-boiler, in combination, a heating chamber, a plurality of substantially vertical partitions extending substantially from the bottom to the top of said chamber, said partitions dividing said heating chamber into a middle and two side passages for the heating gases, a plurality of steam-drums set transversely of said passages in the upper part thereof, passages connecting the steam-space of each of said steam-drums with a common steam passage, whereby the steam-spaces of the said steam-drums are placed in communication with each other, a plurality of tubes connecting the water space of each drum with the water spaces of the adjacent steam-drums, a plurality of mud-drums set transversely of the said passages for heating gases in the lower part thereof, each of said mud-drums being set substantially parallel with and vertically underneath one of said steam-drums, and a plurality of water tubes connecting each of said steam-drums with the underlying mud-drums, whereby each of said steam-drums is made to coöperate with its said underlying mud-drum.

14. In a steam-boiler, in combination, a heating chamber, said heating chamber being divided into a plurality of longitudinal passages for the heating gases by means of substantially vertical partitions, a plurality of substantially vertical partitions, passages around the ends of said partitions farthest from the place of entrance of the heating gases, said passages establishing communication between said longitudinal passages, a plurality of steam-drums located in the upper part of said longitudinal passages, a mud-drum or a plurality of mud-drums located in the lower part of said passages and a plurality of water-tubes connecting the said mud-drum or drums with the said steam-drums.

15. In a steam-boiler, in combination, a steam-generating chamber comprising a middle passage for the flow of the high temperature combustion gases entering the chamber, in one direction, two smaller passages, one located on each side of said middle passage, for the return flow of the partially spent combustion gases, two substantially vertical partitions extending substantially from the bottom to the top of said gas generating chamber, said partitions forming the said middle and side passages, a plurality of steam-drums set transversely of said combustion gas passages in the upper part

thereof, one or more mud-drums set transversely of said combustion gas passages in the lower part thereof, and a plurality of water tubes connecting said mud-drum or drums with the said plurality of steam-drums.

16. In a steam-boiler, in combination, a steam-generating chamber having two substantially vertical longitudinal partitions therein, whereby the said generating chamber is divided into a middle longitudinal passage for the flow of the high-temperature combustion gases entering the chamber in one direction, and a smaller longitudinal passage on each side of said middle passage for the return flow of the partially spent combustion gases, a plurality of steam-drums, each of said steam drums being set transversely of all of said combustion passages in the upper part thereof and a plurality of mud-drums set substantially parallel to said steam-drums, one of said mud-drums being located, substantially, vertically underneath each of said steam-drums and coöperating therewith, and a plurality of water tubes connecting each steam-drum with its coöperating mud-drum, whereby a circulation of water is established between the lower mud-drums and their coöperating steam-drums, the said water ascending through the water-tubes occupying the said middle passage for combustion gases and descending through the tubes occupying the said side passages for combustion gases.

17. In a steam-boiler, in combination, a steam-generating chamber having two substantially vertical longitudinal partitions therein of a less length than the length of said chamber, whereby the said generating chamber is divided into a middle longitudinal passage for the flow of the high-temperature combustion gases entering the said chamber in one direction, and a smaller longitudinal passage on each side of said middle passage for the return-flow of the partially spent combustion gases, the said side passages being in free communication with the said middle passage at the extremity of said steam-generating chamber farthest from the place of entry of said combustion gases, a plurality of steam-drums set transversely of said combustion gas passages in the upper part thereof and a plurality of mud-drums set substantially parallel to said steam-drums, one of said mud-drums being located substantially vertically beneath each of said steam-drums and coöperating therewith, a plurality of water-tubes connecting each steam-drum with its coöperating mud-drum, a plurality of tubes cross-connecting the water spaces of said steam-drums, said cross-connections being located in the said side passages for combustion gas, and a pipe connecting the steam-space of each of said steam-drums with a common steam conduit.

18. In a steam-boiler, in combination, a steam-generating chamber, walls inclosing said chamber, two substantially vertical longitudinal partitions in said chamber, said partitions abutting against the front wall of said chamber but stopping short of the rear wall of said chamber, whereby the said steam-generating chamber is divided into a middle longitudinal passage and two side longitudinal passages, the said side passages being in communication with said middle passage around the rear ends of said partitions, a passage in the front wall of said chamber communicating with the said middle passage of said chamber for conducting the hot combustion gases to said middle passage and one or more passages in the front wall of said chamber in communication with each of said side passages for the exit of the spent combustion gases from said side passages, steam-drums in the upper part of said passages and one or more mud-drums in the lower part of said passages, a plurality of water-tubes in each of said passages connecting the said mud-drum or drums with the said steam-drums, whereby in the operation of said boiler a rapid circulation is established between the said water-drum or drums and the said steam-drums, the water ascending in the bank of tubes occupying the said middle passage and descending through the banks of tubes occupying the said side passages.

19. In a steam-boiler, in combination, a steam-generating chamber, walls inclosing said chamber, two substantially vertical longitudinal partitions in said chamber, said partitions abutting against the front wall of said chamber but stopping short of the rear wall of said chamber, whereby the said steam-generating chamber is divided into a middle longitudinal passage and two side longitudinal passages, the said side passages being in communication with said middle passage around the rear ends of said partitions, a passage in the front wall of said chamber communicating with the said middle passage of said chamber for conducting the hot combustion gases to said middle passage and one or more passages in the front wall of said chamber in communication with each of said side passages, for the exit of the spent combustion gases from said side passages, a plurality of steam-drums set transversely to said passages in the upper part thereof, a plurality of tubes cross-connecting the water spaces of the adjacent steam-drums, the said cross-connections being located in the said side passages, a valved water feed-pipe communicating with the interiors of said steam-drums near the ends thereof, a pipe connecting each of said steam-drums with a common steam conduit, whereby the steam spaces of the several steam-drums are in communication with

each other, means for indicating the water level in said steam-drums, a plurality of mud-drums set parallel to said steam-drums, one of said mud-drums being located vertically beneath each of said steam-drums, a plurality of water tubes in each of said longitudinal passages connecting the said steam-drums with the said mud-drums, wherein in the operation of said boiler, a rapid circulation of the contained water is established between the said mud-drums and the said steam-drums, the water ascending in the bank of tubes occupying the said middle passage and descending through the banks of tubes occupying the said side passages.

20. The combination of a gas producer, a combustion chamber, a passage connecting said combustion chamber with said gas producer, a steam-generating chamber and a passage connecting said combustion chamber with said steam-generating chamber, the said steam-generating chamber comprising forward-flow and return-flow passages for the heating gases, a plurality of steam-drums set transversely of said passages in the upper part thereof, and a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums being set substantially vertically under one of said steam-drums and coöperating with said steam-drum, and a plurality of water-tubes connecting each of said steam-drums with its coöperating mud-drum.

21. In combination, a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber, a passage connecting said combustion chamber with said steam-generating chamber, the said steam-generating chamber comprising, forward-flow and return-flow passages for the combustion gases from said combustion chamber, a plurality of steam-drums set transversely of said passages in the upper part thereof, and a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums coöperating with one of said steam-drums, a plurality of tubes connecting each of said steam-drums with its coöperating mud-drum and a plurality of steam tubes establishing communication between the steam spaces of the steam-drums.

22. In combination, a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber and a passage connecting said combustion chamber with said steam-generating chamber, the said steam-generating chamber comprising in combination a middle and two side passages for heating gases, said passages being formed by two substantially vertical partitions and the two walls of said chamber parallel to said partitions, a substantially horizontal steam-drum set transversely of said passages in the upper part thereof, a substantially horizontal mud-drum set transversely of said passages in the lower part thereof and a plurality of water-tubes connecting said steam-drum with said mud-drum.

23. In combination a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber and a passage connecting said combustion chamber with the said steam-generating chamber, the said steam-generating chamber comprising in combination a middle and two side passages for heating gases, a plurality of steam-drums set transversely of said passages in the upper part thereof, a plurality of mud-drums set transversely of said passages in the lower part thereof, each of said mud-drums being located substantially vertically under one of said steam-drums and coöperating therewith, and a plurality of water-tubes connecting each steam-drum with its coöperating mud-drum.

24. In combination a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber, and a passage connecting the said combustion chamber with the said steam-generating chamber, the said steam-generating chamber comprising a middle passage for the flow of the high temperature combustion gases entering the steam-generating chamber in one direction, two smaller passages one located on each side of said middle passage for the return-flow of the partially spent combustion gases, a plurality of steam-drums set transversely of said combustion gas passages in the upper part thereof, a plurality of mud-drums set transversely of said passages in the lower part thereof, one of said mud-drums being located substantially vertically beneath each of said steam-drums and coöperating therewith, and a plurality of water-tubes connecting each steam-drum with its coöperating mud-drum, whereby a circulation of water is established between the lower mud-drums and their coöperating steam-drums, the said water ascending through the water-tubes occupying the said middle passage for combustion gases and descending through the tubes occupying the said side passages for combustion gases.

25. In combination, a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber, and a passage connecting the said combustion chamber with said steam-generating chamber, the said steam-generating chamber comprising, inclosing outer walls, two substantially vertical, longitudinal partitions there-

in, of a less length than the length of said chamber, whereby the said generating chamber is divided into a middle longitudinal passage for the flow of the high temperature combustion gases entering the said chamber in one direction and a smaller longitudinal passage on each side of said middle passage for the flow of the partially spent combustion gases in the reverse direction, the said side passages being in free communication with the said middle passage at the extremity of said steam-generating chamber farthest from the place of entry of said combustion gases, a plurality of steam-drums suspended transversely of said combustion gas passages in the upper part thereof, a plurality of mud-drums in the lower part of said combustion gas passages, one of said mud-drums being located substantially vertically underneath each of said steam-drums, a plurality of water-tubes connecting each steam-drum with its coöperating mud-drum, whereby the said mud-drums are placed in communication with their coöperating steam-drums and suspended from said steam-drums, a plurality of tubes cross-connecting the water spaces of said steam-drums, said cross-connections being located in the side passages for combustion gas, and a pipe connecting the steam space of each of said steam-drums with a common steam conduit.

26. In combination, a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber, a passage opening from the upper part of said combustion chamber connecting said chamber with the steam-generating chamber, a passage connecting the said combustion chamber with the air discharge-flue of an air recuperator; the said steam-generating chamber comprising inclosing outer walls, two substantially vertical, longitudinal partitions in said chamber, said partitions abutting against the front wall of said chamber but stopping short of the rear wall of said chamber, whereby the said steam-generating chamber is divided into a middle longitudinal passage and two side longitudinal passages, the said side passages being in communication with said middle passage around the rear ends of said partitions, a passage in the front wall of said chamber, communicating with the said middle passage of said chamber, for conducting the hot combustion gases to said middle passage, and one or more passages in the front wall of said chamber in communication with each of said side passages for the exit of the spent combustion gases from said side passages, steam-drums suspended in the upper part of said passages and one or more mud-drums in the lower part of said passages, the said mud-drums being suspended from said steam-drums by a plurality of connecting water-tubes, said water-tubes occupying both the middle and side passages of said steam-generating chamber, whereby in the operation of said boiler a rapid circulation is established between the said steam-drums and the said mud-drum or drums, the water ascending in the bank of said water-tubes occupying said middle passage and descending through the banks of tubes occupying the said side passages.

27. In combination, a gas producer, a combustion chamber, a passage connecting said gas producer with said combustion chamber, a steam-generating chamber, a passage opening from the upper part of said combustion chamber connecting said chamber with the said steam-generating chamber, a passage connecting the lower part of the said combustion chamber with the air discharge-flue of an air recuperator; the said steam-generating chamber comprising inclosing outer walls, two substantially vertical longitudinal partitions in said chamber, said partitions abutting against the front wall of said chamber but stopping short of the rear wall of said chamber, whereby the said steam-generating chamber is divided into a middle longitudinal passage and two side longitudinal passages, the said side passages being in communication with said middle passage around the rear ends of said partitions, a passage in the front wall of said chamber communicating with the said middle passage of said chamber for conducting the hot combustion gases to said middle passage and one or more passages in the front wall of said chamber in communication with each of said side passages for the exit of the spent combustion gases from said side passages, a plurality of steam-drums suspended transversely of said passages in the upper part thereof, a plurality of tubes cross-connecting the water spaces of the adjacent steam-drums, the said cross-connections being located in the said side passages, a valved water feed-pipe communicating with the interiors of said steam-drums near the ends thereof, a pipe connecting each of said steam-drums with a common steam conduit, whereby the steam spaces of the several steam-drums are in communication with each other, means for indicating the water level in said steam-drums, a plurality of mud-drums in the lower part of the combustion gas passages of said steam-generating chamber, the said mud-drums being substantially parallel to said steam-drums, one of said mud-drums being located vertically underneath each of said steam-drums, a plurality of water-tubes in each of said longitudinal passages connecting the said steam-drums with the said mud-drums and suspending the said mud-drums from said steam-drums, whereby in the operation of

said boiler a rapid circulation of the contained water is established between the said mud-drums and the said steam-drums, the water ascending in the bank of tubes occupying the said middle passage and descending in the banks of tubes occupying the said side passages.

28. In combination, a water-heater, an air heater, a gas producer, a combustion chamber, passages connecting the lower part of said combustion chamber with said gas producer and said air heater, respectively, a steam-generating chamber, a passage connecting the upper part of said combustion chamber with said steam-generating chamber, the said steam-generating chamber comprising, a middle longitudinal passage for receiving the high-temperature combustion gases from said combustion chamber, and two side passages, one on each side of said middle passage for receiving the partially spent combustion gases from said middle passage, a plurality of steam-drums set transversely of said combustion gas passages in the upper part thereof, a plurality of mud-drums in the lower part of said combustion gas passages, a plurality of water-tubes connecting each of said steam-drums with its corresponding mud-drum, whereby there is an upward circulation of water established from the said mud-drums to their coöperating steam-drums through the water-tubes occupying the said middle passage for combustion gases and a downward circulation through the water-tubes occupying the said side passages for combustion gases.

Signed at New York city in the county of New York and State of New York this 14th day of Jan. A. D. 1911.

HENRY L. DOHERTY.

Witnesses:

J. M. McMillin,

F. L. Blackburn.