

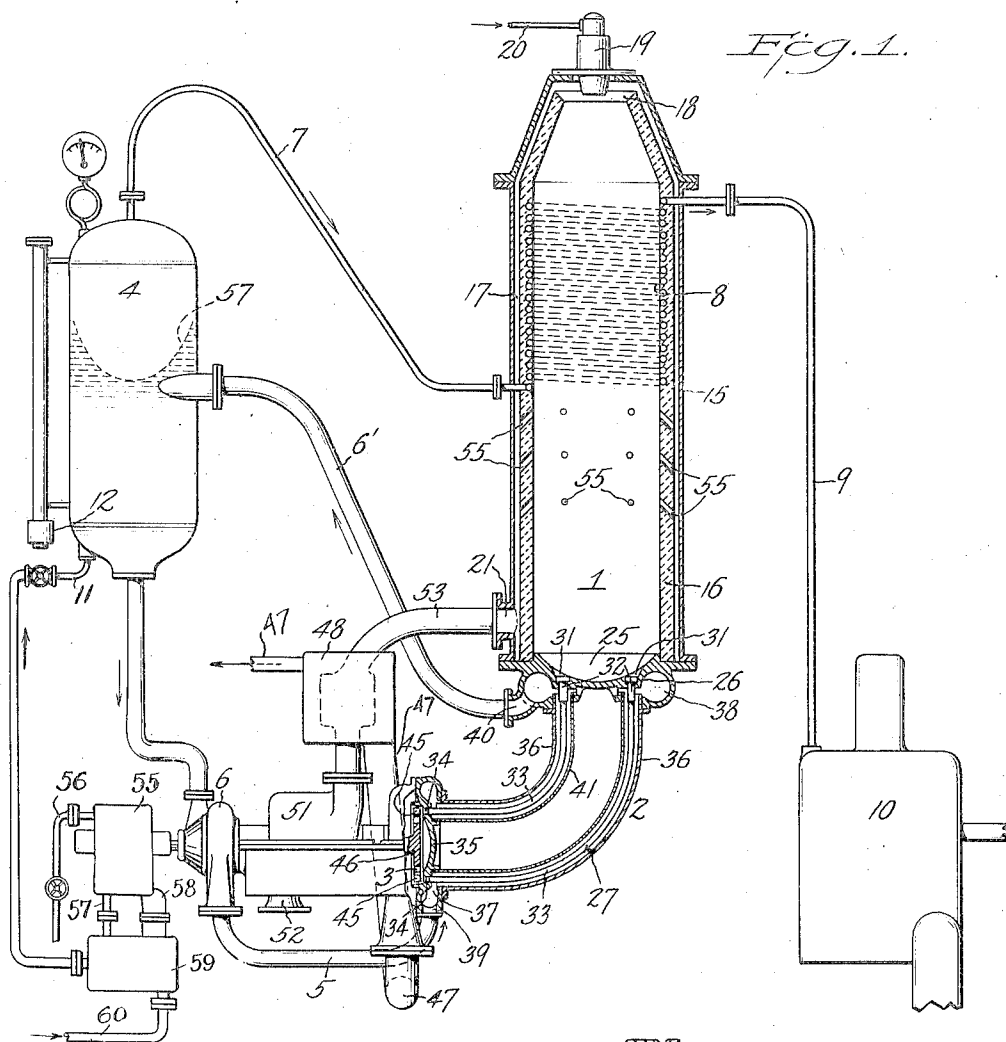
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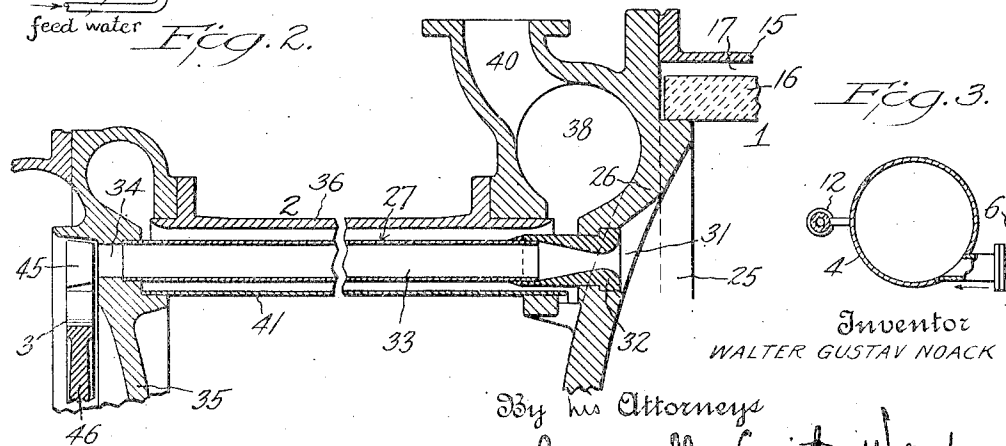
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STEAM GENERATOR

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feed water *Fig. 2.*



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STEAM GENERATOR

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Application January 7, 1930, Serial No. 419,026, and in Germany January 14, 1929

14 Claims. (Cl. 122—24)

This invention relates to steam generators and is a further development of the inventions disclosed in my copending applications Serial No. 333,453, filed January 18, 1929, Serial No. 343,745 filed March 1, 1929, Serial No. 343,746 filed March 1, 1929, Serial No. 375,138 filed July 1, 1929 and Serial No. 414,428 filed December 16, 1929.

Among the objects of the invention is an improved steam generator, in which a compressor driven by a gas turbine supplies a combustible mixture under pressure to a combustion chamber, and after combustion, the hot gases are discharged by the pressure through a set of heat exchanging tubes with a velocity of about 200 meters per second or more, the gases leaving the tubes retaining enough energy to drive the gas turbine with part or all the power necessary to drive the compressor for imparting to the combustion gases the pressure required to drive the gases at the high velocity.

The foregoing and other objects of the invention will best be understood from the following description of exemplifications thereof, reference being had to the accompanying drawing wherein,

Fig. 1 is a diagrammatic view of a heat power system exemplifying the invention; and

Fig. 2 is a detailed sectional view through the heat exchanger and the associated apparatus of the arrangement shown in Fig. 1, with the middle portion of the heat exchanger broken away and the portions shown in alignment; and

Fig. 3 is a horizontal sectional view through the steam collector of Fig. 1.

In steam power plants as built heretofore, the steam boilers used for supplying steam to the engines or the turbines have been very bulky and much greater in size than the engines or turbines which they supplied. There has existed, therefore, for many years a very urgent demand for efficient and practical steam boilers of less bulk and free from the sluggish regulation of the steam generation inherent in the use of large masses of water required for the generation of steam in the large boiler tank structures.

Though it has been known for some time that, by increasing the velocity, the transmission of heat from a gas to the water to be heated may be considerably improved, the velocity of the heating gases has heretofore, in practice, always been kept relatively low, so that it is hardly likely that steam generators exist in which velocities higher than about 25 meters per second, have found application. This, in spite of the fact that scientific research has already extended its investigation into the transmission of heat at higher velocities,

so that, for instance for elastic fluids (gases), velocities have been experimented with up to 100 meters per second. However, heretofore no practical boilers utilizing these velocities were ever built, because no economical way for obtaining these high velocities was apparent to the art.

The idea of utilizing for steam generation combustion gas velocities exceeding 200 meters per second, reaching out in the neighborhood of the velocity of sound, and thereby providing steam generators occupying only a fraction of the space and having only a fraction of the weight of boilers of the same capacity as made heretofore, was advanced by me, after first investigating the behaviour of gas in regard to the transmission of heat and flow resistance at velocities considerably exceeding 100 meters per second, and after finding arrangements and ways for economically developing the necessary pressure drop for the generation of these high velocities. The laws of heat transmission and resistance to flow, as known prior to my investigation, did not all apply when a certain velocity is exceeded. If the velocity of the gas amounts to more than one-third or one-half of the critical speed (velocity of sound at the corresponding pressure and temperature) then the flow of gases is no longer similar to the flow of an inflexible fluid, but properties of the gases become apparent which are caused by the elasticity (compressibility) of the gas. Heretofore no consideration was given to this effect, as none of the tests made in the past ever extended to velocities at which influence of the elasticity becomes pronounced. The cooling of the gas during the flow in the tubes has a further influence, in that this cooling effects a reduction in velocity resulting from an increase of the density which causes the recompression of the gas like in a diffuser (increase of the potential energy as a result of the decrease of the kinetic energy).

To obtain these high flow velocities pressure drops are necessary which amount to many times the draught met with in usual steam generators. These high pressure drops cannot be obtained with the system of forced draught as used in ordinary boilers, but special measures must be provided for, several of which I have already described in previous applications.

In the steam generator of the present invention, a compressed combustible charge is continuously subjected to combustion in a combustion chamber at raised pressure, and the pressure is applied to impart to the hot gases a very high velocity of the order of 200 meters per second or more through a set of heating ducts constituting the

nozzles of a gas turbine driving a compressor to supply the charge, the heating ducts forming part of a heat exchanger holding a steam generating fluid surrounding the ducts to generate steam with the heat transferred by the hot gases flowing through the ducts.

The nozzle body is preferably so arranged that the entire or most of the steam generation is effected within the nozzle body. Furthermore, the individual nozzle inlets are preferably so designed that the available pressure head is transformed therein into velocity without material heat absorption; and that the high flow velocity resulting therefrom is utilized for obtaining a high rate of heat transmission to the walls of the heat exchangers under substantially complete heat absorption at relatively low loss of speed in the flowing gases. The cooled gases retain a relatively high velocity and have sufficient energy for application to the gas turbine to drive the same, and the compressor that is connected thereto.

In the arrangements of the invention, the combustion gases are burned in a combustion chamber under pressure and discharged through suitable nozzles at a velocity of about 200 m/sec. or more without substantial heat loss to the gases; the high velocity gases are then passed at high velocity along heat exchanger tubes so as to deprive the gases of most of the heat contained therein without substantial reduction of the gas velocity; and the relatively cool high velocity gases coming from the exhaust of the heat exchanger are applied to a gas turbine, the gases being discharged into the turbine with sufficient energy to deliver through the turbine power needed to produce in the compressor a combustible mixture of sufficient pressure to impart to the combustion gases the high velocity. The steam generator exemplifying the invention, as shown in the drawing, comprises a combustion chamber 1, a heat exchanger 2, a combustion gas turbine 3, a steam separator drum 4, and associated apparatus referred to hereinafter.

Water from the drum 4 is supplied through supply pipes 5 by means of circulating pump 6 to the heat exchanger 2, and after passing the latter, it is returned with the steam generated therein through pipe 6' to the drum 4 where the steam separates and collects at the top of the drum. The wet steam from the drum 4 may be sent through a pipe 7 to a superheater 8 associated with the combustion chamber 1 and the superheated steam may be supplied through supply pipe 9, to a steam consuming device, such as a main steam turbine 10. Fresh feed water for the boiler system may be supplied through the feed water pipe 11, the feed water supply being controlled in accordance with the water level in the drum 4, as by means of a water level regulating apparatus indicated at 12.

The combustion chamber in the heat exchanger of the exemplification shown in the drawing is of the continuous combustion type in which a compressed combustible charge is continuously delivered to the combustion chamber and there subjected to continuous combustion under constant pressure as described in my application Serial No. 414,428. The combustion chamber comprises an outer sheet metal chamber 15, of steel for instance, built so as to withstand the operating pressures developed within the chamber. Inside of the outer chamber 15 there is mounted an internal chamber 16 which consti-

tutes the combustion chamber proper. The internal chamber 16 is preferably made of a suitable refractory material, for instance chamotte, and is arranged so as to provide free tubular duct 17 between its exterior and the walls of the outer chamber 15. A main inlet opening 18 is provided at the upper end of the inner chamber 16 and opposite this opening there is mounted in the upper wall of the outer chamber 15 a fuel inlet valve 19 through which fuel supplied by fuel line 20 is admitted to the combustion chamber 1. Air is admitted through an air inlet opening 21 at the lower end of the outer chamber 15 and it passes upwardly through duct 17 to the inlet opening 18 of the inner chamber 16. At the inlet opening 18 fuel from the valve 19 is mixed with the air and a combustible mixture is formed which is subjected to a continuous combustion process within the inner chamber 16.

At the lower end of the inner chamber 16 is provided a combustion gas outlet 25. Opposite this outlet is mounted in the conical bottom plate 26 of the outer chamber 15 a system of nozzles 27 extending through the entire length of the heat exchanger 2. This nozzle system and the construction of the heat exchanger is illustrated in detail in Fig. 2.

As shown in the drawing, the bottom plate 26 of the heat exchanger is provided along its periphery with a series of openings 31 in which are mounted expansion nozzles 32. To the end of each expansion nozzle 32, there is connected a gas discharge tube 33, the other end of which terminates in a gas outlet opening 34 in the outlet end plate 35 of the heat exchanger. The expansion nozzles 32 and the gas discharge pipes 33 constitute an annular system of nozzles disposed along the outer walls 36 of the heat exchanger 2. The heat exchanger is provided with an annular water inlet chamber 37 near the outlet end of the gas discharge pipes 33 and an annular water outlet chamber 38 near the inlet end of the gas discharge pipes 33. Water is admitted to the inlet chamber 37 through an inlet opening 39, and the water is conveyed from the outlet chamber 38 through the outlet opening 40. The heat exchanger is provided with an inner wall 41 so as to form around the system of gas discharge pipes 33 an annular conduit for circulating the water from the inlet opening 39 to the outlet opening 40 in the form of a relatively thin layer for more efficient steam generation.

Opposite the gas outlet openings 34 of the heat exchanger, there is mounted a peripheral turbine blade system 45 of a gas turbine wheel 46, so arranged as to be driven by the gases flowing from the gas discharge pipes 33. After passing through the turbine blades 45, the gases are discharged through the discharge pipe 47 and may be passed through an additional air preheater 48 wherein the remaining heat may be utilized for preheating the air that is supplied to the combustion chamber 1.

The turbine rotor 46 is directly coupled and drives a compressor 51 by means of which compressed air admitted at the inlet opening 52 is compressed and delivered through the supply pipe 53, passing through the preheater 48 to the air inlet opening 21 at the lower end of the outer casing 15 of the combustion chamber. The water circulating pump 6 may likewise be directly coupled to the compressor 51 as shown in the drawing.

The gas turbine 46 may be of usual construction and the outlet openings 34 in front of the

gas turbine blades 45 may be formed so as to provide a deflector system whereby the discharge gases are directed against the turbine blades in a direction to produce most efficient turbine action.

The air compressed by the compressor 51 is delivered to the air inlet opening 21 of the combustion chamber 1, passes upwardly through the tubular duct 17 to the inlet opening 18 of the combustion chamber where it is further preheated so that a good utilization of the heat energy of combustion is obtained. Either all or a part of the air that is necessary for complete combustion may be delivered by way of the annular duct 17 to the inlet opening 18. A part of the air may be admitted directly to the chamber 16 through angularly disposed slits 55 in the walls of the inner chamber 16, this air supply being in the nature of a secondary air supply in relation to the air supply at the inlet opening 18 which may be designated as a primary air supply.

The several elements of the system are so arranged that the gases burned under pressure in combustion chamber 1 are brought to a high velocity by expansion in the expansion nozzles 32, and then flow through the gas discharge pipes 33 with the attained high velocity. Pump 6 circulates the water at high velocity through the space surrounding the pipes 33 in a direction opposite to the direction of flow of the gases so as to withdraw substantially the entire heat of the gases, thereby generating steam which is carried through pipe 6 to the separator drum 4 where the steam separates. The inlet of the pipe 6 into the drum 4 is arranged tangentially as shown in Fig. 3. The water and steam mixture entering tangentially into the separator drum 4 imparts to the water a circular movement, producing through centrifugal action quick separation of the steam from the water, the water movement through this centrifugal action being indicated by dotted lines 57.

The gases coming from the gas discharge pipes 33 are substantially entirely deprived of the heat present in the gases at the entrance in the pipes, but these gases still retain kinetic energy due to their high velocity. This kinetic energy of the flowing gases is directed through the guides in the inlet openings 34 against blades 45 of the turbine wheel 46 driving the latter.

The heat exchanger with the gas discharge nozzles and pipes may be arranged either in bent form as shown in Fig. 1, or it may be arranged in the form of a straight cylindrical or tubular body. The gas discharge pipes may be arranged either cylindrically or so as to form the outline of a cone, depending on the relationship of the circumference of the heat exchanger to the circumference of the turbine blade wheel. The gas discharge pipes 33 may be either straight or have any other suitable shape. In order to suitably guide the water in the thin layer, the heat exchanger may be made in the form of a cylindrical or conical annular chamber. Only the outer wall of the chamber has to withstand the entire pressure of the steam. The inner wall may be arranged only so as to act as a guide surface, the water filling the entire space bounded by the outer wall of the heat exchanger.

The size of the combustion chamber may be reduced by utilizing a greater compression of the combustible mixtures, and to this end, pressures above 2.5 atmospheres may be utilized. Under such conditions, a relatively large amount of power is necessary for driving the compressor,

and the entire system is so arranged as to leave in the combustion gases discharged from the outlet of the heat exchanger a sufficient large amount of energy for driving the compressor. The gas turbine is usually arranged so as to have velocity stages with either one or several velocity blade wheels.

Where large energies have to be converted in the gas turbine and the gases must flow with high velocities to give the required driving energy, the temperature rise of the gases due to the blade and the outlet losses may reach a considerable value. Furthermore, the high degree of compression makes it also desirable to cool the air during the compressing process. These operating conditions are utilized by me by connecting the outlet of the gas turbine 47 to the air preheater 48 so as to deprive the exhaust gases of the gas turbine of all the heat that may be present therein and to impart said heat to the air which is admitted to the combustion chamber. A substantially complete utilization of the developed heat is thus obtained and the heat losses are reduced to a minimum.

The amount of power that can be delivered to the compressor-driving gas turbine 47 depends on the pressure drop and the temperature available in the combustion gases above the amount required to heat the water and generate the demanded amount of steam. The amount of energy available in the gases after leaving the evaporator tubes may be made less than needed by the gas turbine for driving the compressor with enough power to produce the required charging pressure. In such cases it is desirable to provide an auxiliary motor for assisting the gas turbine 47 in driving the compressor 51 and other auxiliary apparatus. The auxiliary motor may, for instance, be in the form of a back-pressure, or back-pressure extraction steam turbine 55 coupled to the compressor shaft and supplied with steam through pipe 56, as shown in Fig. 1.

The extraction steam coming from extraction outlet 57 and the exhaust steam coming from exhaust outlet 58 of the auxiliary steam turbine 55 are utilized in preheater 59 to preheat the feed water passing the preheater from pipe 60 to the feed water pipe 11 leading to the water part of the steam separator 4. The entire heat used for the auxiliary steam turbine is in such case retained in the heat cycle of the steam generator, since the mechanical work of the steam turbine is utilized in form of the compression heat of the combustion air (to the extent that the latter is not cooled), and the heat losses of the auxiliary steam turbine together with the vaporization heat of the consumed steam are returned to the feed water.

The invention of the present application is directed to the features disclosed and claimed herein involving generation of steam by subjecting a compressed combustible charge to combustion and applying the pressure of the hot combustion gases to impart to the gases high velocities through heating tubes of an evaporator holding steam generating fluid, and utilizing the energy of the gases discharged from the tubes for impelling a gas turbine driving the compressor supplying the gaseous medium for the combustible charge. The steam generating apparatus and operation disclosed above in connection with the exemplifications of the foregoing invention embodies many other novel features relating to the utilization of high velocity compressed combustion gases for steam generation as described and

claimed in my copending applications, Serial No. 333,453 filed January 18, 1929, Serial No. 343,745 filed March 1, 1929, Serial No. 343,746 filed March 1, 1929, Serial No. 375,138 filed July 1, 1929, and
 5 Serial No. 414,428 filed December 16, 1929.

The invention is not limited to the specific details of construction and methods of operation described above, but many other modifications thereof will suggest themselves to those skilled
 10 in the art. It is accordingly desired that the appended claims be given a broad construction commensurate with the scope of the invention within the art. The terms steam, steam generating fluid and steam generator as used in describing the
 15 practical exemplifications of my invention refer not only to steam generated by heating water which is chiefly employed in all vapor power plants at present, but as used in the specification and claims are intended to include broadly all
 20 other equivalent vaporizable liquids suitable for vaporization by heat conveyed thereto and for utilization as a power medium.

I claim as my invention:

1. A steam generator comprising a pressure-
 25 proof combustion chamber, means including a compressor for continuously supplying a combustible charge under pressure of predetermined range to said chamber and for continuously subjecting said charge to combustion in said chamber,
 30 an auxiliary gas turbine driving said compressor, a heat exchanger holding a steam generating fluid and having a set of heating tubes connected between said chamber and said gas turbine, said heating tubes having expansion
 35 nozzles at their chamber inlets and being constructed and arranged relative to the associated elements to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said tubes at a velocity of
 40 about 200 meters per second or more to heat said fluid and generate steam, and to discharge the cooled down gases from said gas tubes into said gas turbine with only enough energy to drive said gas turbine with an amount of power ap-
 45 proximately equal or less than that required to produce in said compressor means the pressure necessary to so drive the combustion gases, and means for supplying deficiencies between the power required by the compressor and the power
 50 supplied by the gas turbine.

2. A steam generator comprising a pressure-
 proof combustion chamber, means including a compressor for continuously supplying to said
 55 chamber a compressed combustible charge and subjecting said charge to continuous combustion producing therefrom hot combustion gases of a predetermined high pressure range in said chamber, heat exchange means for holding a
 steam generating fluid having heating surfaces
 30 constituting ducts having at one end expansion nozzle inlets connected to said chamber and at the other end outlets for discharging the gases from said ducts, said ducts and associated elements being proportioned and constructed to
 35 convert the pressure head of the gases in said chamber into velocity of the order of 200 meters per second or more imparted to the gases at said nozzle inlets for discharging the gases through the ducts to transfer heat from said gas to said fluid and generate steam, and means for ap-
 40 plying the energy available in the gases discharged from said duct outlets to the heat cycle of said generator, including a gas turbine connected to said outlet openings and impelled by
 45 the discharged gases to drive said compressor.

3. A vapor generator comprising a pressure-
 proof combustion chamber, means including a compressor for continuously supplying to said
 chamber a compressed combustible charge and
 80 subjecting said charge to continuous combustion producing therefrom hot combustion gases of a predetermined high pressure range in said chamber, a gas turbine for driving said compressor, heat exchange means for holding a vaporizable liquid having heating surfaces constituting ducts
 85 having at one end expansion nozzle inlets connected to said chamber and at the other end outlets to said gas turbine, said ducts and associated elements being proportioned and constructed to convert at their chamber inlets the
 90 pressure of the gases into velocity of the order of 200 meters per second or more imparted to the gases for discharging through the ducts to transfer heat from said gas to said liquid and generate vapor, leaving a substantially reduced
 95 amount of energy in the gases discharged from said ducts for impelling said gas turbine, the amount of energy left in the gases discharged from the ducts being only approximately equal or less than the amount needed by the gas turbine to drive the compressor for producing in the
 100 combustion chamber the pressure required to impart to the gases the high velocity, and means for supplying deficiencies between the power required by the compressor and the power delivered
 105 by the gas turbine.

4. A steam generator comprising a pressure-
 proof combustion chamber, means including a compressor for continuously supplying a com-
 pressed combustible charge of predetermined
 110 pressure range to said chamber and for continuously subjecting said charge to combustion in said chamber, an auxiliary gas turbine having a blading driving said compressor, a heat exchanger holding a steam generating fluid and
 115 having a set of heat exchanging ducts constituting nozzles extending from said combustion chamber to said blading to charge the latter with gases of combustion from said chamber driving said turbine, said ducts having expansion nozzles at
 120 their chamber inlets and being proportioned and constructed relative to the associated elements to apply the pressure of the gases in said chamber for imparting to the hot combustion gases a high velocity of the order of 200 meters per second or
 125 more at the chamber inlets into said ducts, driving the gases through said ducts to transfer the heat of the gases to said fluid and generate steam, and to discharge the cooled down high velocity gases from the ducts into said turbine for driving said compressor.

5. A steam generator comprising a pressure-
 proof combustion chamber, means including a compressor for continuously supplying to said
 135 chamber a combustible charge under pressure and subjecting said charge to continuous combustion producing therefrom hot combustion gases of high pressure head in said chamber, a gas turbine for driving said compressor, heat exchange means for holding a steam generating fluid having
 140 heating surfaces constituting ducts connected between said chamber and said gas turbine, said ducts having expansion nozzles at their chamber inlets, and being proportioned and constructed to apply the pressure head of the gases in said
 145 chamber for imparting to the hot combustion gases a high velocity of the order of 200 meters per second or more at the chamber inlets into said ducts, driving the gases through said ducts to transfer the heat of the gases to said fluid and
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generate steam, and to discharge the cooled down high velocity gases from the ducts into said turbine for driving the same.

6. A steam generator comprising a pressure-proof combustion chamber, means including a compressor for continuously supplying a combustible charge of predetermined pressure range to said chamber and for continuously subjecting said charge to combustion in said chamber, an auxiliary gas turbine driving said compressor means, a heat exchanger holding a steam generating fluid and having a set of heating tubes connected between said chamber and said gas turbine, said tubes having expansion nozzles at their chamber inlets and being constructed and arranged relative to the associated elements to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said tubes at a velocity of about 200 meters per second or more to heat said fluid and generate steam, leaving in said gases after discharge from said tubes only enough energy to drive said gas turbine with an amount of power approximately equal or less than that required to produce in said compressor means the pressure necessary to so drive the combustion gases, and an auxiliary motor assisting said gas turbine in driving said compressor and supplying deficiencies between the power required by the compressor and the power supplied by the gas turbine.

7. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for continuously supplying to said chamber a combustible charge under pressure and subjecting said charge to continuous combustion producing therefrom hot combustion gases of predetermined high pressure range in said chamber, a gas turbine for driving said compressor, heat exchange means for holding a liquid having heating surfaces constituting ducts having expansion nozzle inlets connected to said chamber and outlets connected to said gas turbine, said ducts and associated elements being proportioned and constructed to convert at their chamber inlets the pressure of the gases into velocity of the order of 200 meters per second or more imparted to the gases for discharging through the ducts to heat said liquid and generate vapor, leaving a substantially reduced amount of energy in the gases discharged from said ducts for impelling said gas turbine, the amount of energy left in the gases discharged from the ducts being only approximately equal or less than the amount needed by the gas turbine to drive the compressor for producing in the combustion chamber the pressure required to impart to the gases the high velocity, and an auxiliary motor assisting said gas turbine in driving said compressor and supplying deficiencies between the power required by the compressor and the power supplied by the gas turbine.

8. The method of generating steam for supplying a steam consuming load which comprises driving a compressor to continuously supply a compressed combustible charge to a pressure-proof chamber, continuously subjecting said charge to combustion, producing combustion gases of high pressure in said chamber, applying the pressure of the combustion gases to impart to said gases a velocity of about 200 meters per second at expansion nozzle inlets of heating tubes driving the gases through the tubes to transfer a part of the heat of the gases to a steam generating fluid surrounding said tubes, and generating steam, applying the cooled down gases

leaving said tubes to the blades of a gas turbine to drive with the remnant energy of the gases the compressor supplying the compressed charge, while maintaining the amount of energy left over in the gases delivered to said gas turbine about equal or less than the amount of energy required to drive the compressor to supply the charge at a pressure sufficient to drive the gases at the high velocity, and supplying additional compressing power to compress said charge to complement deficiencies in power of said gas turbine below that required to supply to the charge a pressure sufficient to drive the gases at the high velocity.

9. The method of generating steam for supplying a steam consuming load which comprises driving a compressor to continuously supply a compressed combustible charge to a pressure-proof chamber, continuously subjecting said charge to combustion, producing combustion gases of high pressure head in said chamber, applying the pressure head of the combustion gases to impart to said gases a velocity of about 200 meters per second at the expansion nozzle inlets of heating tubes driving the gases through the tubes to transfer the major part of the heat of the gases to a steam generating fluid surrounding said tubes, and generating steam, and discharging the cooled down high velocity gases leaving said tubes into the blades of a gas turbine to drive with the remnant energy of the gases the compressor supplying the compressed charge, while maintaining the amount of energy left over in the gases delivered to said gas turbine about equal or less than the amount of energy required to drive the compressor to supply the charge at a pressure sufficient to drive the gases at the high velocity, and supplying deficiencies between the power required by the compressor and the power supplied by the gas turbine.

10. The method of generating steam for supplying a steam consuming load which comprises driving a compressor to continuously supply a compressed combustible charge to a pressure-proof chamber, continuously subjecting said charge to combustion, producing combustion gases of high pressure in said chamber, applying the pressure of the combustion gases to impart to said gases a velocity of about 200 meters per second at the inlets of heating tubes driving the gases through the tubes to transfer the major part of the heat of the gases to a steam generating fluid surrounding said tubes, and generating steam, applying the cooled down gases leaving said tubes to the blades of a gas turbine to drive with the remnant energy of the gases the compressor supplying the compressed charge, while maintaining the amount of energy left over in the gases delivered to said gas turbine about equal or less than the amount of energy required to drive the compressor to supply the charge at a pressure sufficient to drive the gases at the high velocity, and supplying additional driving power to said compressor complementing deficiencies in power of said gas turbine below that required by said compressor.

11. A steam generator comprising a pressure-proof combustion chamber, means including a compressor for supplying to said chamber a compressed combustible charge and producing therefrom hot combustion gases of predetermined high pressure range in said chamber, heat exchange means for holding a steam generating fluid and having heating surfaces constituting ducts hav-

ing at their inlet side expansion nozzles connected to said chamber proportioned and constructed to apply the pressure in said chamber for driving the hot gases from the chamber through the ducts at a predetermined high velocity range to heat said fluid and generate steam, a gas turbine connected in series with said ducts to apply only enough or less energy of said gases discharged from said ducts in said gas turbine as required for driving said compressor to supply to the charge sufficient pressure for imparting to the gases said predetermined velocity range, and an auxiliary motor supplying to said compressor additional driving power in an amount sufficient to enable the compressor to produce the required pressure in said combustion chamber.

12. A steam generator comprising a pressure-proof combustion chamber, charging means including a compressor for supplying to said chamber a compressed combustible charge and producing therefrom hot combustion gases of predetermined high pressure range in said chamber, heat exchange means for holding a steam generating fluid and having heating surfaces constituting ducts having at their inlet side expansion nozzles connected to said chamber, said ducts and the associated elements being proportioned and constructed to apply the pressure in said chamber for driving the hot gases from the chamber through the ducts at a velocity of about 200 meters per second or more to heat said fluid and generate steam, a gas turbine connected in series with said ducts to apply a lower portion of said pressure for impelling said gases discharged from said ducts at lowered temperature safe for gas turbines through said gas turbine for driving said compressor, and an auxiliary motor supplying to said compressor additional driving power in an amount sufficient to enable the compressor to produce the required pressure in said combustion chamber.

13. A steam generator comprising a pressure-proof combustion chamber, means including a compressor for supplying to said chamber a combustible charge under pressure and producing

therefrom hot combustion gases of high pressure head in said chamber, heat exchange means for holding a steam generating fluid and having heating surfaces constituting ducts connected to said chamber proportioned and constructed to apply the pressure head in said chamber for driving the hot gases from the chamber through the ducts at a high velocity to heat said fluid and generate steam, a gas turbine connected in series with said ducts to convert the energy of said gases discharged from said ducts within said turbine into mechanical power for driving said compressor, and an auxiliary heat motor supplying to said compressor additional driving power in an amount sufficient to enable the compressor to produce the required pressure head in said combustion chamber, said auxiliary heat motor having its heat cycle coupled to the heat cycle of said steam generator returning thereto heat not utilized in compressing work.

14. A steam generator comprising a pressure-proof combustion chamber, means including a compressor for supplying to said chamber a combustible charge under pressure and producing therefrom hot combustion gases of high pressure head in said chamber, heat exchange means for holding a steam generating fluid and having heating surfaces constituting ducts connected to said chamber proportioned and constructed to apply the pressure head in said chamber for driving the hot gases from the chamber through the ducts at a high velocity to heat said fluid and generate steam, a gas turbine connected in series with said ducts to convert the energy of said gases discharged from said ducts within said turbine into mechanical power for driving said compressor, an auxiliary steam turbine supplying to said compressor additional driving power in an amount sufficient to enable the compressor to produce the required pressure head in said combustion chamber, and means for applying the exhaust steam of said auxiliary steam turbine for preheating the steam generating fluid of said heat exchanger means.

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