June 23, 1942. C. B. PAGE 2,287,057

STEAM PRODUCTION SYSTEM

Filed July 27, 1936

Fig. 1.

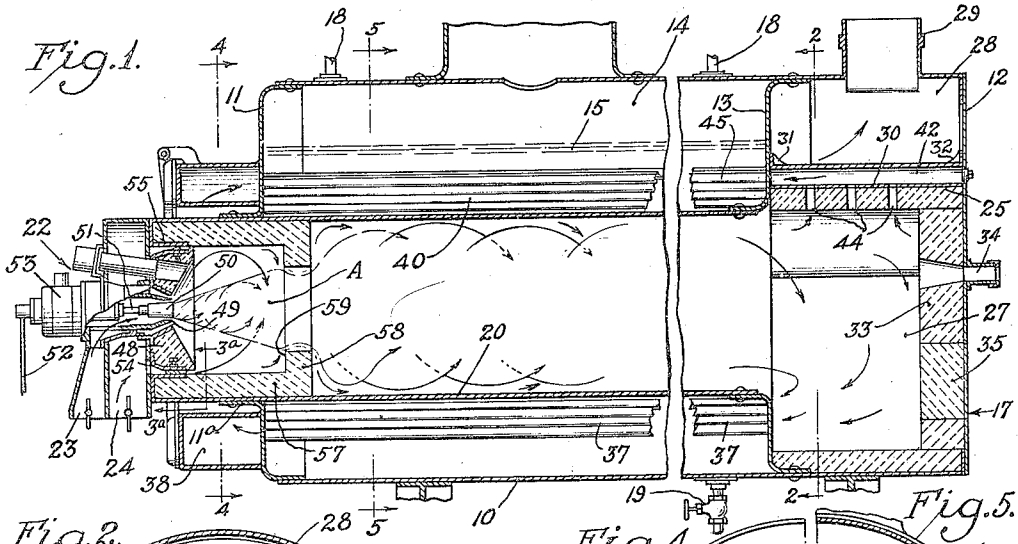


Fig. 2.

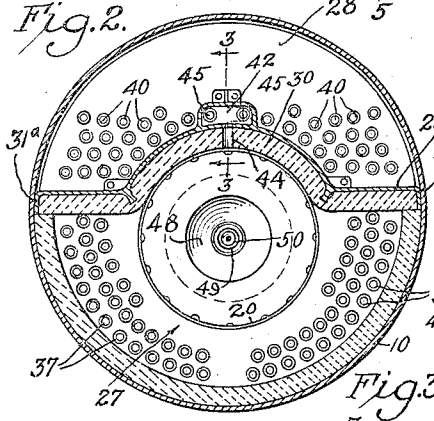


Fig. 3.

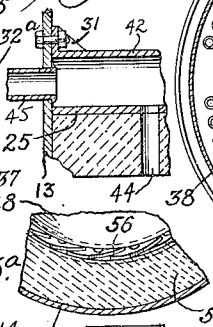


Fig. 3a.

Fig. 4.

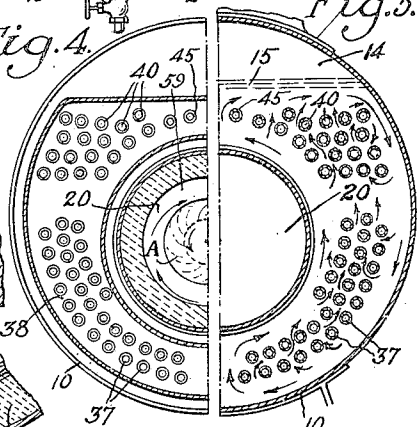


Fig. 5.

Fig. 6.

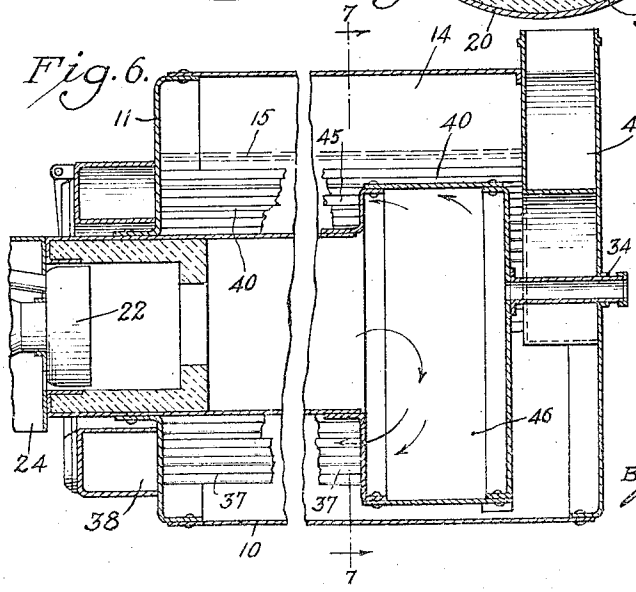
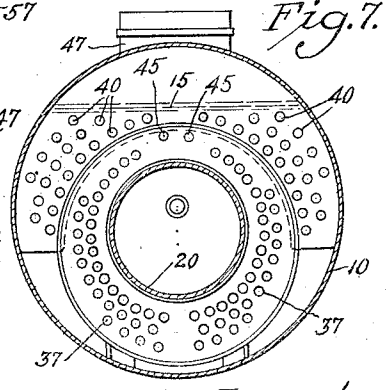


Fig. 7.



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STEAM PRODUCTION SYSTEM

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Application July 27, 1936, Serial No. 92,735

21 Claims. (Cl. 122—149)

This invention relates to steam production and more particularly concerns improvements in the operation and construction of marine type boilers in which the gases of combustion are passed in heat transferring relation through a body of water.

The general object of the invention is to improve the capacity and efficiency of boilers by effecting more efficient combustion and by extracting and efficiently transferring to the boiler water as nearly as possible all of the heat of combustion generated in operation.

A further object of the invention resides in the provision of a novel heat transfer flow system for the products of combustion, and the attainment thereby of more rapid circulation of the water, higher steam capacity and greater efficiency.

Another object is to provide an improved method and means for creating highly effectual forced draft combustion.

Another object of the invention is to provide an improved marine type boiler in which the hot combustion gases are directed through the body of water in an inverse heat transfer ratio, that is, the gases while hottest passing through the coolest part of the body of water, and the cooled but still useful gases then passing through the heated water, thus producing a uniform, thorough water circulation, and assuring maximum heat transfer thereto.

Stated more specifically, an object of the invention is to provide an improved marine type boiler, in which the hot gases of combustion are lead from the combustion chamber in maximum heated condition first through return tubes which are banked in the lowest region of the body of water to set up active boiling and attendant strong, swift currents sweeping the tubes and the combustion chamber, and in which the cooler gases are thereafter lead through tubes banked in the uppermost region of the water body where the residual heat therefrom will be most effective to aid in steam generation.

Another object is to provide novel means in a boiler of the foregoing general improved character for preventing the accumulation of combustible gases in the flow system thereof during periods of inactivity.

Other objects of the invention reside in the improved disposition of the combustion chamber near the water line to allow quick escape of generated steam, in the improved fireback construction, in the novel arrangement of the return tubes to attain high efficiency, in the improved relationships of parts whereby expansion and stress are substantially equalized, and in general to provide the improved construction and the novel combinations of parts for carrying out the foregoing and other objects and advantages of the invention.

In the drawing:

Figure 1 is a fragmentary longitudinal sectional view through a boiler assembly embodying the principles of the invention.

Fig. 2 is a transverse section substantially along the plane of line 2—2 of Fig. 1.

Fig. 3 is an enlarged fragmentary longitudinal sectional view taken substantially along the compound planes of line 3—3 of Fig. 2.

Fig. 3ª is an enlarged fragmental view substantially along line 3ª—3ª of Fig. 1.

Figs. 4 and 5 are fragmental transverse sectional views taken substantially along the planes of lines 4—4 and 5—5 respectively of Fig. 1.

Fig. 6 is a fragmentary longitudinal sectional view through a modified form of the invention.

Fig. 7 is a transverse section taken substantially along the plane of line 7—7 of Fig. 6.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawing and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

In the practical embodiment of the invention shown by way of example in the drawing, a preferably annular, elongated tubular enclosure or boiler casing 10 is closed at its front and rear ends by a head 11 and a rear wall 12, respectively. The casing is unequally partitioned by an intermediate wall 13 into a large conversion chamber 14 for a body of water 15 to be changed into steam, and a fire back generally indicated by the numeral 17. The level of the water body 15 may be maintained by replenishment through inlets 18, and drainage may be effected through a valve controlled outlet 19.

Passing through the conversion chamber 14 in heat transferring relation to the body of water 15 is a tubular furnace or primary combustion chamber 20 of substantially smaller diameter than the casing 10 and having its front and rear ends supported by and opening through the head 11 and the wall 13, respectively. Preferably the front end of the chamber casing 20 extends a short distance beyond the head wall 11 and is

riveted or otherwise secured to an exteriorly projecting axial flange 11a. Suitable forced draft oil, coal or gas fuel combustion means, herein shown by way of example as an improved blower type oil burner 22, may be associated with the front end of the combustion chamber to project burning fuel thereinto, air under pressure being delivered to the burner from any desired source as, for example, through ducts 23 and 24. A more complete description of the improved burner and its operation will appear further on.

The present invention contemplates an improved flow system wherein the hot products of combustion are lead through a plurality of successive heat transfer passes, herein three in number, in such a manner as to attain utmost steam production efficiency. To this end the primary chamber 20 which in operation is the most intensely heated pass in the flow system is disposed in substantially the central part of the body of water 15, spaced from the bottom of the casing 10 and close enough to the water line to permit free, quick escape of steam. From the primary chamber the hot products of combustion flow into the fire back 17, which is of improved construction including a horizontal wall 25 spanning the walls 12 and 13 from front to rear and transversely above the mouth of the primary chamber to produce a secondary combustion chamber 27 and a superposed flue chamber 28 which has a stack outlet 29 leading therefrom to atmosphere.

Preferably the wall 25 is constructed as a casting having a central arcuate portion 30 conforming generally to the contour of the upper part of the chamber 20. Lugs 31 and 32 may be provided on the casting for attaching the same to the intermediate and rear walls respectively, and side flanges 31a and 32a may serve for attachment to the casing 10. It will be observed that the upper wall of the secondary combustion chamber 27 is substantially coincident with the upper part of the primary combustion chamber while the lower part of the secondary chamber extends substantially below the lower part of the primary chamber. The interior of the secondary chamber may be equipped with a refractory lining 33 through which extends a sight port 34 opening through the rear wall 12. A cleanout door 35 may also be provided in the lower part of the secondary chamber.

The second pass in the flow system carries hot combustion gases into the lower region or bottom of the body of water 15, through a bank of return tubes 37 which lead to one or more return or mixing chambers 38 on the front wall 11.

Each of the tubes 37 is preferably of small flow area so as to attain greatest heat transfer efficiency per unit volume and the aggregate flow area of all the tubes is such that the gases will pass therethrough with predetermined resistance under the forced draft gas circulation. Referring to Figs. 2, 4 and 5, it will be seen that the bank of tubes 37 comprises two spaced groups disposed on either side of a vertical plane through the primary combustion chamber 20. Each group of tubes lies partially below and partially beside the primary combustion chamber in such relation that the convection currents produced by active boiling of the water passing in contact with the tubes will sweep inwardly and upwardly between the spaced tubes and past the primary chamber to assist in carrying generated steam to the water line. The complete, active water circulation thus established includes all portions of the water body, attaining high efficiency in steam formation and reducing the amount or deposit or scaling upon the parts of the boiler, the materials separated out of the water being deposited on the bottom of the boiler casing as a sludge that may easily be removed.

Upon reaching the return chamber 38, the gases of combustion are in a relatively cool state, but still possessed of useful heat. Within the chamber 38 the gases are mixed to prevent stratification and they flow upwardly into the third pass of the flow system consisting of a second bank of return tubes 40 which extend in heat transferring relation through the upper region of the body of water 15 and communicate with the flue chamber 28 at the rear of the boiler. This second bank of tubes is preferably divided into two groups disposed on either side of the vertical plane through the primary chamber and with the positions of the tubes in each group graduated to overlie the primary chamber only in small number so as to avoid interference with rapid escape of steam upwardly therefrom.

Part of the water sweeping upwardly through the tubes is converted into steam, and the steam bubbles traveling upwardly from below are broken up and disbursed so that the formation of foam at the water line will be avoided. Preferably, the aggregate flow area of the tubes 40 is reduced relative to the aggregate area of the lower bank of tubes 37 in a ratio proportionate to the shrinkage in the volume of gases resulting from loss of heat in traveling through the second pass, thus assuming uniform pressure flow resistance in the transit of the gases through the boiler.

In periods of inactivity, combustible gases may tend to accumulate in the gas flow system, as, for example, due to faulty valves or the like in the combustion producing mechanism. Means for venting such gases freely to atmosphere may therefore be provided, herein including an auxiliary chamber 42 forming part of the highest point of the arcuate portion 30 of the wall 25. Small ports 44 of relatively slight flow area extend upwardly from the secondary chamber 27 into communication with the auxiliary chamber 42. From the auxiliary chamber the gases pass toward the front of the boiler through means herein comprising a pair of tubes 45 and are delivered into the return chamber 38 from which they may pass through the return tubes 40 to the stack outlet 29. During operation of the boiler, such small quantities of hot gases as may pass upwardly into the auxiliary chamber are led in heat transferring relation twice through the body of water 15 so that substantially all of the heat therefrom will be utilized for useful work.

The construction thus far described has been of the type known as the dry back. The invention, however, is equally well adapted to the wet back type of construction an example of which is shown in the modified form of Figs. 6 and 7. The operation of the wet back boiler is similar to that hereinbefore described, but a secondary combustion chamber 46 which is entirely surrounded by water is substituted for the dry back. The secondary chamber is preferably annular in shape and eccentrically disposed downwardly relative to the primary chamber and the first bank of tubes 37 is arranged in two groups on opposite sides and below the primary chamber with the greatest concentration of tubes in the lowest part. In this construction, moreover, the return tubes 37 may be shorter than

the second or upper bank of tubes 40 and the latter will extend over and beyond the secondary chamber 46 to communicate with a flue chamber 47 constructed at the rear of the boiler casing. Gases which may accumulate during periods of inactivity are vented through the tubes 45 which communicate with the highest part of the secondary chamber.

The great heat transfer potential of the described gas flow system and the balanced, strain free arrangement of heated parts renders efficient, high capacity combustion necessary in a boiler unit of the present character. Unusually high heat to fuel ratio is developed herein by the improved method wherein fuel and primary air are projected in the form of an ignited whirling frusto-conical sheet toward the interior of the primary combustion chamber; and when the fuel has become heated a large volume of whirling secondary air is abruptly forced thereinto peripherally at the base of the cone, thus creating an intense burst of combustion which entirely consumes the fuel. For this purpose the burner mechanism 22 comprises a concave, refractory lined burner base 48 axially apertured to receive therethrough a primary air nozzle 49 which is in communication through the body of the burner with the dust 23 variably supplying high pressure, low volume primary air. Fitting in closely spaced relation within the orifice of the nozzle is a conically shaped spinner cup 50 to which a regulated supply of fuel oil is delivered from a suitable source in the usual manner through a hollow fixedly connected shaft 51 and a supply conduit 52.

The cup and shaft assembly are driven rotatably at high speed by a motor within a housing 53, and a thin film of oil is thrown at great velocity, radially from the lip of the spinner cup. This film is entrained in the high velocity primary air which issues from the nozzle about the fuel cup as a concentric jet rotating rapidly preferably in the same direction as the cup and produces a frusto-conical sheet A of intimately mixed fuel and primary air, the flare of the cone being governed by the resultant of the axial and radial forces of the united fluids. The fuel and air sheet is ignited and the heat generated vaporizes the atomized fuel.

Complete combustion producing an intense burst of flame within that part of the combustion chamber 20 which is surrounded by the body of water 15 is effected by abruptly directing a large volume of secondary air into the heated whirling fuel. Herein this result is attained while utilizing the secondary air to cool the forward or protruding end of the chamber 20 to prevent overheating and strain on the connection between the flange 11a and the furnace wall. To this end, a large volume, low pressure supply of secondary air is delivered from the duct 24 through an annular series of apertures 54 registering with the periphery of the burner base 48. The latter is of slightly smaller diameter than an axial flange 55 in the mouth of the chamber 20, and is maintained in fixed relation therein by a plurality of spacers 56 (Fig. 3a). These spacers are formed as vanes for imparting a rotary whirling motion to the secondary air concentrically along the inner surface of a refractory lining 57 extending a short distance into the chamber and serving as insulation for the outwardly, protruding portion thereof. At the inner end of the refractory is an inward transverse flange 58 providing a shoulder 59 which serves to divert the secondary air abruptly peripherally into the primary air-fuel mixture. The secondary air thus forms a cooling envelope moving along the refractory lining and surrounding in spaced relation the burning sheet-cone of primary air and fuel, and the preheated secondary air forced from all sides into the fuel air mixture will cause a great outburst of combustion which expands into the water surrounded portion of the combustion chamber 20. Preferably the secondary air stream is caused to rotate oppositely to the direction of rotation imparted by the fuel cup 50 but at less velocity so that while great turbulence will be created upon union of the primary air and fuel, the flame will appear as a white-hot inferno whirling in the direction of rotation of the cone A when viewed through the sight port 34. This whirling movement of the flame carries heat uniformly to the entire inner surface of the chamber 20.

From the foregoing it will be apparent that the present invention provides an improved steam production system in which steam may be raised more quickly and produced more efficiently than heretofore. The boiler construction causes active boiling and steaming to occur in the lower third of the water body as well as in the central and upper regions of the body so that strong, swift currents continuously sweep all parts of the heat transfer surfaces. Improved water circulation entirely avoids cold bottom and substantially prevents adherence of precipitates upon the heating surfaces. Exceptionally high fuel efficiency and increased steam capacity result from the improved combustion method employed.

Although the flow of the products of combustion is forced in a circuitous path downwardly contrary to the normal tendency of heated gases, no accumulation of combustible, explosive gases is permitted during periods of inactivity, thus rendering the improved boiler safe against leaky fuel valves or other causes of gas formation.

I claim as my invention:

1. A boiler construction comprising, in combination, an outer casing providing a steam conversion chamber, an inner casing defining a combustion chamber of smaller diameter than said conversion chamber passing therethrough in heat transferring relation to the water contained therein, and a bank of return tubes for the combustion gases from said combustion chamber passing through the lower region of the body of water principally below a horizontal median plane through said combustion chamber and in part below said combustion chamber, said bank of tubes being divided into two groups affording an unobstructed space in a vertical plane below said combustion chamber to permit upward circulation of water into contact with the latter chamber.

2. A marine type boiler construction comprising, in combination, an outer casing for a body of water to be converted into steam, an inner casing structure forming an elongated combustion chamber passing horizontally through said body of water in spaced relation to the bottom of said outer casing, forced draft combustion means operative in said chamber, and a plurality of horizontal pipes communicating with said chamber arranged in the majority below the horizontal median plane of said combustion chamber and in part underlying said chamber to convey the hot gases of combustion directly from said chamber in heat transferring relation through said body of water below the said cham-

ber to create convection water currents sweeping upwardly around said chamber to accelerate upward removal of steam therefrom.

3. In combination in a boiler including a casing for a body of water to be converted into steam and means defining a primary combustion chamber submerged in and extending from front to rear through the central part of the body of water, means at the front end of said chamber for effecting forced draft combustion therein, means providing a secondary combustion chamber communicating with the rear end of said primary chamber and extending in its lower part below the latter chamber, a bank of return tubes communicating with said lower part and extending in heat transferring relation through the lower region of said body of water to effect water circulation upwardly about said primary chamber, the uppermost of said tubes being substantially lower than the uppermost portion of said secondary chamber, means forming a return chamber near said front end of said primary chamber communicating with said bank of tubes for receiving the cooled gases therefrom, a second bank of tubes leading from the upper part of said return chamber toward the rear of said casing and passing through the upper region of the body of water to cause further heat transfer to the water, and means affording a restricted passage above said primary chamber from the upper part of said secondary chamber to said return chamber for venting combustible gases from said combustion chambers to prevent accumulation of these gases during periods of inactivity in the boiler.

4. A marine type boiler construction comprising, in combination, an enclosure for a body of water to be converted into steam, a tubular casing providing a horizontal combustion chamber within said enclosure with its axis at substantially the horizontal center of said body of water, and means for circulating the gases of combustion horizontally first through the lower region and thereafter through the upper region of said body of water, said means in that portion thereof above said casing being in spaced relation to leave a substantially unobstructed passage for steam from said casing to the water line to permit formation of strong transversely moving convection currents thereabout for carrying generated steam rapidly to the water line.

5. In combination in a marine type boiler construction of the character described, an enclosure for a body of water to be converted into steam, means defining a primary combustion chamber passing from front to rear through said enclosure in heat transferring relation to said body of water, means providing a secondary combustion chamber at the rear of said primary chamber and having a part extending downwardly in said enclosure, a plurality of return tubes communicating with said part for conveying the gases of combustion from said secondary chamber through the lower region of said body of water, the uppermost of said tubes being in a plane substantially below the top of said secondary chamber, means providing an auxiliary chamber above the top of said secondary chamber, the top of said secondary chamber having a plurality of small passages leading therefrom into said auxiliary chamber and of a flow area to permit the passage therethrough of only a small volume of gases, and means leading from said auxiliary chamber to atmosphere to vent gases which pass thereinto from said secondary chamber.

6. In combination in a marine type boiler, a casing for a body of water to be converted into steam, means providing a primary combustion chamber passing in heat transfer relation through said body of water, means defining a secondary combustion chamber at the rear of said primary chamber, means communicating with the lower part of said secondary chamber for conveying therefrom the gases of combustion through said body of water below a horizontal plane through the center of said primary chamber, and means for preventing accumulation of gases in said secondary chamber including a small auxiliary chamber and a restricted passage leading therefrom into the upper part of said secondary chamber through the top wall of the latter and communicating with atmosphere.

7. Apparatus for steam production comprising, in combination, an enclosure, a casing providing a combustion chamber at least partially within said enclosure, and combustion producing means at the mouth of said chamber having means for projecting a mixture of ignited fluid fuel and primary air toward the interior of said chamber, a secondary air nozzle arranged to project a whirling cooling layer of air along the wall of said chamber in enveloping relation to the primary air fuel mixture, means for delivering air to said secondary air nozzle under forced draft, and means spaced inwardly from the mouth of the chamber for diverting the secondary air layer into the ignited fuel and primary air mixture.

8. A steam boiler construction comprising, in combination, an enclosure means defining a combustion chamber within said enclosure, combustion producing means in the mouth of said chamber having means for projecting mixed ignited fluid fuel and high pressure low volume primary air toward the interior of said chamber, means for projecting low pressure high volume secondary air in the form of an envelope about the ignited fuel-air mass, and means within said chamber spaced from said mouth to divert said secondary air abruptly inwardly into the heated fuel-air mass to effect intense complete combustion.

9. A steam production system which includes the steps of effecting intense combustion within a combustion chamber disposed centrally of a body of water, and transporting the hot products of combustion in heat transfer relation through the body of water in a flow circuit passing first through the lowermost region of the body of water principally below the horizontal median plane of the chamber and thereafter through the upper region of the body of water substantially at opposite sides of the combustion chamber so as to utilize substantially all of the heat of combustion and to create strong currents sweeping inwardly and upwardly throughout said body of water without obstructing free and efficient escape of steam from the combustion chamber to the water level.

10. A marine type boiler construction comprising, in combination, an outer casing defining a conversion chamber, an inner tubular casing forming a combustion chamber extending in radial spaced relation through the interior of said conversion chamber, means providing a second chamber at the rear of and opening into said combustion chamber, said second chamber having a top wall projecting upwardly at the center,

means including a small auxiliary chamber mounted above the highest part of said top wall, said top wall having a plurality of ports in said highest part thereof communicating with said auxiliary chamber, a plurality of tubes extending forwardly from said second chamber through said conversion chamber in a plane substantially below said highest part of said top wall, means about the front end portion of said inner casing defining a return chamber for receiving the gases from said tubes, a tube passing forwardly above said combustion chamber for conveying gas from said auxiliary chamber to said return chamber, a plurality of tubes leading rearwardly from said return chamber through said conversion chamber, and a structure adjacent to said auxiliary chamber forming a stack chamber communicating with the rear ends of said last mentioned tubes.

11. In combination in a marine type boiler of the character described, means defining a conversion chamber, a tubular casing forming a combustion chamber extending horizontally through said conversion chamber, means at the front of said casing for effecting forced draft combustion, a box-like structure opening into the rear of said casing and defining a secondary chamber extending radially beyond the periphery of said casing, a bank of tubes for conveying the products of combustion downwardly through the lower region of water to be converted into steam, the uppermost of said bank of tubes being in a plane substantially below the inside top portion of said secondary chamber, and vent means communicating with said inside top portion of said secondary chamber to prevent accumulation of combustible gases during periods of inactivity in the boiler and being of such restricted outlet that the escape of the products of combustion therethrough during operation of the boiler will be negligible.

12. A marine type boiler construction comprising, in combination, a casing for holding a body of water to be converted into steam, an inner structure providing a tubular combustion chamber passing through substantially the center of said body of water and a fireback communicating with the rear end of said combustion chamber including a generally dome-shaped upper wall having its apex above the top of said combustion chamber and substantially on the vertical median line of the latter, the opposite side portions of said upper wall extending downwardly toward the opposite sides of said combustion chamber, means for circulating the gases of combustion from said chamber through said water including a plurality of spaced return tubes passing through the lower region of said body of water and communicating at their rear ends with said fireback below said side portions of said upper wall, said tubes being grouped in the majority below the horizontal center line of said combustion chamber and below the latter and being individually of small flow area permitting the passage of a predetermined flow of gases therethrough under a given pressure to afford maximum heat transfer efficiency per unit volume, a plurality of upper tubes communicating with the front ends of said first mentioned tubes for conveying said gases in heat transferring relation through the upper region of said body of water to utilize residual heat therefrom, said upper tubes being arranged in two groups located at opposite sides of the apex of said upper wall of said fireback to leave a substantially unobstructed space between the two groups for upward passage of circulating boiler water and steam from said combustion chamber and affording a flow area for the gases reduced substantially in proportion to the shrinkage of the gases in passing through the first mentioned tubes, and an exhaust chamber for receiving the spent gases of combustion from the rear ends of said upper tubes.

13. A marine type boiler construction comprising, in combination, a tubular furnace shell adapted to extend horizontally through a body of water to be converted into steam, a fireback chamber communicating with the rear end of said furnace shell and having a centrally raised upper wall provided with side portions extending below the top of said furnace shell, and means communicating with said fireback chamber for conveying the combustion gases from said fireback chamber through the body of water and including two groups of spaced parallel horizontal tubes located above said fireback chamber at respectively opposite sides of the apex of said raised upper wall portion, said groups of tubes being substantially spaced apart over said combustion chamber to permit unobstructed upward circulation thereby of water and steam from said combustion chamber.

14. A boiler construction of the character described comprising, in combination, an outer casing for a body of water to be converted into steam, a tubular furnace shell of substantially smaller diameter extending horizontally through said outer casing below the water level, a fireback communicating with the rear end of said furnace shell and having a dome-shaped upper wall having its apex above the top of said furnace shell and at its opposite sides extending below the top of said furnace shell, a plurality of first return tubes extending in planes below said dome-shaped upper wall from said fireback forwardly through the water space within said outer casing, a return chamber communicating with the forward ends of said tubes, a plurality of second return tubes extending rearwardly from said return chamber in two groups located in planes above said fireback at respectively opposite sides of the vertical median plane of the apex of said dome-shaped upper wall of said fireback, said groups of second return tubes being spaced apart to avoid obstructing upward circulation of boiler water and steam from said combustion chamber, and a tube communicating with the apex portion of said dome-shaped upper wall and extending forwardly above said combustion chamber in the space between said groups of second return tubes to convey from said fireback to said return chamber combustible gases which may enter said fireback during periods of inactivity in the boiler.

15. A marine type boiler construction comprising, in combination, an outer casing for containing a body of water to be converted into steam, an elongated tubular furnace shell of substantially smaller diameter than said outer casing extending axially in spaced relation through the latter, a plurality of return tubes adjacent to said furnace shell and in the majority below the horizontal median plane of the latter for conveying combustion gases therefrom through the boiler water, a circular fireback chamber of substantially smaller diameter than said outer casing but of larger diameter than said furnace shell communicating with the rear end of said furnace shell and with the rear ends of said tubes to receive the combustion gases from said furnace shell for delivery to said tubes, said circular

chamber being mounted to be completely immersed within the boiler water so as to permit heat abstracting circulation of the boiler water to sweep the circular exterior thereof, a return chamber for receiving the combustion gases from the front ends of said tubes, additional return tubes extending from said return chamber through the boiler water above said first-mentioned tubes for conveying the combustion gases from said return chamber rearwardly, and a flue chamber to receive the spent combustion gases from the rear ends of said additional tubes.

16. A boiler of the character described comprising, in combination, a generally horizontally disposed tubular conversion chamber, a tubular combustion chamber of smaller diameter extending in radially spaced relation into said conversion chamber, a fireback chamber opening rearwardly from said combustion chamber, a plurality of return tubes leading from said fireback chamber forwardly in the majority below a horizontal median plane through said combustion chamber, said tubes being divided into two groups lying at opposite sides of a vertical median plane through said combustion chamber to afford an upward water circulation passage from the bottom of said conversion chamber to said combustion chamber, and means communicating with the forward ends of said tubes to receive the combustion gases therefrom.

17. A boiler of the character described comprising, in combination, a generally horizontally disposed tubular conversion chamber, a tubular combustion chamber of smaller diameter extending in radially spaced relation into said conversion chamber, a fireback chamber opening rearwardly from said combustion chamber, a plurality of return tubes leading from said fireback chamber forwardly in the majority below a horizontal median plane through said combustion chamber, said tubes being divided into two groups lying at opposite sides of a vertical median plane through said combustion chamber to afford an upward water circulation passage from the bottom of said conversion chamber to said combustion chamber, a return chamber connected with the forward ends of said tubes, and an additional plurality of tubes communicating at their front ends with said return chamber and extending rearwardly above said first-mentioned tubes.

18. A boiler construction of the character described comprising, in combination, an enclosure for a body of water to be converted into steam, a tubular casing providing a horizontal combustion chamber within said enclosure with its axis at substantially the horizontal center of said body of water, and means for circulating the gases of combustion horizontally first through the lower region and thereafter through the upper region of said body of water, said means in that portion thereof below the casing being in spaced relation to leave a substantially unobstructed passage for upwardly sweeping water circulation about said casing and in that portion thereof above the casing being in spaced relation to leave a substantially unobstructed passage for steam from said casing to the water line, whereby to permit formation of strong transversely moving convection currents about the casing for carrying generated steam rapidly to the water line.

19. In a system of steam production the steps of projecting a whirling ignited mass of fuel and primary air toward the interior of a combustion chamber, heating a supply of secondary air by direct exposure for a substantial time to the heat of said ignited mass, and after the ignited mass has traveled for an interval sufficient to permit thorough heating of the fuel and has reached a point within the chamber spaced from the point of inception of the mass directing a large volume of the preheated secondary air turbulently from all sides into said ignited mass to effect complete combustion.

20. In a system of steam production the steps of forcing a whirling mass of ignited fuel and primary air toward the interior of a combustion chamber, enveloping said mass in an oppositely whirling spaced layer of secondary air traveling in the same axial direction as said mass, permitting said mass and secondary air to travel in substantially separated condition until both have become heated, and then abruptly uniting said mass and the secondary air to produce intense complete combustion.

21. A boiler construction including, in combination, an elongated tubular casing forming a combustion chamber, combustion producing means at one end of said chamber having rotary fuel impelling means and a primary air nozzle for projecting a cone-shaped sheet of ignited fluid fuel toward the interior of said chamber, a concentric secondary air nozzle about said combustion producing means, said secondary air nozzle being arranged to project a whirling layer of air interiorly along the wall of said chamber, and means within said chamber spaced from said one end traversing the path of said whirling layer of said secondary air to divert such secondary air layer abruptly inwardly equally from all directions into said cone-shaped sheet of ignited fuel to effect a burst of intense combustion.

CHARLES B. PAGE.