May 21, 1940. W. D. LA MONT 2,201,620

HIGH SPEED STEAM PRODUCING APPARATUS

Original Filed Nov. 13, 1933 3 Sheets-Sheet 1

Fig. 1.

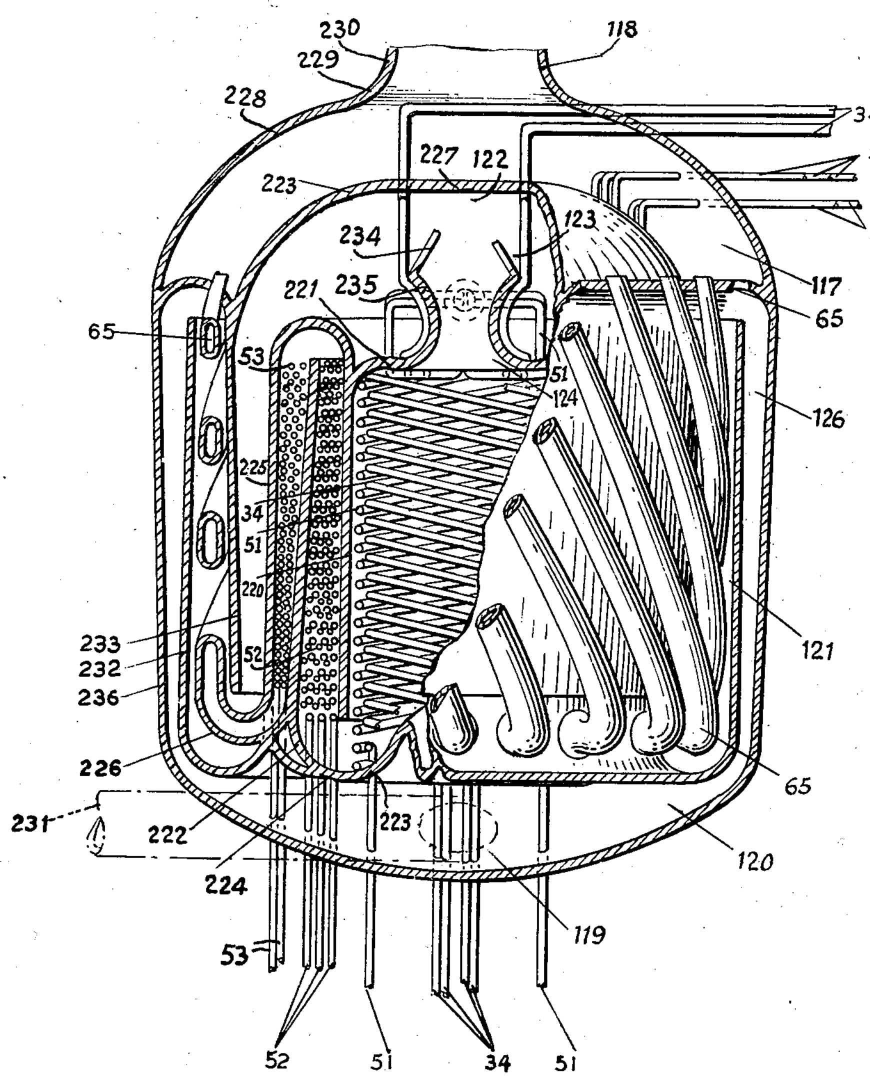
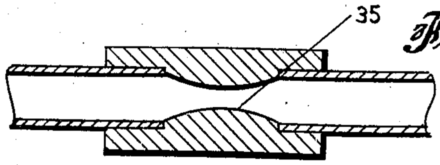



Fig. 8.

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HIGH SPEED STEAM PRODUCING APPARATUS

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Fig. 5.

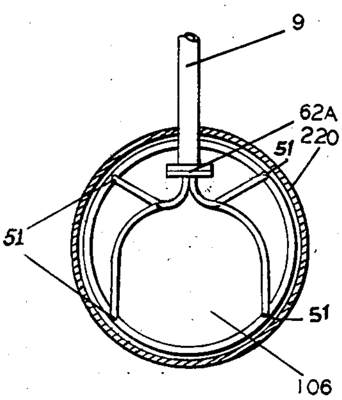


Fig. 4.

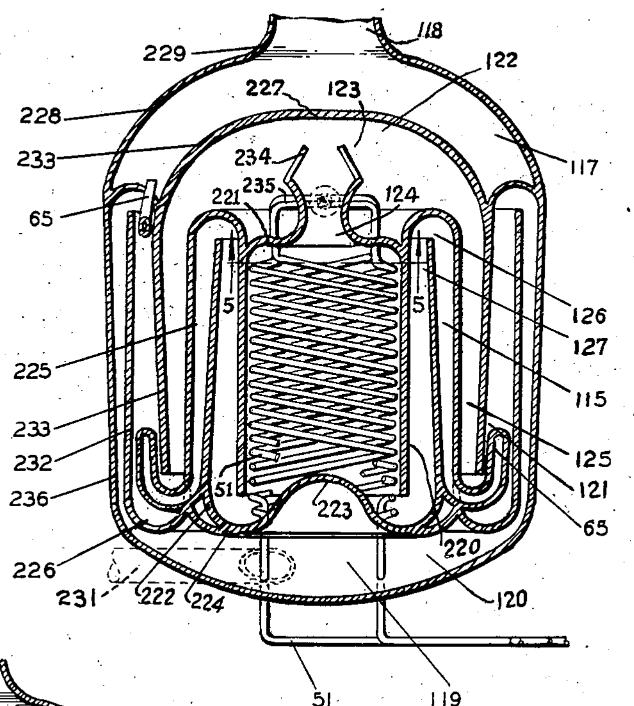


Fig. 2.

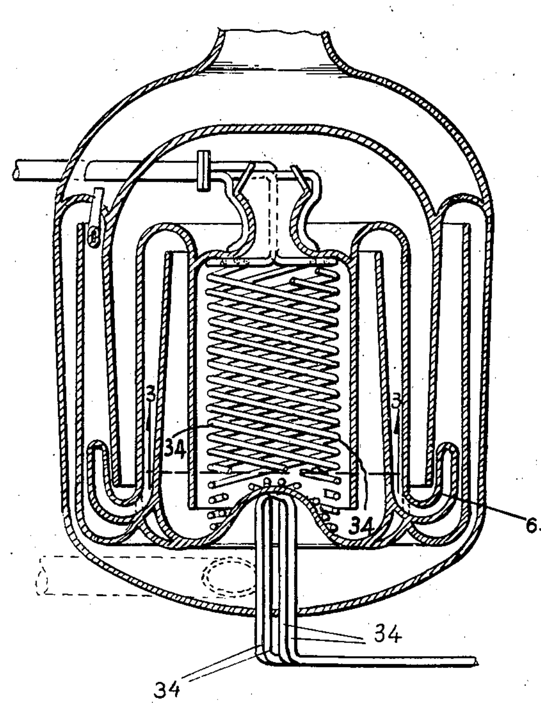


Fig. 3.

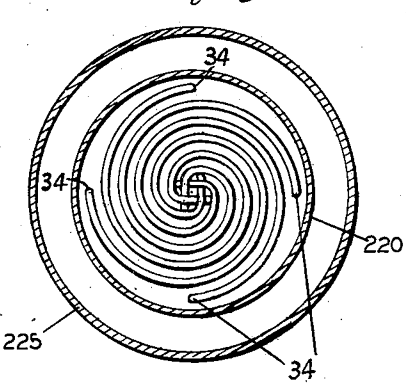


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Fig. 7.

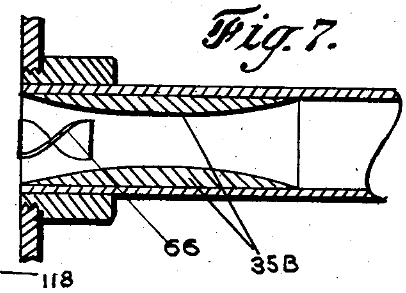
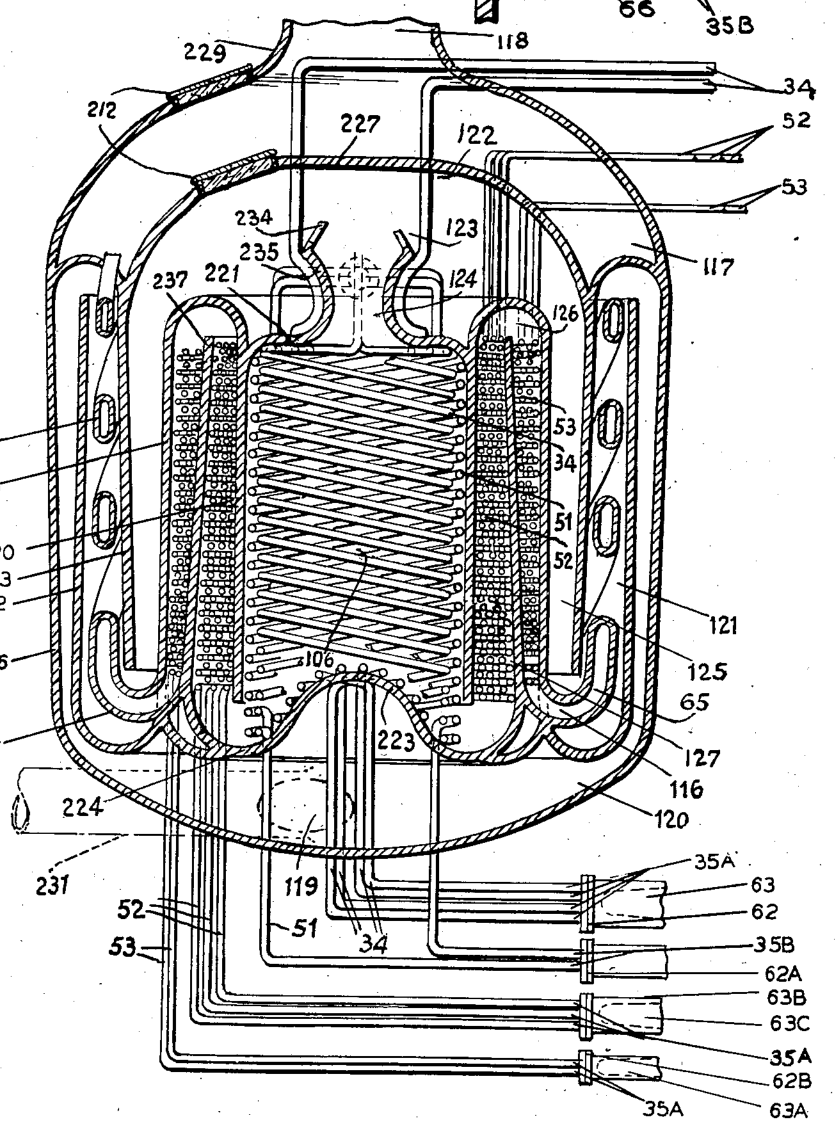



Fig. 6.

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Patented May 21, 1940 2,201,620

# UNITED STATES PATENT OFFICE

2,201,620

## HIGH SPEED STEAM PRODUCING APPARATUS

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Original application November 13, 1933, Serial No. 697,788. Divided and this application July 9, 1934, Serial No. 734,347

16 Claims. (Cl. 122—250)

This invention relates to a steam boiler adapted for high capacity outputs.

This application is a division of my application Serial No. 697,788, filed November 13, 1933.

A main object of my invention is to reduce the size, weight and cost of high speed steam generators and high speed steam power plants. I do this by increasing their speed of operation.

It is another obejct of the invention to provide a steam boiler capable of meeting high heat demands embodying a combustion chamber with auxiliary heating chambers and in which are disposed steam generating tubes, steam-superheater tubes, and water pre-heater tubes which mutually cooperate with each other to attain the desired outputs with safety and certainty.

It is another object of my invention to arrange a spirally coiled superheater tube behind a steam generating tube within a combustion chamber to obtain desired heat transfer effects to the former while protecting it against destructive temperatures.

It is a further object of my invention to form a coiled steam superheater wall from a plurality of tubes arranged to have equal lengths thereof exposed to uniform heats. A like arrangement may be used in the formation of the water-wall in the combustion chamber.

Other objects and purposes will appear from the more detailed description of the invention following hereinafter taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a detailed sectional view partially diagrammatic showing my high speed steam boiler with its various inter-related parts, properly assembled.

Fig. 2 is a sectional view of my high speed steam boiler showing my tubular waterwall elements in position protecting the side walls and the ends of the combustion chamber.

Fig. 3 is a view, partially in section and partially in elevation taken along the lines 3—3 in Fig. 2, of my high speed steam boiler, showing the bulbous end portion of my tubular waterwall in position at the outlet end of my steam boiler combustion chamber.

Fig. 4 is a sectional view of my high speed steam boiler showing my tubular superheater elements in position protecting the side walls and the ends of the combustion chamber.

Fig. 5 is a view taken along the line 5—5 in Fig. 4.

Fig. 6 is a sectional view of my high speed steam boiler.

Fig. 7 shows a preferred form of pressure drop device for the tube outlets.

Fig. 8 illustrates another form of pressure drop device.

With my supercharged combustion chamber and light weight construction, I have found it preferable to eliminate all insulation material in the combustion chamber, not only because of its weight, but also because of its low conductivity or inability to immediately transfer any received heat to an adjacent cooling medium. This leads to constantly increasing temperatures of the insulation material, bringing it to a high temperature, making it incandescent, and causing its final deterioration. Jars or shocks of the power unit received when in use for transportation purposes crack and tend to destroy such material. If the power unit has been operating for some time and the combustion is suddenly stopped, the insulation material will glow and remain hot for some time afterwards, representing an undesirable fire hazard in event of emergencies such as often occur with apparatus used for transportation purposes.

Supercharged combusion chambers produce high combustion gas pressures and insulation alone is not satisfactory to make and keep the combustion chamber wall gas tight.

As a result I use metal alloy mainly throughout the construction of my steam generator including the combustion chamber walls.

When using metal construction for this purpose it is necessary to properly and thoroughly protect the metal wall from exposure to too high heat effects from the radiant gases.

This can be accomplished by putting cooling and protecting tube surface of the steam generating apparatus in front of and in contact with the metal walls.

If the points of contact of the tube cooling surface to the combustion chamber walls are sufficiently close together and if there is a proper degree of shielding of the metal walls from radiant heat action, the alloy metal can withstand any designed rate of heat release.

Due to the high heat conductivity of the metal transferring heat received immediately to adjacent cooling tubes, it is not necessary to put a solid bank of tubes in front of and adjacent to it. The degree of spacing of the protecting and cooling surface depends on the designed heat load for which the steam generating apparatus is to be used.

If the tubes are placed unnecessarily close to each other the radiant heat will act on only a small part of the tube surface, giving lower heat transfer results per unit of surface used in the tubes. The tubes should be spaced as far apart as is practicable without allowing the metal walls to become overheated.

I have found that it is necessary to protect the ends of the combustion chamber metal walls as well as the sides.

In many cases of designing it is undesirable to cover the ends of the combustion chamber with separate tubes.

In many other cases, especially as the size of the unit increases, a single tube to cover both ends and the sides would be too long. Further as the size increases, the volume of steam in the waterwall tube increases and therefore the velocity makes it necessary to use large diameter tubes where single tubes of great length are used; otherwise the resulting very high velocity with the long, small diameter tube would give large and undesirable pressure drops. A large diameter tube greatly increases the weight per square foot of the heating surface. As a result it is generally of advantage to use multiple small diameter tubes of moderate length for the combustion chamber of my high speed and light weight steam generators, both for the superheater and waterwall, and it is also generally of advantage to have said tubes assist in covering the ends of the combustion chamber as well as the sides.

In my present invention I accomplish this purpose as follows:

In the superheater I use four small diameter, moderate length superheater tubes **51**. At the steam inlet end these four tubes are secured to the top of the water level cylinder wherein the generated steam is separated from the water. The four tubes then lead to the top of the combustion chamber metal casing covering or combustion chamber inlet end wall **221**, entering into the combustion chamber through the metal covering at four diametrically opposite points where they are spiralled on a circumference which will bring them into the combustion chamber **106**, tangent to the combustion chamber side walls **220**, as the spirals extend downwards on the diameter of said circumference.

If the four tubes entered the combustion chamber **106**, together or nearly together, and they were then wound in the form of a spiral they would leave a considerable part of the combustion chamber wall exposed at the top, beginning of the spiral when the first turn is complete and at the bottom of the combustion chamber when the last turn is completed.

By entering the four tubes at diametrically opposite points on the circumference, or at widely separated points on the circumference the rise of each spiral as each tube passes above the tube starting a spiral just ahead of it, is gradual and the section of combustion chamber wall left exposed is small, especially if the tube passing above the tube ahead of it is brought tangent or nearly tangent, to the tube ahead of it before the spacing of the spirals between the two tubes is started. This brings the maximum width of the space of the combustion chamber wall not covered by a tube down to the width of the tubes diameter used.

When the four spiralled superheater tubes reach the bottom of the combustion chamber they pass through the bottom casing or combustion chamber outlet end wall **222** at four diametrically opposite points in a manner similar to that described for the top, so that all parts of the combustion chamber casing are properly protected.

The four tubes are then led to a common point where they are secured in a compact manner to a disc **62A**, with ends parallel to each other and arranged to discharge directly into the steam lead to the turbine. At this point, each tube has a properly adjusted pressure drop device in its outlet end.

Saturated steam enters the tubes from the top of the water level cylinder and superheated steam leaves the tubes at the bottom of the boiler into the main steam line **9**.

I have found that with supercharged high speed generators, with high speed turbines for light weight and small size efficient power units, that it is necessary to produce high pressures and high final temperatures of unusual degree from the steam generator to permit using light weight, small and efficient turbines.

The requirement for a very high final steam temperature from the steam generator, makes it difficult to produce a superheater of light weight with a minimum of surface and a maximum of heat transfer rate without overheating the metal of the superheater tubing.

With supercharged combustion the initial temperature in the combustion chamber is considerably higher than in present day practice and any superheating surface placed in such a combustion chamber must have protection from the full and direct effect of the radiant heat action in said combustion chamber.

To keep the amount of surface used in the superheater to a minimum, it is desirable to expose as much as possible of the superheating surface to radiant heat action, especially when, as in this invention, the final steam temperatures are very high.

I have found that by placing the superheater behind the waterwall tubes and by spacing the waterwall tubes apart so that the superheater receives radiant heat action from between the waterwall tubes, the amount of radiant heat exposure which the superheater tubing can safely withstand, is a matter of the rate of heat release in the combustion chamber and by separating or bringing together the waterwall tube spacing and the superheater tube spacing (the latter spacing preferably to correspond with the change in waterwall tube spacing), the superheater can be made to receive radiant heat action on all of its surface or to receive the radiant heat action on only part of its surface, the remainder being shielded by the waterwall tubes from the direct rays of radiant heat.

This brings the problem of the use of the superheater surface in the combustion chamber zone to a point where the spacing of the waterwall tubes and superheater tubes is arranged in each design of unit to meet the maximum heat load conditions to be imposed on said unit.

As a result in some designs radiant superheating surface is fully exposed to radiant heat action from between the fully spaced waterwall tubes in the combustion zone and in others, that which I term semi-radiant superheating surface is used where the superheating surface is only partially exposed to radiant heat action from between closely spaced waterwall tubes spaced apart less than the diameter of the superheater tubes.

By the term semi-radiant superheating surface, is meant superheating surface part of which is exposed to radiant heat action and part of which is shielded from radiant heat action, by other cooling surface than that of the superheater.

I have also found that as the steam in the superheater approaches its high final temperature, that the metal of the tube has a tendency to overheat from direct radiant heat action.

To avoid this, I place the superheating surface, which has steam of high temperature in it, near to that of the desired final steam temperature; practically entirely behind the waterwall tubes, so that said portion of the superheating surface is practically entirely shielded by the waterwall tubes and said portion of the superheating surface, still in the combustion chamber space receives practically no heat transfer action except by convection. This makes possible a superheater in the combustion zone which may have full radiant action on a portion of its surface, semi-radiant action on another portion and convection action on still another portion.

In some designs of this new type of combustion chamber superheater, I arrange the initial part of the surface with the steam of low temperature therein to receive full radiant heat action from between and behind the waterwall tubes properly spaced apart to at least, one full diameter of the superheater tube. To accomplish this purpose, I arrange the central portion of the surface with the superheater steam of medium temperature therein, to receive semi-radiant heat action from between the waterwall tubes properly spaced apart to less than the full diameter of the superheater tube to accomplish this purpose, and I arrange the last portion of the surface with the superheated steam of high temperature therein, to receive practically no heat except by convection heat transfer, by placing the superheater tubes directly behind the waterwall tubes.

In my co-pending application 693,714, of October 16, 1933, I have discussed more fully my various types of combustion chamber superheaters and means for moving my superheater and waterwall surfaces to control the final temperature of the steam from my steam generators. It is within the scope of this invention to use the art for my superheaters as disclosed in my copending application 693,714 of October 16, 1933, selecting that type and use best suited for each design of my steam generator as applied to this present invention but it is not intended to limit the scope of this invention to any particular form or use of a superheater.

I have found that with supercharged combustion and high rates of heat transfer with high velocities of steam flow, the column of steam in the superheater tubes, should be kept compact and the flow of steam in each superheater tube regulated to protect and insure proper operation of each superheater tube.

In the embodiment of the present invention, I preferably accomplish this purpose by using a pressure drop device at or near the inlet to each one of my superheater tubes and adjust its size with reference to the amount of steam flow desired for each tube, to distribute the flow of steam in each tube in the required quantity for various heat loads, also I add a pressure drop device to the outlet of each superheater tube and adjust its size with reference to the degree of compactness desired for the steam column in each tube for proper operation of that tube at various heat loads. However, it is within the scope of this invention to use pressure drop devices and locate same in my superheater tubes as disclosed in my co-pending applications.

It is not intended to limit the scope of this invention to any particular form or use of pressure drop devices if any pressure drop devices are used in my superheater tubes.

In the embodiment of my present invention I place pressure drop devices at the outlet of each superheater tube adjusted to provide proper flow of steam in each tube to protect the tube and insure its proper operation.

The waterwall tubing is spiralled in a manner similar to the superheater tubing except the spirals are arranged to cover the bottom and top ends of the combustion chamber as well as assisting in protecting the side walls and superheater tubing. The main diameter of the waterwall spiral tubes is arranged so that the waterwall spiral coil as a whole fits inside of the superheater coil and just clears the superheater spiral coil making it possible to separate and replace or repair either coil.

The waterwall tubing is made up of four small diameter tubes **34**, of moderate length. The ends of the four tubes are arranged parallel to each other in a compact group secured into a disc **62**, which in turn is secured directly into the discharge lead, from the steam generator circulating pump at the bottom of the steam generator so that the circulating water discharges directly into each tube. A cone distributor **63**, with its apex pointed toward the oncoming circulating water is placed in front of said disc **62**, with holes leading to each tube.

If the generator is to be exposed to extreme heat loads a pressure drop device is not placed in the inlet end of each tube.

If the generator is not to be exposed to extreme heat loads a pressure drop device **35A**, is added to the inlet end of each tube for certain designs.

The four tubes **34**, lead from the discharge end of the circulating pump to four diametrically opposite points at the bottom of the combustion chamber where they enter the bottom casing **222** and spiral around in a manner similar to that described for the superheater tubing **51**, the waterwall spirals at first being adjacent to and protecting the bottom casing **222**, then travelling up along the sides of the combustion chamber, not adjacent to the casing **220**, but on an inside diameter which fits the spiral coil inside of the superheater coil **51**. This diameter is held by the waterwall tubes **34**, until they reach and become adjacent to the top casing **221**. They now spiral inwards following the curve at the top casing **221** and being adjacent thereto until they reach the central portion at the burner end where each spiral tube turns up through the top casing **221** at diametrically opposite points, through stuffingboxes and then lead to the water level cylinder.

The spiral coils of the waterwall tubing **34**, are so spaced relative to the spacing of the superheater coils **51**, that the superheater coils receive radiant and/or semiradiant and convection heat as previously described for the superheater in this invention.

Each waterwall tube **34**, at its outlet end has a pressure drop device **35B**, adjusted in it of proper size, relative to the quantity of water circulated in it, and relative to the heat load imposed on it.

In addition, just beyond the pressure drop device **35B**, which in itself is a separator of steam and water, and helps to break up steam bubbles; there is placed a mechanical separating device, to assist in the separation of the steam and water output from said tube only.

The saturated steam enters the superheater 51, as described, and the excess water from the various points of separation of steam and water, if there is any excess water over that evaporated in the waterwall tubes 34, falls to the water level in the water level cylinder, and is again picked up with water from the fluid heater for forced circulation into the waterwall tubes 34.

I streamline many of my fluid passageways throughout the boiler structure, especially at the turns and at changes in direction of the flow of gases, high velocity of gas flow can be maintained throughout the system with small draft loss at these points leaving the main draft loss available for high speed travel over the heating surfaces where such loss is more than repaid by the increased heat transfer rates obtained.

In streamlining the steam generator, I use a smooth turn where the combustion chamber inlet end casing 221, meets the waterwall casing 220, to guide any gas flowing radially from the burner to the sides to turn said gases smoothly toward the outlet end of the combustion chamber.

At the outlet end of the combustion chamber, I use a circular bulbous nose 223, projecting toward the interior of the combustion chamber at the central portion of the bottom casing to spread and guide the high velocity gases toward the outer circumference of the combustion chamber at this point; and where the gases are to be guided into the entrance of the convection heating surface.

The bulbous central portion 223, in the casing 222, is followed by a portion depressed 224, relative to the interior of the combustion chamber and this portion in turn is followed by a smooth curved turning 224, of the casing 222, leading to the convection gas passage wall 237, so that radially from the central portion of the top casing to the circumference, the said casing 222, is first bulbous, then depressed, then curved, relative to the interior of the combustion chamber, to guide the gases in a smooth streamlined flow from the center of the combustion chamber 106, to the entrance to the convection heating surface 52, including the turn into the convection heating passage 127, made from the combustion chamber.

The convection heating passage 127, is tapered from the top of the steam generator toward the bottom, to obtain the proper high velocity for the heated gas as it changes in volume and density during the cooling of the gas by the convection generator tubing 52, as the heated gas flows from the bottom of the combustion chamber spirally upward toward the top of the tapered convection gas passage 127.

The top of the tapered convection gas passage 127, is curved making a circular burnt gas passage 126, connecting the convection steam generator tapered passage 127, with the inlet end of the fluid heater tapered passage 115, the curve of circular gas passage 126, being streamlined to guide the gases smoothly into the fluid heater passage 115.

At the bottom of the convection gas passage 115, a row of small diameter air preheater tubes 65, are used, secured into the vertical outside casing 225, of the convection gas passage, with a close spacing of their openings. The outside casing 237 of the convection gas passage is streamlined, curving to guide the high velocity gases into the openings of the air preheater tubes 65.

The air preheater tubes 65, are also curved at the bottom ends, to guide the gases entering them, upward to their outlet.

Each of the air preheater tubes 65, is tapered so that the proper gas velocity inside of them is obtained to meet the changing volume and density of the gas therein as it is cooled by the air travelling in the opposite direction at high velocity on the outside surface of said tubes 65.

The tapered air preheater tubes 65, leave the bottom of the outer convection gas, fluid heater tapered passage, outer casing 225, at an angle to the vertical and spiral upwards close to said casing in a smooth spiral to guide the gases upward and the air downward.

At the bottom of the fluid heater circular passage 116, and outlet to the air preheater tubes, the air preheater tubes 65, conveying the burnt gases are streamlined outward in a smooth curve to guide the gases into the stack gas passage. The stack gas passage outer casing 228, is streamlined with a smooth curve at the point where the gases from the air preheater tubes 65, enter said passage and said casing curves upward toward the stack. The inner and outer stack gas passage casings 227 and 228, forming two dome shaped pieces with the stack gases guided smoothly in its flow between them up to the stack opening 118, the two dome shaped pieces forming an expanding gas passage so as to decrease rather than to increase the velocity of the gases, no longer needed, as they travel toward the central portion of the domes to turn up into the stack.

The stack opening 118, is in turn curved at 229 where it meets the central part of the dome forming the stack gas casing 228, guiding the gases smoothly from this point to the atmosphere.

The stack 230, is Venturi shaped as it leads to the atmosphere.

The air used for combustion enters the outside casing 236, of the circular air passage 120, tangentially of said passage at a central part.

This gives the air a centrifugal or whirling motion in the circular air passage 120, leading to the air preheater tapered spiral air passages 121.

The whirling air now enters between the spiral air preheater tubes 65, and the outer casing of the tapered convection gas fluid heater passage 115, and the air preheater tapered air passage outer casing 232.

The outer casing 232, of the air preheater, and the outer casing 225, of the fluid heater convection gas passage, form the air passage 121, for the air preheater in which are placed the closely spaced spiral row of tapered air preheater tubes 65.

The curved portion of the bottom casing 222, of the combustion chamber, and convection gas passage 116 with the dome shaped outer casing 236, of the circular air passage and outer casing 232 of air passages 121 form a tapered smooth curved passage 120, for the air guiding it and increasing its velocity as it whirls and begins entering the air preheater passage 121, between the spiral air preheater tubes 65.

The tapered ends of the air preheater tubes 65, also assist to permit the air to enter between them with a minimum of draft loss.

The air travelling in the air preheater passage 121, between the spiral air preheater tubes 65, is given a further whirling motion as it passes in a combination of spiral and cross flow motion past and between the tubes 65, downward in to the circular air chamber 125, and then upward to circular air inlet to burner entrance 122.

The tangential lead 231, from the supercharger fan to the dome like outer casing 236, of the circular air passage 120, is placed on that side of the dome casing 236, which will give the air a whirling motion in the same direction as the whirling motion imparted to the air by the spiral air preheater tubes 65.

The casings of the air preheater air passages 121, form a tapered passage so arranged, that the proper velocity of the air is obtained as it passes between the tapered air preheater tubes 65, in counterflow to the gases therein, proper allowance being made for the change in volume and density of the air as it is heated and the tapering of the air preheater tubes 65, and the decreased amount of surface present in each tapered tube 65, toward the outlet end compared to the inlet end per unit of length of each tube 65.

Heated air leaves the air preheater passage 121, with a whirling motion and is guided by the streamlined burner housing 233, in a smooth curve into the curved guide vanes for air entering the burner 2.

The spiralled air preheater tubes 65, have the direction of their spiral arranged so that the whirling air travelling therefrom, to the curved guide vanes of the burner, will continue to whirl in the same direction as it enters and is directed by said vanes into the burner.

The spiralled superheater tubes 51, and waterwall tubes 34, have the direction of their spirals arranged so that air whirling from the burner 2, will continue to whirl in the same direction with the gas formed as the gases travel up the combustion chamber 106, among the spiralled waterwall tubes 34, and superheater tubes 51, to the combustion chamber outlet end wall 222.

The spiralled convection steam generator tubes 52, in the convection gas passage 127, have the direction of their spirals opposite to that of the waterwall tubing 34, and the superheater tubing 51, arranged so that when the combustion gases reach the combustion chamber outlet end wall 222, and turn upward travelling in a combination of cross flow and spiral flow among the spiralled convection steam tubes 52, the gases will continue to whirl in the same direction as they whirled in the combustion chamber 106. Spiralled fluid heater tubes 53, in the tapered fluid heater passage 115, have the direction of their spirals arranged opposite to that of the convection steam generator tubes 52, so that the gases will continue to whirl in the same direction as they whirled in the convection steam generator tapered passage 127, the combustion chamber 106, the burner guide vanes of burner, the air preheater air passages 121 leading from the tangential air inlet passage 119.

I have found that with supercharged combustion initial temperature in the combustion zone can be attained of such degree that a large part of all of the steam generation required for the steam generating apparatus can be obtained from the water wall surface and by using my new type of properly protected superheating surface in said combustion chamber as previously described practically all of the superheat required can be obtained from said surface.

As a result by using my new type of fluid heater described herein, practically all of the heat of the convection gases can be utilized by said fluid heater down to the point where the remaining heat to be absorbed of said gases by the steam generating apparatus is removed by the air preheater.

This results in a new type of steam generating apparatus using waterwall steam generating surface and superheating surface mainly in the combustion chamber, fluid heating surface in the convection gas passage, the final heat of the gases being removed by air preheater heating surface.

This arrangement gives full advantage of the maximum heat heads available relative to the gases and fluids always in counterflow.

The air used for mixture with the fuel for combustion enters through line 119, which enters the circular air entrance dome passage 120, tangentially, giving the entering air a whirling motion in said passage.

Air from the circular air entrance dome passage still whirling, enters through and into the stream lined air passages 121, of the tapered spiral cross flow air preheater. The air, as it is forced at high velocity into said air preheater air passage 121, past the spiral tapered air preheater burnt gas tubes 65, meets with more resistance to cross flow than to spiral flow along the tapered spiral coiled air preheater burnt gas tubes 65, which result in a combination of spiral flow and cross flow of the air in its air passages 121, giving spiral cross flow of the air along the heat transfer surfaces. The spiral tubes 65, of the air preheater are wound around the circular tapered fluid heater outer casing 225, so that the air continues to have the same whirling motion in the air preheater air passages as it had when leaving the circular entrance dome chamber.

Air leaving the tapered spiral cross flow air preheater air passages 121, still whirling in the original direction, enters the circular air inlet passage 125, and then the circular air inlet burner chamber 122, to the burner guide vanes at the burner entrance 123.

The burner guide vanes augment the whirling of the air, leaving the circular air inlet chamber 122, without change of direction of the whirl, guiding the air into the burner throat passage 124, and on into the combustion chamber 106, where it mixes with the atomized fuel oil from the burner to form the combustion gases.

The combustion gases formed in the combustion chamber 106, from the mixed and ignited oil and air, are driven at high velocity throughout the burnt gas passages of the steam generator 1 by the oncoming air.

The main part of the combustion gases in the combustion chamber 106, striking the bulbous central position of the combustion chamber outlet end wall 223, are dispersed toward the depressed and curved turn 224, of the combustion chamber outlet end wall 222, near the circumference and thereby guided smoothly into the combustion chamber circular burnt gas passage 114, and then into the convection generating spiral tapered burnt gas passage 127. As the combustion gases pass down the sides of the spiral coiled waterwall tubes 34, and superheater tubes 51, in the combustion chamber 106, these tubes tend to whirl in the same direction it had when leaving the throat 124, and this air with the combustion gases, continues to whirl as it enters the convection generating spiral tapered burnt gas passage 127.

Since the spiralled convection generating coils 52, in the spiral tapered convection generating passage 127, are coiled in the opposite direction to the waterwall coiled tubes 34, and superheater coiled tubes 51, in the combustion chamber 106, the combustion gases continue to whirl in the same direction they had when leaing the combustion chamber, as they travel through the convection generating passage 127, the circular outlet convection generating passage 126, and into the spiral tapered fluid heater passage 115. Water is introduced into the coils 52 by hollow cone distributor $63^B$.

Since the fluid heater tubes 53 are coiled in the opposite direction to the convection steam generating tubes 52, the gases continue to whirl in the same direction while passing through the fluid heater tapered spiral cross flow passage 115, as they whirled when passing through the convection steam generating gas passage 127. Water is introduced into the tubes 53 by hollow cone distributor $63^A$ adjacent the disk $62^B$ to which these tubes are connected.

The combustion gases travelling through the spiral tapered fluid heater passage 115, at high velocity, strike the coiled fluid heater tubes 53, meeting with more resistance to cross flow than spiral flow and resulting in a combination of spiral flow along the fluid heater tubes 53, and cross flow across them, giving spiral cross flow of the gases on the heat transfer surfaces.

The combustion gases leaving the spiral cross flow tapered fluid heater passage 115, are guided by the streamlined entrance into the spiral tapered air preheater burnt gas tubes 65, travelling in counterflow to the air on the other side of said tubes 65, in the air preheater air passages 121, to the stack gas passages 117.

The gases leaving the stack gas passages 117, enter the streamlined entrance 118, into stack and leave the Venturi shaped stack exit to the atmosphere. Doors 212 in the boiler casings permit the inspection of the boiler chambers and the ignition of the boiler to be instituted.

I claim:

1. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube forming a water wall within said combustion chamber on the inside of said combustion chamber wall, and a plurality of steam superheater tubes forming a superheated steam conducting wall between the combustion chamber wall and said water wall, said steam superheater tubes entering and leaving said combustion chamber at substantially equidistantly displaced points.

2. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube forming a water wall within said combustion chamber on the inside of said combustion chamber wall, and a plurality of spirally coiled steam superheater tubes forming a superheated steam conducting wall between the combustion chamber wall and said water wall, said plurality of spirally coiled steam superheater tubes entering and leaving said combustion chamber at substantially equidistantly displaced points.

3. In a steam generator, a wall defining a combustion chamber, a plurality of spirally coiled steam generating tubes forming a water wall within said combustion chamber on the inside of said combustion chamber wall, and a plurality of spirally coiled steam superheater tubes forming a superheated steam conducting wall between the combustion chamber wall and said water wall, said plurality of spirally coiled steam superheater tubes entering and leaving said combustion chamber at substantially equidistantly displaced points.

4. In a steam generator, a wall defining a combustion chamber, a plurality of spirally coiled steam generating tubes forming a water wall within said combustion chamber on the inside of said combustion chamber wall, and a plurality of spirally coiled steam superheater tubes forming a superheated steam conducting wall between the combustion chamber wall and said water wall, said plurality of spirally coiled steam generating tubes and said plurality of spirally coiled steam superheater tubes entering and leaving said combustion chamber at substantially equidistantly displaced points.

5. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube forming a water wall within said combustion chamber on the inside of said combustion chamber wall, and a plurality of steam superheater tubes forming a superheated steam conducting wall between the combustion chamber wall and said water wall, said steam superheater tubes entering and leaving said combustion chamber at substantially equidistantly displaced points, and a spirally coiled tube in fluid circuit with said steam generating tube and said steam superheater tube arranged in a passage on the outside of said combustion chamber wall and exposed to combustion gases passing from said chamber.

6. The combination set forth in claim 1, wherein said wall defining the combustion chamber is substantially cylindrical.

7. The combination set forth in claim 4, wherein the wall defining the combustion chamber is substantially cylindrical and the spirally coiled steam generating tubes and the spirally coiled steam superheater tubes enter and leave the combustion chamber at diametrically opposed points.

8. The combination set forth in claim 1, wherein said plurality of steam superheater tubes are provided with pressure drop devices.

9. The combination set forth in claim 3, wherein said plurality of steam generating tubes and said steam superheater tubes are provided with pressure drop devices.

10. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube within said combustion chamber displaced from the inside of said wall, and a spirally coiled steam superheater tube between said wall and said steam generating tube having at least some of the coils thereof staggered with respect to the coils of said steam generating tube, whereby said first mentioned coils of said superheater tube are exposed to the radiant heat in said combustion chamber passing between the coils of said steam generator tube.

11. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube within said combustion chamber displaced from the inside of said wall, and a spirally coiled steam superheater tube between said wall and said steam generating tube having at least some of the coils thereof partially offset with respect to the coils of said steam generating tube, whereby said first mentioned coils of said superheater tube are exposed partially to the radiant heat in said combustion chamber passing between the coils of said steam generator tube.

12. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube within said combustion chamber displaced from the inside of said wall, and a spirally coiled steam superheater tube between said wall and said steam generating tube having some of the coils thereof staggered alternately with re-

spect to the coils of said steam generating tube, whereby said first mentioned coils of said superheater tube are exposed to the radiant heat in said combustion chamber passing between the coils of said steam generating tube, others of the coils thereof being partially offset with respect to the coils of said steam generating tube, whereby said last mentioned superheater coils are exposed partially to the radiant heat in said combustion chamber passing between said steam generating coils, and others of the coils thereof are in alignment with respect to the steam generating coils, whereby these superheater coils are exposed to convection heat.

13. The combination set forth in claim 12 wherein the first group of superheater coils exposed to radiant heat is disposed near the burner end of the combustion chamber, the last group of superheater coils exposed to convection heat is disposed at the opposite end of the combustion chamber, and the second group of superheater coils exposed partially to the radiant heat is disposed between the other two groups of coils.

14. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube within said combustion chamber displaced from the inside of said wall, and a spirally coiled steam superheater tube between said wall and said steam generating tube having some of the coils thereof staggered with respect to the coils of said steam generating tube, whereby said first mentioned coils of said superheater tube are exposed to the radiant heat in said combustion chamber passing between the coils of said steam generator tube, and others of the coils thereof being partially offset with respect to the coils of said steam generating tube whereby said last mentioned superheater coils are exposed partially to the radiant heat in said combustion chamber passing between said steam generating coils.

15. In a steam generator, a wall defining a combustion chamber, a spirally coiled steam generating tube within said combustion chamber displaced from the inside of said wall, and a spirally coiled steam superheater tube between said wall and said steam generating tube having some of the coils thereof staggered with respect to the coils of said steam generating tube, whereby said first mentioned coils of said superheater tube are exposed to the radiant heat in said combustion chamber passing between the coils of said steam generator tube, and others of the coils thereof are in alignment with respect to the steam generating coils, whereby these last mentioned superheater coils are exposed to convection heat.

16. In a steam generator, a wall defining the combustion chamber, a spirally coiled steam generating tube within said combustion chamber displaced from the inside of said wall, and a spirally coiled steam superheater tube between said wall and said steam generating tube having some of the coils thereof partially offset with respect to the coils of said steam generating tube, whereby said first mentioned coils are exposed partially to the radiant heat in said combustion chamber passing between the coils of said steam generator tubes, and others of the coils thereof are in alignment with respect to the steam generating coils, whereby these last mentioned superheater coils are exposed to convection heat.

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