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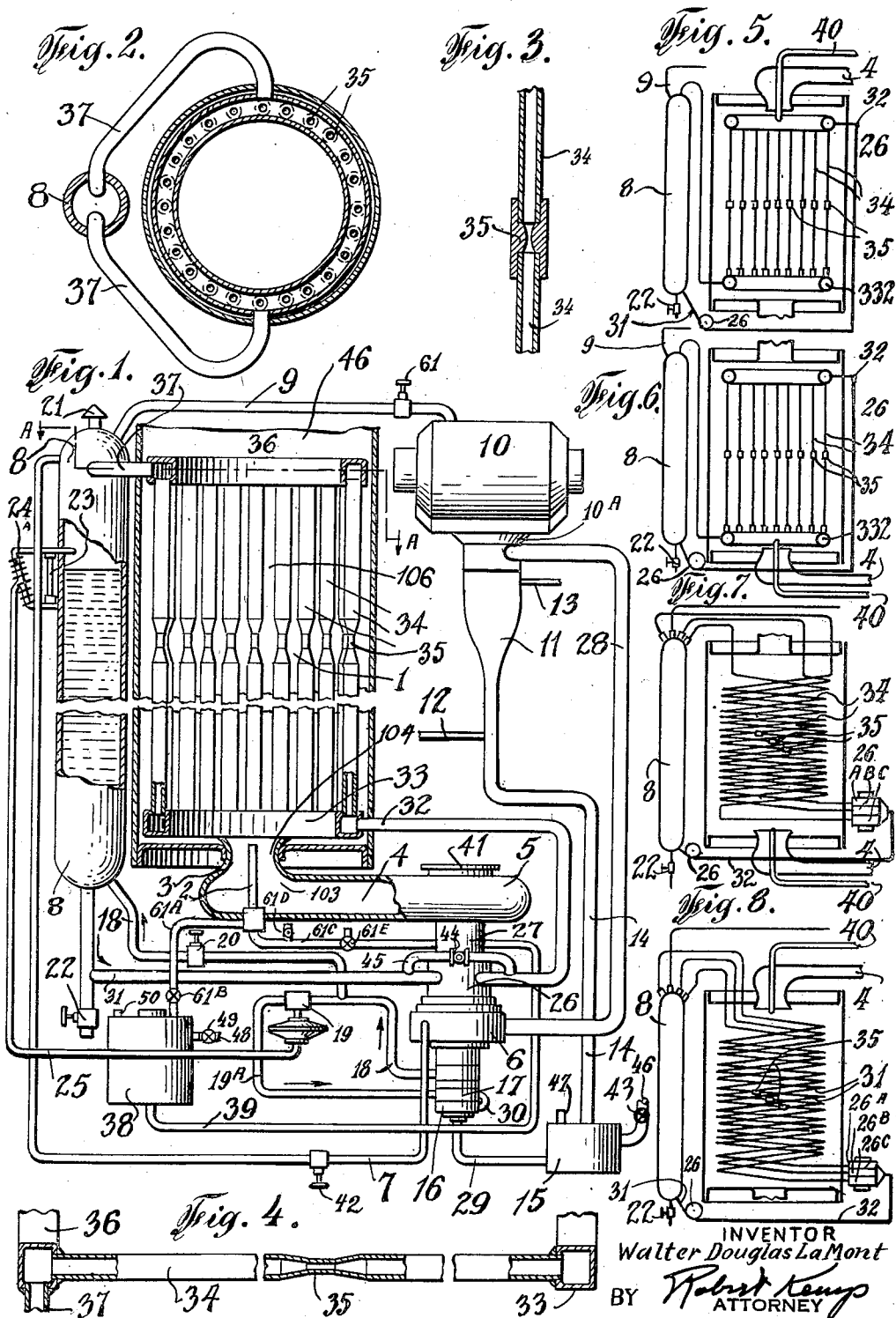
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2,201,617

STEAM GENERATING APPARATUS

Original Filed Oct. 5, 1933

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

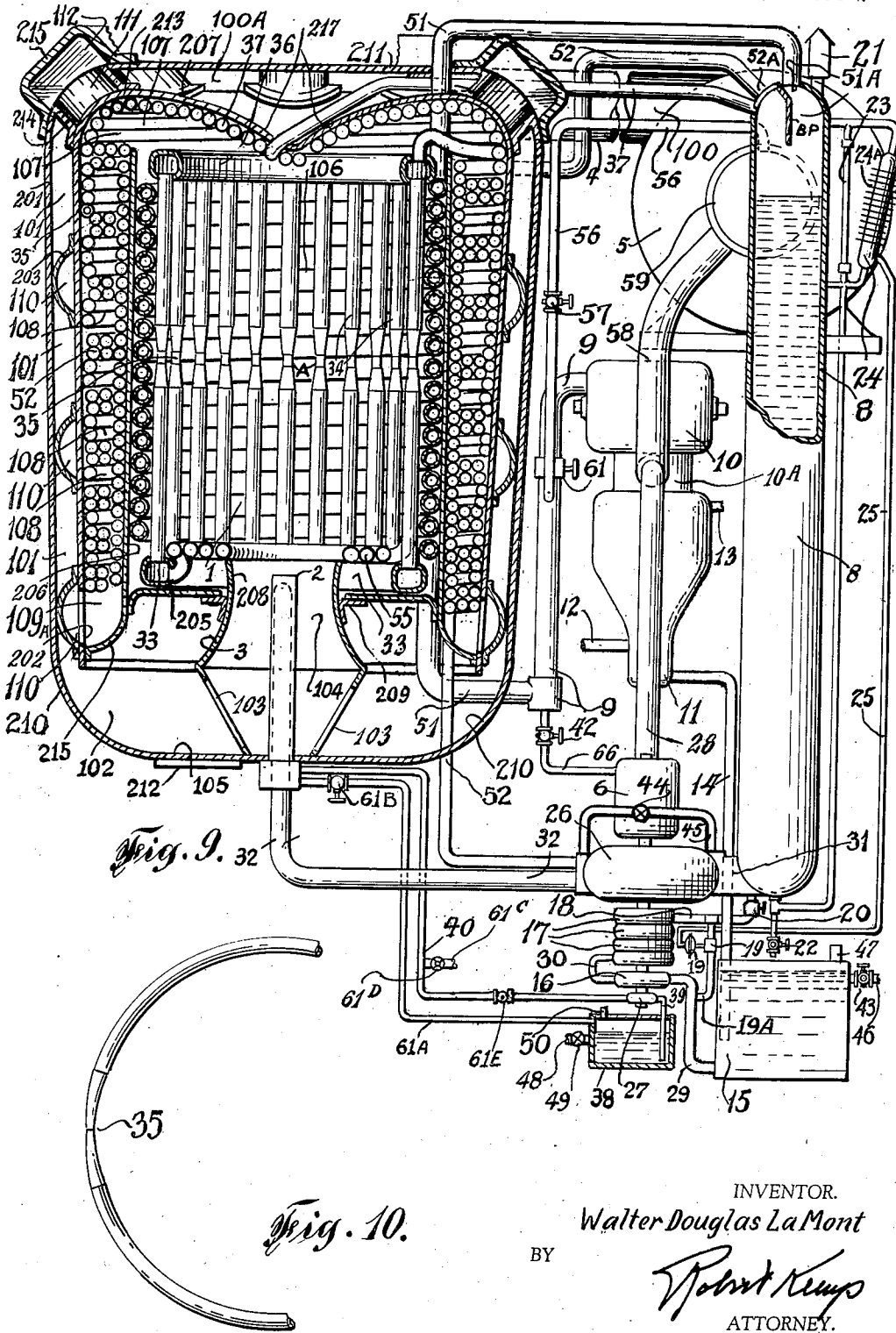


Fig. 9.

Fig. 10.

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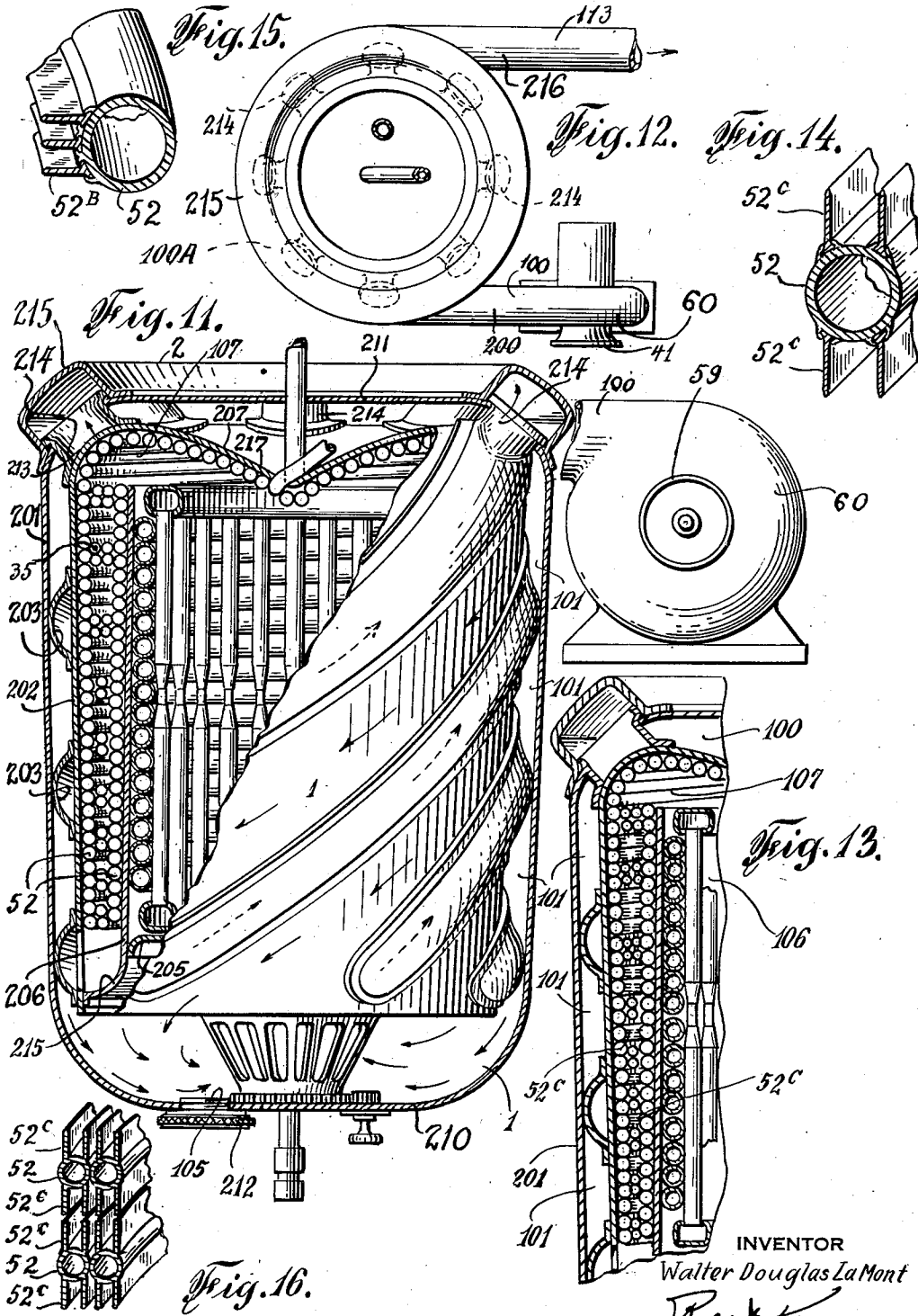
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3 Sheets-Sheet 3



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STEAM GENERATING APPARATUS

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Application October 5, 1933, Serial No. 692,236
Renewed December 29, 1939

26 Claims. (Cl. 122—235)

This invention relates to high speed steam apparatus.

The steam generating apparatus in accordance with the present invention comprehends unidirectional flow in part of the main working fluid in my steam generating elements under conditions of high temperature radiant and/or convection heat transfer at high rates of heat release.

A main object of my invention is to reduce the size, weight, and cost of high speed steam producing apparatus. I do this by increasing its speed of operation.

It is vital that the main working fluid especially, flow at least unidirectionally at all times, under all steam making loads and speeds, substantially regardless of firebox temperatures or rates of heat release.

In my previous inventions, as disclosed in Re-issue U. S. Patent 16,895 and U. S. Patent 1,884,979 and others, using less than sufficient water than would normally be required to fill boiler tubes, I endeavored to secure a unidirectional flow of my main working fluid flowing through radiant heat receiving water wall tubes, each tube of considerable length, and of small size, and preferably of substantially uniform diameter to insure rapid radiant and convection heat pick up.

Several difficulties were present. When firebox or so-called combustion chamber pressures on unburned gases and on burned gases remained down around a few inches of water, and I employed forced circulation with orifices or restrictions for pressure drop delivery and water distribution purposes at or near the inlets for working fluid entering each long, small diameter boiler tube in my boilers, preferably having constant circulation of water through a steam and water separating device, I found in the case of fluid fuel fires, a tendency for these fires to rove back and forth or here and there in the combustion chamber, momentarily intensifying locally certain heat receiving areas in the tubular water wall while these tubes carried rapidly flowing water in their interiors.

With stoker fires it was possible, in each individual installation of a water wall in the firebox, when said water wall comprised long tubes of small diameter, in accordance with my previous water wall inventions, not using so-called full tubes, to experimentally determine where local hotter areas were, and to provide larger orifices in the water wall tubes passing through these areas and/or accomplish larger pressure drops through the orifices. This preliminary experimental work of determining exactly where local hotter areas

were to provide larger orifices in the water wall tubes passing through these areas and/or large pressure drops through the orifices, was no matter for a novice to undertake, because often in boilers of identical design, intensely hot areas would be found in different places in the walls of the combustion chamber, and further, would wander as fire box temperatures changed, not similarly, for some unaccountable reason, even though all factors may have appeared identical.

With hotter, higher speed, fluid fuel fires, this wandering action becomes a roving action, of great intensity and suddenness, abruptly delivering, or failing to deliver, heats rapidly to certain sections of waterwall tubes at various localized areas, always impossible to determine in advance and constantly changing in position.

These abrupt changes in the heat supplied at localized and constantly varying water wall heat reception areas are due to combustion conditions in the firebox changing constantly.

When rates of heat release or the temperatures in the combustion chamber are raised to a high point, steam and water delivery from the outlets of the tubular water wall members develop a rhythm, the wall "pants" (with a noise somewhat like a fatigued animal), the tubes rhythmically belching steam and water, pausing, or gulping in their steam and water delivery, then belching more steam and water. The water wall tubes as a whole when acting in the above manner using my pump circulation with orifices at the inlets of the tubes and less than enough water to fill the tubes throughout the length of the tubes, positively deliver water and steam in one path flow to the tube inlets, but this working fluid delivery at the outlets, and throughout the length of the tube is intermittent. It is not continuously uniform nor is it semi-unidirectional nor unidirectional.

There is a distinct difference in the operating characteristics of a so-called full water tube making steam, compared to a tube in which steam is being produced with less than sufficient water to fill the tube; especially when tubes of both types are subjected to exceptionally high rates of heat release.

Other objects of my present invention are to attain: a positive and controlled supply of water to each of the steam generating tubes or elements conveying working fluid through the water wall surrounding the combustion zone and through the steam making elements exposed to convection heat; to provide steady and continuous circulation of the water through the water passages or tubes of the water wall or water wall

boiler and steam generating elements exposed to convection heat; to provide for the proper and adequate flow of water through the different parts of the steam generating apparatus and in such relation to the steam generated in said parts or to the condition of the steam generated therein that an adequate flow of water may be maintained through each part and in suitable relation in one part relative to the other. It is a still further object of the invention to provide for the positive control of the amount of water delivered to or flowing through the different parts and to control the conditions under which it flows so as to accomplish the proper delivery to and flow through the different parts of the steam generating apparatus to suit conditions of steam generation in said parts.

A still further object of the present invention, is to increase the amount of water circulated and therefore the speed of the circulation of steam and water in the tube with the increase in the rate of heat release, in order to increase the rate of heat transfer from the metal of the tubes to the water and steam by moving the forming bubbles of steam away from their point of formation faster, thus protecting the water wall tubes especially, and the other tubes of the boiler from the increasing heat to which they are exposed with every increase in the rate of heat release in the combustion chamber.

An important object of this invention is to disclose how so-called full water wall tubes can be operated with positive input of water into each tube in sufficient quantity to protect each tube regardless of how rapid rates of heat release are obtained in the combustion chamber, up to the maximum heat effects for which it is designed to withstand; and to show and describe how unidirectional flow of steam and water within and throughout a portion of the length of the tube can also always be uniformly obtained under any combustion chamber heat releasing condition for which it is designed.

In accordance with my invention, the placing of pressure drop devices beyond the water inlet end of the tubes, or in that part of the tube exposed to radiant and/or convection heat, is a preferred position for these pressure drop devices, or orifices, if orifices are used as pressure drop devices.

Also in accordance with my invention, the pressure drop devices are placed preferably at any point in the tube beyond the point where steam begins to form, at the designed rate of heat release for the steam generator, thus insuring under the proper load conditions, the passing through the pressure drop device of at least some steam with the water.

This immediately gives the advantage of a larger area for steam and water passage through the pressure drop device for a given pressure drop, and a given quantity of water, than would be possible if water alone were passed through the pressure drop device.

This new position of my pressure drop device is also of immediate advantage to reduce the possibility of clogging, whether the steam generator is used, as in my present invention, of operating a part of the steam generating tube with a so-called full tube condition, or if the heat release permits, and it is desirable to operate a part of the steam generator under conditions of my previous inventions using less than enough water than is normally required to fill the tube.

However, the most desirable position of my pressure drop device is at that position of the length of the tube which at the maximum rates of heat release for which it is designed will insure a sufficient length of the tube to give unidirectional flow of the working fluid so that the steam generator operating as a whole will not have serious steam and water surging conditions caused by that part of the tube in which unidirectional flow is not insured. A steam generating apparatus operating in this way has certain advantages over my previous boiler inventions (using steam generating tubes with less than enough water to fill the tubes in their steam generating portion). Where the rate of heat release is not too great, my new type of steam generator, as outlined herein, can be profitably used.

By advancing the orifice toward the outlet end of the tube, as in the present invention, the proportion of the length of the tube behind the orifice which has a compact column of steam and water, increases; and the proportion of length past the orifice toward the outlet end, which is subject to the surging action, decreases; reducing the degree of interference to proper steam making operation from back and forth or surging flow. The tube under this condition has an assured unidirectional flow for that part of its length between the orifice and the inlet end, while the part of the length from the orifice to the outlet end may have some degree of surging or non-unidirectional flow. This results in the tube as a whole giving what is termed unidirectional flow in part.

As the rate of heat release increases, the need of advancing the orifice along the tube, toward the outlet end of the tube, likewise increases, until the exit end of the tube is finally reached. This is further discussed in my co-pending application Serial No. 686,268, filed August 22, 1933.

The selection of the point along the length of the tube where the orifice can best be used is a matter of the general duty for which the apparatus is designed and for which it is to be put in use. The main factors to be considered are,

1. The rate of heat release in the combustion zone.

2. The degree of fluid compactness required to prevent surging in the hydraulic column from behind the orifice to the inlet end of the steam generating tube.

3. The degree of fluid compactness required to prevent surging in the hydraulic column from immediately beyond the orifice to the outlet end of the steam generating tube, in which some surging can be permitted without interfering with the proper steam making operation of the boiler.

4. The amount of water most desirable for circulation.

5. The degree of pressure drop required to insure one path flow and/or unidirectional flow in part of the working fluid.

6. The size of orifice, or pressure drop device desirable to avoid clogging.

7. Mechanical and boiler cleaning considerations.

8. The question as to whether it is better to operate a portion of the steam generating section with the so-called full tube condition, or with less than sufficient to fill the tubes condition.

In practical application of my previous inventions, using an orifice at or near the entrance to the tube and passing only water through it, I found, especially in waste heat work and with

water wall tubes of very short length exposed to moderate rates of heat release; that a very small diameter hole for the orifice in each tube was required to pass the proper amount of water into the tube for protection of the tube without circulating an unnecessarily large amount of water and to still have a pressure drop of sufficient amount to insure one path flow into the tube.

Without use of distilled water, or in cases where water containing large amounts of carbonates is used; this small orifice at the entrance to each tube, presents a serious problem to prevent clogging which screening of the circulating water line, and of orifices, does not entirely eliminate.

As previously stated, I found that if the orifice is placed at a point in the steam generating element where both steam and water is passed, a much larger hole can be used, or with other forms of resistors or pressure drop devices, much larger areas can be used. This is due to the great increase in volume of steam compared to water per lb. of either.

If the orifice is placed beyond the point in the tube where steam begins to form there is also a marked increase in the size of the hole which can be used to pass a given amount of water with a given pressure drop.

As the orifice is moved forward in the tube toward the end, the size of the hole used can be increased, reaching a maximum, of course, at the outlet end where it will be passing a maximum of steam with the excess water.

I have found that with steam generator units, designed for certain load conditions, using an economizer that gives considerable steam generation at full load, or with an economizer which steams; the art of placing the orifice or pressure drop device at the proper position along the length of the economizer tube to insure unidirectional flow in part may be used in the same way as previously outlined for waterwall and convection generating tubes. The placing of the orifice or pressure drop device past the point where steam may form is especially advantageous in the economizer to permit the use of larger orifices or pressure drop devices than would be possible if feed water only passed through such devices with sufficient pressure drop to insure one path flow under full load conditions.

A prime object of the present invention is to increase the speed of steam generation and power production, thus making my steam generating apparatus and my steam power plant smaller, lighter weight, and less expensive.

In one of its aspects my invention is a high speed steam generator whose water walls in the radiant heat releasing and receiving area, namely the combustion zone, and whose steam generating tubes exposed to convection heat transfer in the convection heat zone, will not give an undue amount of surging of steam and water travelling back and forth in the tubes, but will have positive unidirectional flow in part of water in each wall tube, at all times, regardless of combustion conditions in the firebox or the size or movement of large steam bubbles shifting from side to side in individual water wall tubes, or group of water wall tubes, up to the maximum rate of combustion at which the steam boiler is designed to operate.

This present invention is particularly concerned with the improvement of high speed steam boilers, but where my invention, and/or any of its features, applies to flash boilers or mass boil-

ing boilers, such improvements are well within the scope of my invention as herein described.

While my invention has been described herein as relating to steam generating apparatus which is intended especially for the generation of steam from water, it will be understood that the terms "steam" and "water" as used in the specifications and claims are intended to include as equivalents, any liquids which might be handled by the novel apparatus herein described, resulting in the generation of any vapors which might be handled by, or be useful in connecting with my apparatus, and it will also be understood that many of the novel features of this invention are applicable in other fields than that for which the apparatus herein specifically illustrated and described is particularly intended.

Other objects and features will be particularly pointed out and disclosed hereinafter in the illustrations, descriptions, specifications and claims of this present patent application.

In the drawings:

Fig. 1 is a complete view of a power plant operating in accordance with certain modifications of my invention;

Fig. 2 is a section taken along the line A--A of my high speed steam boiler shown in Fig. 1;

Fig. 3 is one method of placing an orifice or pressure drop device in my working fluid heating element;

Fig. 4 is a view partially in elevation and partially in section of one of my preferred forms of one of my working fluid steam generating water-wall elements attached to its intake manifold and its outlet manifold as shown in Fig. 1 in accordance with my present invention;

Fig. 5 is a diagrammatic view of a down-flow tubular water wall in a radiant heat releasing firebox or combustion zone made in accordance with my invention and wherein the fuel air mixture and the burned gases travel practically parallel to the water flowing in the water wall tubes;

Fig. 6 is similar to Fig. 5 the difference between the two figures being that here the fuel gases, unburned and burned, travel in counter-current relation to the high velocity flow of the main working fluid in the water wall tubes;

Fig. 7 illustrates a coil type of water wall diagrammatically the coils leading the water upward, the flow of unburned and burned gases also being upward; the circulating pump preferably has a separate wheel for each steam generating tube to discharge water directly and only to the tube connected to it;

Fig. 8 is a similar diagrammatic view of that in Fig. 7 wherein the coils forming a water wall or a liquid wall of working fluid around the firebox or combustion chamber lead the water upward while the unburned and burned gases flow counter-current or downwardly; the circulating pump preferably here again having a separate wheel (or plunger, if a reciprocating pump is used) for each tube, to discharge directly into and maintain hydraulic pressure inside of each water tube;

Fig. 9 is a complete power plant showing the direction, the various fluids flow in their respective paths through my boiler and the close interrelation between the action of the boiler and my high speed power plant as a whole of which my boiler forms a part;

Fig. 10 is a plan view of one of my fluid heater heat absorbing elements, with its pressure drop device as shown in position in Fig. 9 at point A;

Fig. 11 is an enlarged detailed assembly draw-

ing partially cut away, partially in elevation and section of parts of my high speed steam boiler;

Fig. 12 is a view looking downward on the top of the boiler (reduced in size) showing the turbine driven air supercharger delivering air tangentially to my boiler and a pipe releasing burnt gases tangentially;

Fig. 13 is a detail of Fig. 1, showing the path of travel of burnt gases as applied in connection with my new methods of heat extraction and heat transfer to the working fluid of the boiler;

Fig. 14 is an enlarged view of certain of the working fluid tubes or steam generating elements shown in other figures of the drawings;

Fig. 15 is an enlarged sectional view of my heat interchanging tube with longitudinal fins attached;

Fig. 16 is a sectional view of several heat interchanging tubes as they are arranged in the assembly sectional view shown in Fig. 13.

In Figure 1 of the drawings is shown a power plant including, as a part thereof, a steam generator adapted to produce steam of high energy content, in accordance with the present invention. The steam generator is designated by 1, having a plurality of steam generator water wall tubes 34 therein receiving water from the water well inlet header 33, and discharging water and/or steam to the steam generator outlet water wall collecting header 36. These tubes are exposed to a source of radiant heat produced by a flame fed with fuel from burner 2 in the burner throat 3. The combustion of the fuel oil is assisted by a source of air which may be supplied from the supercharger 5, to which air is admitted through inlet 41, feeding air through the discharge lead 4 to the burner throat. The steam generator tubes are shown fitted with pressure drop devices 35, for controlling the input of water into each tube in sufficient quantity to protect the tube and to control the flow of steam and water in each tube to insure the proper operation thereof, said pressure drop devices being placed in an intermediate portion of the length of each tube, in accordance with the present invention. These devices are shown in greater detail in Figures 3 and 4.

The steam and water collected in header 36 discharges by way of conduits 37 (Figure 2) into water level cylinder 8 for maintaining a water level in the system, furnishing reserve power, and insuring water supply to the circulating pumps. The steam is separated from the water in the cylinder 8, and passes through the main high pressure steam line 9, having main control valve 61 therein for controlling the steam to the main turbine 10. Furthermore, a pipe line 7 extends from the upper end of cylinder 8 to auxiliary steam turbine 6 having control valve 42 therein for controlling the drive of auxiliary turbine 6, which drives the air supercharger fan 5, fuel oil pump 27, boiler feed pump 17 and boiler circulating pump 26.

The main exhaust lead 10^A from the main turbine extends from the latter to the main condenser 11. Pipe 12 represents the inlet for circulating cooling water to the main condenser 11, and pipe 13 is the outlet pipe therefor. Pipe 14 is the condensate water discharge from the main condenser 11 to the main feed tank 15 having feed water inlet 46 and control valve 43 therefor. Vent 47 is associated with the feed water tank, and suction lead 29 extends from the latter to the condensate pump 16 or feed pump 17. 18 is a discharge pipe connecting feed pump 17

with the water level cylinder 8; 19^A is a by-pass line for by-passing feed water around the feed pump 17 through water level regulator valve 19, for controlling the water level in the system; and 20 is a feed stop and check valve on the feed pump discharge lead 18 for stopping and checking the feed of water into the system.

Associated with the cylinder 8 is a safety valve 21 for the boiler at the top of the cylinder, and a blow-off valve 22 at the bottom thereof. The cylinder has a gauge glass 23, and an automatic water level regulator 24^A from which extends a pipe 25 to the control valve 19.

The main steam generator circulating pump is represented at 26. The suction line for pump 26 is connected with the water level cylinder 8, through pipe 31, and the discharge pipe 32 of this pump extends therefrom to the inlet header 33. The main circulating pump is fitted with a by-pass 45 therearound, to control the quantity of water which is circulated by means of control valve 44 in this by-pass.

The fuel oil tank is represented at 38 with its suction line 39, vent 50, filling line 48, and control valve therefor, 49, and burner by-pass return oil discharge lead 61^A. Opening into the fuel line into the burner is a pipe having a control valve therein 61^D for introducing starting oil into the burner, and 61^E is a valve for shutting off the oil normally used in the operation of the plant, while using the starting fuel oil. Pipe 28, constituting the exhaust lead from the auxiliary turbine 6, opens into the main turbine exhaust lead 10^A.

Figures 5 and 6 show schematically arrangements similar to that shown in Figure 1. In Figure 5, the fuel air mixture and burned gases travel substantially parallel to the flow of water in the steam generator tubes fitted with pressure drop devices 35 at intermediate points of the length thereof, in accordance with the present invention. In Figure 6, the gases travel in a countercurrent direction to the direction of the flow of water.

Figures 7 and 8 show spiral sets of water wall generator tubes fitted with pressure drop devices 35 with each set having an individual circulating pump 26^A, 26^B, and 26^C.

In Figure 9 is shown a complete high speed power plant embodying the highly efficient boiler generating superheated steam. The circulating system for water and fuel resembles that illustrated in Figure 1, and a detailed description of the duplicate parts will not be set forth below.

The central combustion chamber 106, as shown, has water wall tubes 34 therein through which water is circulated from inlet header 33 to outlet header 36. The steam and water produced in accordance with the present invention, is discharged into the tube 37 at the end of the boiler opposite the burner, and thence to the water level cylinder 8 where it strikes a baffle plate BP which causes the water in the mixture to be separated and to drop by gravity whereas the steam accumulates at the top of the cylinder for passage therefrom. Tube 51 extends from the upper end of the cylinder 8 at 51^A, to deliver saturated steam therefrom to the superheater tubes coiled around the interior of the combustion chamber which are shielded by the water wall tubes 34.

In addition to the steam generating tubes 34 in the combustion chamber, auxiliary steam generating tubes 52 are coiled in annular passage 108, formed on the outside of the combustion

chamber 106, and confined by an external wall 202, which forms a tapered passage extending from the inlet thereof at 107, to the outlet thereof, at 109. The combustion gases travel upwardly to the top end of the chamber 106 and then pass through passage 107 downwardly, through the passage 108, giving up the heat contained therein to the steam-generating tubes 52. The tubes 52 may be supplied with circulating water from the main steam generator circulating pump 26 and these tubes discharge the steam and water therein into the water level cylinder at 52^A. These tubes 52 in the convection passage may be provided with fins 52^B and 52^C, extending in parallel to the axis of the tubes, as shown in Figures 14, 15 and 16, for the purpose of more effectively extracting the heat from the combustion gases.

In addition to the steam generating tubes 34 and 52 described above, tubes 55 may be provided for protecting the combustion chamber inlet wall 205, which receive water from the inlet header 33 and discharge water and/or steam to the collecting header 36.

The combustion gases passing downwardly through the convection passage 108, pass through the exits 109^A into a series of spirally disposed burnt gas passages 110. These spiral passages terminate near the top of the boiler into a passage 111, which opens into a common outlet passage 112, to which is connected the tangential stack outlet passage 113 opening into the atmosphere.

The incoming air used for combustion which is commingled with the fuel supplied by burner 2 in the throat 104, is admitted to the throat through openings 103, after passing in heat-exchanging relationship with the burnt gas passages 110. The air is supplied from the air supercharger 60 (Figure 12), to the pipe 100 opening tangentially into the casing of the boiler 201. This casing forms in conjunction with the walls 203 forming the passages 110, a plurality of spiral air-preheater passages 101, which travel downwardly in Figures 9 and 11 towards the air inlets 103.

In the boilers shown in Figures 9 and 11, an inspection and ignition port 105 is provided covered by detachable closure 212.

The constituent parts of the boiler in accordance with the present invention are preferably constructed of non-corrosive metal alloys. With such a construction it is necessary to properly and thoroughly protect the metal walls from exposure to excessive heat effects from the radiant gases. This is accomplished by placing cooling protective surfaces in front of and in contact with the metal walls.

I claim:

1. In a combustion chamber, a wall member, a burner adjacent said wall member, a conical water wall across the end of said combustion chamber comprising a conically spiralled tube, conically pointed toward the burner end of said combustion chamber, and a wall member adjacent said water wall.

2. A conical tubular water wall positioned at the burnt gas outgoing end of a combustion chamber, pointed toward the interior of said combustion chamber, and a wall member adjacent said water wall.

3. In a combustion chamber, a wall member, a burner adjacent said wall member, a conical tubular water wall positioned in said combustion chamber opposite a fluid fuel burner, pointed

toward the interior of said combustion chamber, and a wall member adjacent said water wall.

4. In a steam generating circuit the combination including a vessel in which a water level is maintained, positive water circulating means operatively connected to said vessel, water wall tubes operatively connected to said positive circulating means and to said vessel, said positive circulating means circulating water from said vessel in said water wall tubes, and fluid flow altering means in an intermediate position in said water wall tubes to control the flow of water and steam in said water wall tubes, said water wall tubes receiving water in quantity greater than is evaporated.

5. An apparatus as in claim 4 wherein said flow altering means comprises a pressure drop means.

6. In a vapor generating circuit, the combination including a vapor liquid separation device, positive liquid circulating means operatively connected to said separation device, liquid wall tubes operatively connected to said separation device and to said circulating means, said positive circulating means circulating liquid from said separation device into and through said liquid wall tubes, pressure drop devices in that portion of said liquid wall tubes through which mixtures of vapor and liquid pass while receiving heat, said pressure drop devices controlling the flow of vapor and liquid mixtures in said tubes and said liquid wall tubes receiving liquid in quantity greater than is evaporated.

7. In a steam generating circuit, the combination including a steam and water separation device, positive water circulating means operatively connected to said separation device, water wall tubular elements operatively connected to said separation device and said circulating means, steam generating tubular elements operatively connected to said separation device and said circulating means, said positive circulating means circulating water from said separation device through said water wall elements and said generating elements, and fluid flow altering means in an intermediate portion of said liquid wall elements to control the flow of steam and water mixture in said water wall tubular elements, said water wall elements and said generating elements receiving water in quantity greater than is evaporated.

8. An apparatus as in claim 7, characterized by fluid flow altering means in an intermediate portion of said generating tubular elements to control the flow of steam and water mixture in said generating elements.

9. In a vapor generating circuit, the combination including a vapor and liquid separation device, positive liquid circulating means operatively connected to said separation device, liquid wall tubes operatively connected to said separation device and said circulating means, vapor generating tubes operatively connected to said separation device and said circulating means, said positive circulating means circulating liquid from said separation device through said wall tubes and said generating tubes, and pressure drop means in that portion of said liquid wall tubes and said vapor generating tubes through which mixtures of vapor and liquid pass to control the flow of vapor liquid mixtures in said tubes while said mixtures are receiving heat, said liquid wall tubes and vapor generating tubes receiving liquid in quantity greater than is evaporated.

10. An apparatus as in claim 9 wherein economizer tubes are operatively connected to said

separation device and to said circulating means.

11. An apparatus as in claim 4 wherein a superheater tube is operatively connected to said vessel, said superheater tube positioned adjacent said water wall tubes and delivering superheated steam.

12. An apparatus as in claim 6 wherein a superheater tube is operatively connected to said separation device, said superheater tube positioned adjacent said liquid wall tubes and conveying steam undergoing superheating in a direction opposite to the flow of heating gases.

13. In a steam generating circuit the combination including a vessel in which a water level is maintained, positive water circulating means operatively connected to said vessel, water wall tubes operatively connected to said positive water circulating means and said vessel, said positive circulating means circulating said water in said water wall tubes, water and steam separating means in the circuit of said steam generator, and fluid flow altering means in an intermediate position in the length of said water wall tubes to control the flow of water and steam in said water wall tubes, said water wall tubes receiving water in quantity greater than is evaporated.

14. An apparatus as in claim 13 wherein said flow altering means comprises a pressure drop means.

15. An apparatus as in claim 13 wherein said flow altering means comprises pressure drop devices through which a mixture of steam and water is passed.

16. In a steam generator the combination including a vessel in which a water level is maintained, positive water circulating means operatively connected to said vessel, steam generating tubes operatively connected to said positive circulating means and to said vessel, steam and water separating means in said steam generating tubes and operatively connected to said vessel, said positive circulation means circulating said water in said steam generating tubes, fluid flow altering means in an intermediate position in the length of said steam generating tubes to control the flow of steam and water mixture in said steam generating tubes, said steam generating tubes receiving water in quantity greater than is evaporated.

17. In a steam generator the combination comprising, a vessel in which a water level is maintained said vessel being away from the path of the combustion gases, positive water circulating means operatively connected to said vessel, steam generating tubes operatively connected to said positive water circulating means, said positive water circulating means circulating water in said steam generating tubes, fluid flow altering means in an intermediate position in the length of said steam generating tubes to control the flow of steam and water mixture in said steam generating tubes, and a steam and water separation device operatively associated with said steam generating tubes and said water level vessel, said steam generating tubes receiving water in quantities greater than is evaporated therein.

18. In a steam generating circuit the combination including a vessel in which a water level is maintained, positive water circulation means operatively connected to said vessel, water wall tubes operatively connected to said positive water circulation means and said vessel, said positive circulation means circulating said water in said waterwall tubes, water and steam separating means in the circuit of said steam generator and

fluid flow altering means in said water wall tubes to control the flow of steam and water mixtures in said tubes, said water wall tubes receiving water in quantity greater than is evaporated.

19. In a steam generator circuit, the combination including a vessel in which a water level is maintained, positive water circulation means operatively connected to said vessel, water wall tubes operatively connected to said positive circulation means and said vessel, said positive circulation means circulating said water in said water wall tubes, and steam and water pressure drop devices in an intermediate portion of the length of said water wall tubes through which water and steam is passed to control the flow of water and steam in said water wall tubes, said water wall tubes receiving water in quantity greater than is evaporated.

20. In a steam generating circuit, the combination including a steam and water separation device, positive water circulating means operatively connected to said separation device, water wall tubular elements positioned mainly in a radiant heat zone and operatively connected to said separation device and said circulating means, steam generating tubular elements positioned mainly in a convection heat zone and operatively connected to said separation device and said circulating means, said positive circulating means circulating water from said separation device through said water wall elements and said steam generating elements, fluid flow altering means in an intermediate portion of said liquid wall elements to control the flow of steam and water mixture in said water wall tubular elements, and fluid flow altering means in an intermediate portion of said steam generating tubular elements to control the flow of steam and water mixture in said generating elements, said water wall elements and said steam generating elements receiving water in quantity greater than is evaporated therein.

21. In a steam generating circuit the combination including a vessel in which a water level is maintained, positive water circulating means operatively connected to said vessel, steam generating tubes exposed mainly to radiant heat operatively connected to said positive water circulating means and said vessel, said positive circulating means circulating water in said steam generating tubes, water and steam separating means in the circuit of said steam generator, and fluid flow altering means in an intermediate position in the length of said steam generating tubes exposed mainly to radiant heat to control the flow of water and steam in said steam generating tubes, said steam generating tubes receiving water in quantity greater than is evaporated.

22. In a steam generating circuit the combination including a vessel in which a water level is maintained, positive water circulating means operatively connected to said vessel, steam generating tubes operatively connected to said positive water circulating means and said vessel, said positive circulating means circulating said water in said steam generating tubes, water and steam separating means in the circuit of said steam generator, and fluid flow altering means in an intermediate position in the length of said steam generating tubes to control the flow of water and steam in said steam generating tubes, said steam generating tubes receiving water in quantity greater than is evaporated.

23. In a steam generating circuit the combi-

5 nation including a vessel in which a water level is maintained, positive water circulation means operatively connected to said vessel, steam generating tubes operatively connected to said positive
10 water circulation means and said vessel, said positive circulation means circulating said water in said steam generating tubes, water and steam separating means in the circuit of said steam generator, and fluid flow altering means in said
15 steam generating tubes to control the flow of steam and water mixtures in said tubes, said steam generating tubes receiving water in quantity greater than is evaporated.

24. A vapor generating circuit as set forth in claim 9, wherein the pressure drop means in said liquid wall tubes and said vapor generating

tubes are of proper size in relation to said tubes to obtain the desired flow conditions of the fluids therein.

25. An apparatus as set forth in claim 19 wherein said pressure drop devices are of proper size in relation to said water wall tubes to obtain the desired flow conditions of the fluids therein. 5

26. A steam generating circuit as set forth in claim 20 wherein said fluid flow altering means comprise pressure drop devices of proper size in relation to said water wall elements and steam generating elements in which they are disposed to obtain the desired flow conditions of the fluids therein. 10

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