Feb. 27, 1934. W. G. NOACK 1,948,535

HEATING SYSTEM

Original Filed March 1, 1929 2 Sheets-Sheet 1

Fig. 1.

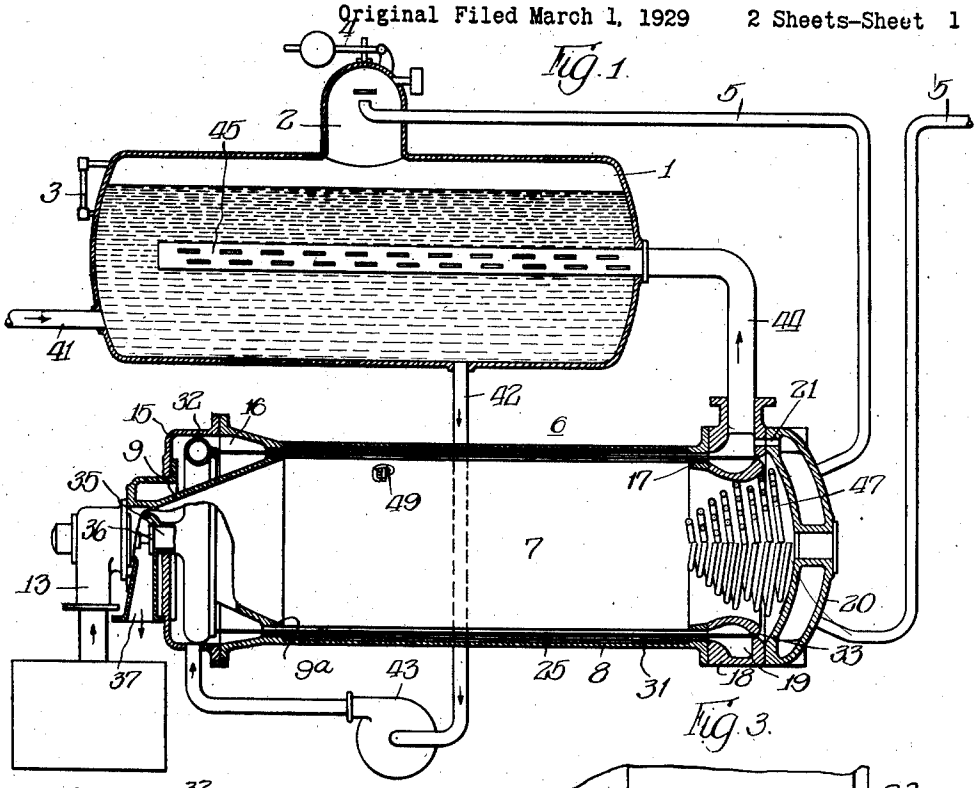


Fig. 3.

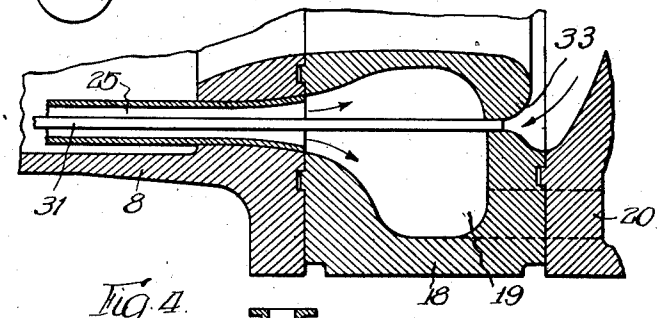


Fig. 2.

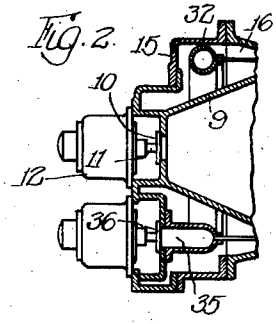
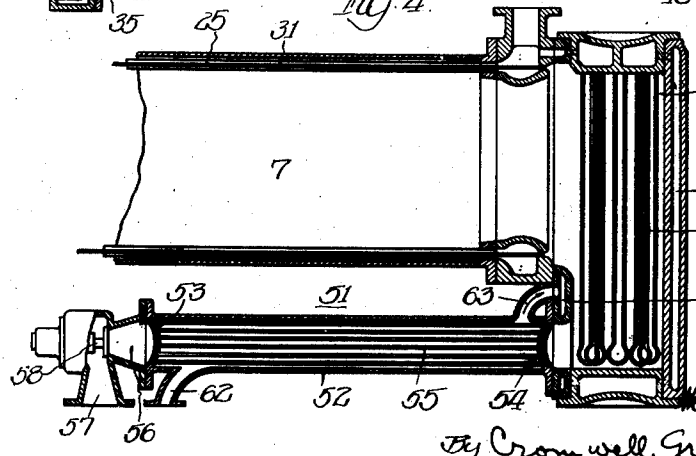


Fig. 4.



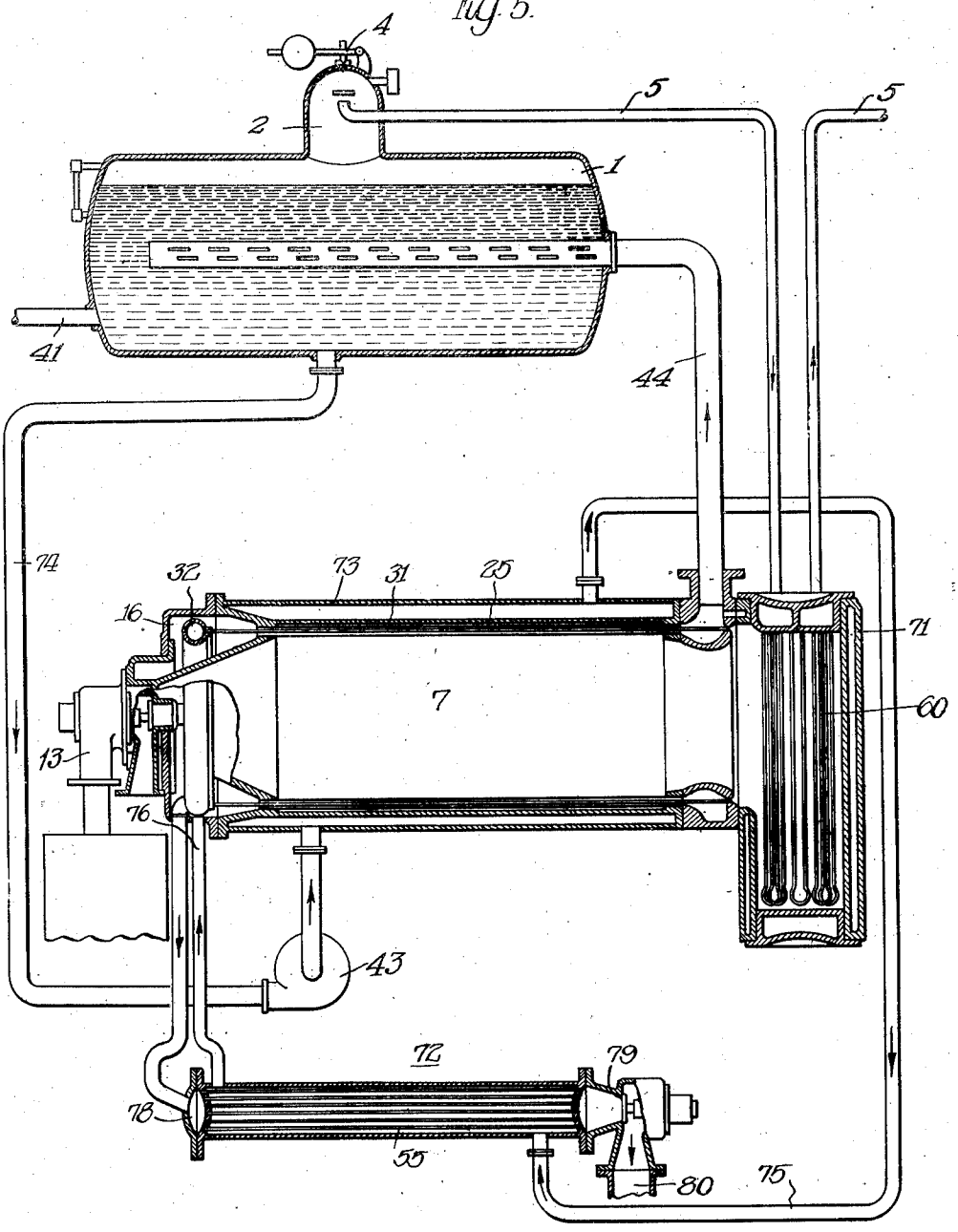
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HEATING SYSTEM

Original Filed March 1, 1929 2 Sheets-Sheet 2

Fig. 5.



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UNITED STATES PATENT OFFICE

1,948,535

HEATING SYSTEM

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Application March 1, 1929, Serial No. 343,745, and in Germany March 19, 1928. Renewed May 26, 1933

18 Claims. (Cl. 122—24)

This invention relates to heating systems and it has among its objects the provision of an improved heat generating and exchanging system, and more particularly, a steam generator, in which the fuel is burned under pressure in a pressure-proof combustion chamber, and the energy freed by the combustion is conveyed to the medium to be heated by causing the pressure in the chamber to drive the combustion gases at high velocity along heat exchange surfaces holding said medium.

A particular object of the invention is the provision of a novel steam generator in which a combustible mixture is subjected to combustion in a pressure-proof combustion chamber at high pressure and the pressure is utilized to drive the combustion gases at high velocity along heat exchanging surfaces at which the heat of the combustion gases is transferred to the liquid to be heated for steam generation.

Through the use of heat systems and boilers made according to the invention the cost and space requirements, as compared with the heater systems and boilers in which the combustion gases are passed along the heat exchange surfaces at low velocities, as at present, are greatly reduced.

The foregoing and other objects of the invention will be best understood from the accompanying drawings, wherein

Fig. 1 is a diagrammatic sectional view through a steam generating plant exemplyfying the invention;

Fig. 2 is a horizontal sectional view across the front portion of the combustion chamber showing the arrangement of the inlet and outlet valves;

Fig. 3 is a detail sectional view through the bottom rear portion of the combustion chamber showing the mounting of the heater tubes;

Fig. 4 is a diagrammatic sectional view through a part of the combustion chamber illustrating another form of the invention; and

Fig. 5 is a diagrammatic sectional view through a steam generating plant illustrating a still further form of the invention.

The broad features of the invention will be explained in connection with exemplifications thereof in various forms of steam generating plants although the principles of the invention are useful in many other applications.

In steam generators made according to the invention the fuel or a combustible mixture formed by the fuel is subjected to combustion under pressure, or exploded, in a closed combustion chamber. The combustion gases so obtained are passed along heat exchange surfaces for heating the boiler water or other medium to be heated, the pressure in the combustion chamber being utilized for imparting to the combustion products a high velocity, thereby increasing the heat transfer to the heat exchange surfaces along which they pass.

For reasons of manufacture, maintenance and exchangeability of parts, it is important that in the practical construction of steam generators of the foregoing type the several parts thereof, such as the combustion chamber, the heat exchange bodies for preheating and steam development, the superheater, and the various regulating devices, shall be constructed and arranged as separate machine parts or units. Such construction, however, is made difficult through the requirement that the combustion chamber and all other parts which are in contact with the highly heated combustion gases must be provided with proper cooling. Since for various reasons transfer of the heat to the walls is very large, only the liquid itself that is to be vaporized can be used efficiently for cooling, unless a special heat-carrying liquid of high boiling point is used. Because of the foregoing conditions the cooling spaces must be made a part of the steam generator itself and must be able to withstand the pressure of the steam that is to be generated, which is usually very high. The cooling jackets or casings must accordingly be made of large wall thickness and the connections of the individual cooling spaces, as well as the removal of the steam generated in the individual cooling spaces, present very great difficulties of design and operation.

According to the invention these difficulties are avoided in steam generators of the type described above by arranging all or the principal parts which serve for the heat exchange within the walls of the combustion chamber itself. Thus, for instance, the heat exchange surfaces for the preheating and generating the steam in the water as well as the superheater are disposed within the interior of the combustion chamber and are so arranged that no special cooling jackets are necessary for the main parts of the combustion chamber. The inlet and outlet channels for the fluid that is to be heated or converted into steam are furthermore so arranged that they constitute cooling jackets at the portions of the heating devices which are not provided with heat exchange surfaces.

In Fig. 1 is shown an exemplification of the invention as applied to a steam generating plant.

The plant comprises a separator drum 1 which is filled with preheated water that is to be converted into steam up to the level indicated. The drum is provided with a steam dome 2 and has the usual appurtenances, such as a water gauge 3 and a safety valve 4. Steam is taken off from the drum by a steam outlet pipe 5.

The water is heated and converted into steam by means of a pressure proof compression or explosion-type combustion heater 6 shown in the drawing below the drum 1. The principal part of the heater arrangement is a pressure proof combustion chamber 7 in which the combustion mixture is burned or periodically exploded and in which the energy developed by the combustion is conveyed to the water for heating it and converting it into steam. The combustion chamber consists essentially of a cylindrical shell 8 having a tapered front wall 9 terminating in an inlet opening 10 which is arranged to be closed or opened by an inlet valve 11 having an inlet chamber 12 that communicates through a fuel feed pipe 13 with a combustible mixture supply source.

The tapered front wall portion of the combustion chamber is surrounded by an outer casing 15. A closed annular chamber 16 is thus formed around the conical front wall 9 of the combustion chamber, the annular chamber 16 serving as a water inlet, as described hereinafter. The rear portion of the cylindrical shell 8 is provided with an inwardly extending flange 17 and has secured thereto a rear closure member 18 provided with an annular hollow chamber 19 that serves as the water outlet. A hollow rear cover 20 secured to the rear wall of the rear closure member 18 completes the combustion chamber, the hollow space in the rear wall 20 communicating with the hollow annular chamber 19 through suitable channels 21.

Along the cylindrical inner walls of the shell 8 of the combustion chamber is mounted a layer of water tubes 25 as shown in detail in Fig. 3. The front ends of the water tubes are tightly secured in a series of annular holes at the base 9a of the conical front wall 9 adjacent the outer shell 8, thus communicating with the water inlet chamber 16 formed at the front end of the combustion chamber. The rear ends of the water tubes 25 are similarly secured in holes provided in the inwardly projecting flange 17 of the shell 8 thereby communicating with the annular outlet chamber 19 in the rear closure member 18.

Through each of the water tubes 25 there extends a second smaller tube serving as a gas conduit or nozzle 31 for discharging the gases of combustion from the combustion chamber 7. The gas conduits 31 are connected with their front ends to an annular gas outlet chamber 32 provided within the annular water inlet chamber 16. The rear ends of the gas conduits or nozzles are secured within a series of annular nozzle shaped inlet holes 33 disposed at the rear side of the closure member 18 in alignment with the holes on its front side which communicate with the openings of the water tubes 25. In this way the gas conduits or nozzles open directly into gas outlet chamber 32 in the rear of the combustion chamber 7.

From the gas outlet chamber 32 the gases are let out through an outlet opening 35 which is arranged to be closed and opened by an outlet valve 36 as shown in Fig. 2, the gases being discharged through an exhaust duct 37.

The water circulation between the boiler tank 1 and the heater 6 is secured by a system of pipes as shown in the drawings. Feed water may be supplied to the separator drum 1 through a feed water inlet pipe 41 opening near the bottom of the drum into the water space. Through another pipe 42 leading from the bottom of the drum 1 preheated water is led through a circulating pump 43 into the water inlet chamber 16 of the heater, the water flowing then through the chamber water tubes 25 into the annular outlet chamber 19 from where it is returned through pipes 44 and 45 into the separator drum. The steam separates and rises to the steam dome while the water is recirculated.

The operation of the arrangement shown in Figs. 1 to 3 is as follows:

A combustible gas mixture is admitted into the interior space of the combustion chamber 7 through the inlet valve 10. At that time the outlet valve 36 is in closed position. As soon as the chamber is filled with the combustible charge, the mixture is exploded as by means of suitable spark plugs indicated at 49. Because of the limited combustion space complete combustion will be effected very rapidly, developing a high temperature and pressure. The outlet valve 36 is then opened and, because of the great pressure, the gases of combustion are discharged with great velocity through the gas tubes or nozzles 31, giving up their energy in the form of heat to the water in the surrounding water tubes 25, the gases escaping into the discharge ducts 37. Thereupon a fresh charge is admitted into the combustion chamber 7 and the process is thus continuously repeated. The operation of the inlet and outlet valves and of the spark plug is controlled by means of any well known control arrangement to operate in sequence as described above.

Efficient steam generation is obtained by circulating, by means of the circulating pump 43, the water from the boiler through the water tubes 25, the water flowing in a thin layer adjacent the surfaces along which the hot combustion gases pass with great velocity. The water tubes 25 are arranged close to each other so that the walls of the combustion chamber are very effectively protected against the high temperature of the combustion gases, thus eliminating the necessity of special cooling of the outer walls of the combustion chamber or their construction with the degree of safety necessary for boiler tanks proper.

In the construction shown, the parts of the combustion chamber which are not covered by the water tubes, namely, the front and the rear ends, are protected against overheating by arranging the water inlet and outlet chambers around these parts.

In the arrangement of Fig. 1 there is also shown a superheater for the steam in the form of a coil pipe system 47 connected in the steam pipe 5. The superheater coil 47 is arranged in front of the rear cover 20 of the combustion chamber.

In order to secure better utilization of the heat in the exhaust gases escaping through the outlet or exhaust duct 37, the feed water may be circulated along the surfaces over which the expanded exhaust gases of combustion pass. Such preheaters may also be built in into the combustion chamber, forming a part of the protection of the walls.

In Fig. 4 is shown an arrangement of the boiler plant in which the feed water preheater is made as a separate unit. Only a part of the combustion chamber 7 and the associated elements of the feed water heater and superheater are shown in this figure. The feed water preheater is made in the

form of a separate unit 51 and comprises an elongated tubular chamber 52 carrying between its front wall 53 and its rear wall 54 a set of heater pipes 55 forming discharge nozzles for the gases from the combustion chamber 7. The gases escape through an outlet chamber 56 into an exhaust duct 57, a valve 58 controlling the discharge of the gases in a way similar to the outlet valve 36 of the main combustion chamber 7. At the rear end of the combustion chamber 7 is mounted a superheater chamber 59 which communicates with the combustion chamber and holds a set of superheater coils 60. The walls of the superheater chamber 59 are provided with hollow spaces 61 for the feed water which is admitted into the preheater chamber 52 through the inlet 62 near one end of the chamber and flows from the outlet 63 into the hollow spaces 61 within the walls of the superheater chamber. In this way the feed water may be preheated till near the temperature of evaporization before sending it to the water tubes 25 of the steam generating and combustion chamber 7.

The outlet valves for releasing the gases produced by the combustion in the combustion chamber 7 of Fig. 4 are arranged at the outlet ends of the gas discharge pipes or nozzles 31 and 55, respectively. This has an advantage over an arrangement in which the discharge valve is placed at the outlet from the combustion chamber proper before the inlet into the discharge pipes, because it gives a simple construction without impairing the operating efficiency. This is due to the fact that the volume of the heater pipes is relatively small compared with the volume of the combustion chamber proper so that the pressure conditions during the combustion are by this arrangement in no way detrimentally affected.

A particular advantage of this arrangement of the outlet valves at the end of the gas heating pipes is due to the fact that the gases streaming through the valve are already relatively cool, having given up most of the heat to the water surrounding the heater tubes. Accordingly, no special cooling jackets or water connections are needed around the outlet valves.

In the arrangement of Fig. 4 the part of combustion gases which goes into the preheater 51 passes first through the superheater coils 60 as shown, the superheater chamber forming thus an inlet space for the preheater.

In Fig. 5 is shown a somewhat modified arrangement of a boiler plant embodying the principles of my invention. The superheater pipes 60 are arranged in a superheater chamber 71 at the end of the combustion chamber similar to the construction shown in Fig. 4. The feed water preheater is arranged as a separate unit 72 like the preheater 51 of Fig. 4. A special preheater jacket 73 is also arranged around the main combustion chamber 7 to additionally preheat the feed water. The feed water or the circulating water is delivered into the preheater jacket 73 through a pipe 74, and after passing through the jacket, it flows through a pipe 75 into the preheater 72 from whence it flows through the connecting conduit 76 into the water inlet chamber 16 of the combustion chamber 7. The water, after passing through the tubes 25 where the steam is generated, is then conveyed to the separator drum 1 where the steam separates.

In this construction the combustion gases all pass through the annularly arranged gas tubes 31 into the gas outlet space 32 of the combustion chamber and from there they are conveyed into the gas inlet space 78 of the preheater, passing then through the preheater gas pipes 55 and the outlet valve 79 to the exhaust duct 80.

The present invention is directed only to the features of my invention disclosed and claimed herein involving the special arrangements of fluid and gas discharge ducts and the combination of the combustion chamber with the gas discharge ducts and the valves for controlling their periodical discharge. The novel apparatus for and methods of steam generation disclosed above in connection with the exemplifications of my invention embody many other novel features for causing high temperature compressed combustion gases to discharge at high velocity over a small evaporator structure and generate steam at a high rate as described and claimed in my copending applications, Serial No. 333,453 filed January 18, 1929, Serial No. 640,025 filed October 28, 1932, Serial No. 343,746 filed March 1, 1929, Serial No. 414,428 filed December 16, 1929, Serial No. 419,026 filed January 7, 1930, and Serial No. 558,260 filed August 20, 1931.

Many other modifications of the invention will suggest themselves to those skilled in the art and I accordingly desire that the appended claims be given a broad construction commensurate with the scope of the invention within the art.

I claim:

1. A steam generator comprising a closed, pressure-proof combustion chamber, means for subjecting a combustible mixture to combustion in said chamber to produce therein combustion gases of high temperature and high pressure, a heat exchanger having heat exchange surfaces in the form of duct means connected to said chamber and so arranged relative thereto that the high pressure of the produced combustion gases in said chamber imparts to said gases a high velocity through said duct means at which the major portion of the heat present in the produced combustion gases is transferred through said heat exchange surfaces while they flow at high velocity, and means for cooling said combustion chamber comprising a set of fluid conduits of relatively small cross-section carrying a steam generating fluid to be heated by said duct means and generate steam said fluid conduits being arranged in a layer over the surface of said chamber to divert the combustion gases from the walls of said chamber and to direct them to said duct means.

2. A steam generator comprising a combustion chamber, means for subjecting a combustible mixture to combustion in said chamber to produce therein combustion gases of high temperature and high pressure, a heat exchanger having heat exchange surfaces in the form of duct means connected to said chamber and so arranged relative thereto that the high pressure of the produced combustion gases in said chamber imparts to said gases a high velocity along said duct means at which the major portion of the heat present in the produced combustion gases is transferred through said heat exchange surfaces while they flow at high velocity, and means for cooling said combustion chamber comprising a set of conduits of relatively small cross-section carrying a fluid to be heated and arranged in a layer over the surface of said chamber, said duct means extending through the interior of said conduits to deliver to the fluid in said conduits the heat given up by the gases flowing through said duct means at high velocity.

3. In a steam generator, a pressure-proof com-

bustion chamber, means for subjecting a combustible mixture to combustion in said chamber to produce therein combustion gases of high temperature and high pressure, a heat exchanger having fluid conduits of relatively small cross section holding a steam generating fluid and disposed in said chamber as heat protection for the walls thereof, and heat exchange duct means extending through said fluid conduits and connected to said chamber to cause the high pressure of the produced combustion gases in the chamber to impart to said gases a high velocity through said duct means sufficient to transfer during the flow the major portion of the heat present in the produced combustion gases to the surrounding fluid in said conduits.

4. In a steam generator comprising a combustion chamber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having heat exchange surfaces in the form of ducts connected to said chamber and so arranged relative thereto that the high pressure of the produced combustion gases in the chamber imparts to said gases a high velocity through the interior of said ducts at which the major portion of the heat present in the produced combustion gases is transferred through said heat exchange surfaces while they flow at high velocity, and tubular conduits surrounding said ducts and holding around them a fluid to be heated, said conduits and ducts extending through the interior of said combustion chamber and constituting a layer over the surface thereof to protect the chamber walls against heat.

5. In a steam generator, a pressure-proof combustion chamber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having a set of fluid tubes extending through the interior of said chamber along the walls thereof cooling the same, means for passing a fluid to be heated through said tubes, and a set of relatively narrow gas discharge pipes extending through said fluid tubes and connected to said chamber to cause the pressure produced by the explosion of the combustible mixture in said chamber to impart to the combustion gases a high velocity through the interior of said pipes sufficient to transfer during flow the major portion of the heat present in the combustion gases to the fluid in the surrounding fluid tubes.

6. A steam generator comprising a pressure-proof combustion chamber, means for periodically exploding a combustible mixture in said combustion chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having a set of fluid tubes extending through the interior of said chamber along the walls thereof cooling the same, means for passing a steam generating fluid through said tubes, and a set of relatively narrow gas discharge pipes extending through said fluid tubes and connected to said chamber to cause the pressure produced by the explosion of the combustible mixture in the chamber to impart to the combustion gases a high velocity through said pipes sufficient to transfer during flow the major portion of the heat in the gases to the fluid in the tubes surrounding said discharge pipes to generate steam.

7. In a steam generator, a combustion chamber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having heat exchange surfaces in the form of duct means having at one end inlets directly opening into said chamber and at the other end closable outlets for discharging gases of combustion passing from said chamber through said duct means, and enclosure means surrounding said duct means arranged to pass a fluid to be heated therearound, said duct means being so arranged relative to said combustion chamber and associated elements that upon opening of said outlets after an explosive combustion, the high pressure of the produced combustion gases will impart to said gases a high velocity through said duct means at which the major portion of the heat present in the produced combustion gases is transferred to the surrounding fluid to generate steam while they flow with high velocity.

8. In a steam generator, a pressure-proof combustion chamber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having heat exchange surfaces in the form of duct means having at one inlet openings directly communicating with said chamber and outlet openings at the other end, and enclosure means surrounding said duct means arranged to pass a steam generating fluid to be heated therearound, valve means at said outlet openings for releasing gases of combustion from said chamber through said duct means, the area and volume of said duct means being so chosen relative to said combustion chamber and associated elements that upon opening of said valve means after an explosive combustion the high pressure of the produced combustion gases will impart to said gases a high velocity through said duct means at which the major portion of the heat present in the produced combustion gases is transferred to the surrounding fluid to generate steam while they flow with high velocity.

9. In a steam generator, a pressure-proof combustion chamber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having heat exchange surfaces in the form of a plurality of relatively narrow gas discharge pipes with inlets at one end opening directly into and in communication with said chamber and outlets at the other end, and enclosure means surrounding said duct means arranged to pass a steam generating fluid to be heated therearound, valve means for said outlets for releasing gases of combustion from said chamber through said discharge pipes, the area and volume of said discharge pipes being so chosen in relation to said combustion chamber and the associated elements that upon opening of said valve means after an explosive combustion, the high pressure of the produced combustion gases will impart to said gases a high velocity through said pipes at which the major portion of the heat present in the produced combustion gases is transferred to the surrounding steam generating fluid to generate steam while said gases flow with high velocity.

10. In a steam generator, a combustion cham-

ber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having heat exchange surfaces in the form of duct means having at one end inlets directly opening into said chamber and at the other end outlets for discharging gases of combustion passing from said chamber through said duct means, said duct means being so arranged relative to said combustion chamber and associated elements that upon opening of said outlets after an explosive combustion, the high pressure of the produced combustion gases will impart to said gases a high velocity through said duct means at which the major portion of the heat present in the produced combustion gases is transferred through said heat exchange surfaces while they flow with high velocity, and conduits surrounding said duct means for carrying a liquid to be heated by contact with the surfaces of said duct means, said conduits with said duct means extending through the interior of said combustion chamber.

11. In a steam generator, a combustion chamber, means for periodically exploding a combustible mixture in said chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having heat exchange surfaces in the form of a plurality of relatively narrow gas discharge pipes with inlets at one end opening directly into and in communication with said chamber and outlets at the other end, valve means for said outlets for releasing gases of combustion from said chamber through said discharge pipes, the area and volume of said discharge pipes being so chosen in relation to said combustion chamber and the associated elements that upon opening of said valve means after an explosive combustion, the high pressure of the produced combustion gases will impart to said gases a high velocity through said pipes at which the major portion of the heat present in the produced combustion gases is transferred through the surfaces of said discharge pipes while said gases flow with high velocity, and tubes surrounding said gas discharge pipes and carrying around said pipes a steam generating fluid to be heated by said gases and generate steam, said tubes with the gas discharge pipes in the interior thereof extending through the interior of said combustion chamber along the walls thereof, cooling the same.

12. A steam generator comprising a combustion chamber having an outlet space at one end thereof, means for subjecting a combustible mixture to combustion in said chamber, a first enclosure around the outlet end of said combustion chamber for carrying fluid to be heated, a second enclosure around the opposite end of said combustion chamber for carrying fluid to be heated for generation of steam, gas outlet duct means associated with said second enclosure, a plurality of fluid tubes extending through the interior of said combustion chamber and opening at their ends into said enclosures to carry fluid to be heated between the same, said tubes being arranged along the interior walls of said combustion chamber and constituting a heat protecting screen therefor, and gas discharge pipes extending through said tubes and connected between said gas outlet space in said combustion chamber and said outlet duct to discharge gases of combustion from said chamber through said pipes.

13. A steam generator comprising a combustion chamber having an inlet and an outlet end, an enclosure around said inlet end of said combustion chamber constituting a fluid inlet chamber, an enclosure around the outlet end of said combustion chamber constituting a fluid outlet chamber, a plurality of fluid tubes extending along the walls of said combustion chamber and opening at their ends into said fluid inlet and outlet chambers respectively, a gas outlet duct associated with said fluid inlet chamber, a set of gas pipes extending through the interior of said tubes and opening at one end into the outlet end of said combustion chamber and at the other end into said gas outlet duct, means for subjecting a combustible mixture to combustion in said chamber and for discharging the gases of combustion through said gas pipes, and means for circulating a vapor-generating fluid through said tubes in the direction from said fluid inlet chamber to said fluid outlet chamber.

14. A steam generator comprising a combustion chamber having an inlet and an outlet end, an enclosure around said inlet end of said combustion chamber constituting a fluid inlet chamber, an enclosure around the outlet end of said combustion chamber constituting a fluid outlet chamber, a plurality of fluid tubes extending along the walls of said combustion chamber and opening at their ends into said fluid inlet and outlet chambers respectively, a gas outlet duct in said fluid inlet chamber, a set of gas pipes extending through the interior of said tubes and opening at one end into the outlet end of said combustion chamber and at the other end into said gas outlet duct, means for subjecting a combustible mixture to combustion in said chamber and for discharging the gases of combustion through said gas pipes, and means for impelling a vapor-generating fluid through said tubes in the direction from said fluid inlet chamber to said fluid outlet chamber to generate steam through heat transfer from said gases, said gas pipes and associated elements being so arranged with respect to said combustion chamber that the pressure of the produced combustion gases in the chamber imparts to said combustion gases a high velocity through said gas pipes at which the major portion of the heat present in the produced combustion gases is transferred through said pipes to the fluid flowing there around in said tubes.

15. In a steam generator, a pressure-proof combustion chamber, means for subjecting a combustible mixture to combustion in said chamber to produce therein combustion gases of high temperature and high pressure, a heat exchanger having fluid conduits of relatively small cross section holding a steam generating fluid and disposed in said chamber as heat protection for the walls thereof, a steam separator vessel, means for impelling a steam generating fluid through said fluid conduits into said separator vessel to separate steam from the fluid, and heat exchange duct means extending through said fluid conduits and connected to said chamber to cause the high pressure of the produced combustion gases in the chamber to impart to said gases a high velocity through said duct means sufficient to transfer during the flow the major portion of the heat present in the produced combustion gases to the surrounding fluid in said conduits to generate steam therefrom.

16. A steam generator comprising a pressure-proof combustion chamber, means for periodi-

cally exploding a combustible mixture in said combustion chamber to produce therein combustion gases of high temperature and higher pressure than said combustible mixture, a heat exchanger having a set of fluid tubes extending through the interior of said chamber along the walls thereof cooling the same, a steam separator vessel, means for impelling a steam generating fluid through said fluid conduits into said separator vessel to separate steam from the fluid, and a set of relatively narrow gas discharge pipes extending through said fluid tubes and connected to said chamber to cause the pressure produced by the explosion of the combustible mixture in the chamber to impart to the combustion gases a high velocity through said pipes sufficient to transfer during flow the major portion of the heat in the gases to the fluid in the tubes surrounding said discharge pipes to generate steam therefrom.

17. A steam generator comprising a combustion chamber having an inlet and an outlet end, an enclosure around said inlet end of said combustion chamber constituting a fluid inlet chamber, an enclosure around the outlet end of said combustion chamber constituting a fluid outlet chamber, a plurality of fluid tubes extending along the walls of said combustion chamber and opening at their ends into said fluid inlet and outlet chambers respectively, a gas outlet duct in said fluid inlet member, a set of gas pipes extending through the interior of said tubes and opening at one end into the outlet end of said combustion chamber and at the other end into said gas outlet duct, means for subjecting a combustible mixture to combustion in said chamber and for discharging the gases of combustion through said gas pipes, a steam separator vessel, and means for impelling a vapor-generating fluid through said tubes in the direction from said fluid inlet chamber to said fluid outlet chamber and therefrom into said separator vessel, to convert the fluid into steam in said tubes and to separate the generated steam from the fluid in said separator, said gas pipes and associated elements being so arranged with respect to said combustion chamber that the pressure of the produced combustion gases in the chamber imparts to said combustion gases a high velocity through said gas pipes at which the major portion of the heat present in the produced combustion gases is transferred through said pipes to the fluid flowing therearound in said tubes.

18. In a steam generator, a pressure-proof combustion chamber, means for subjecting a combustible mixture to combustion in said chamber to produce therein combustion gases of high temperature and high pressure, a heat exchanger having fluid conduits of relatively small cross section holding a steam generating fluid and disposed in said chamber as heat protection for the walls thereof, heat exchange duct means extending through said fluid conduits and connected to said chamber to cause the high pressure of the produced combustion gases in the chamber to impart to said gases a high velocity through said duct means sufficient to transfer during the flow the major portion of the heat present in the produced combustion gases to the surrounding fluid in said conduits, and superheater tubes extending through the interior of said combustion chamber.

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