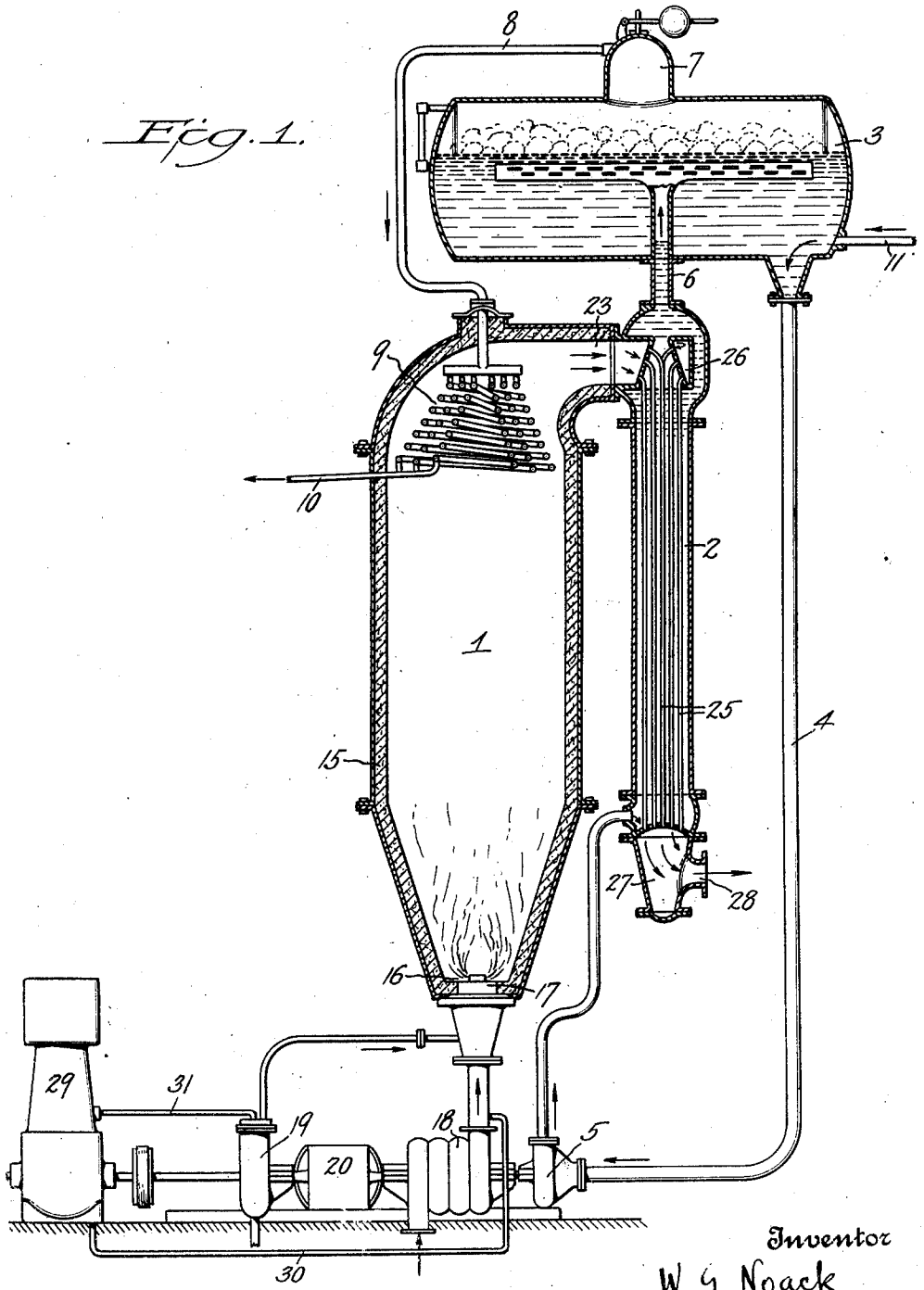
Feb. 27, 1934. W. G. NOACK 1,948,537

STEAM GENERATOR

Filed Dec. 16, 1929 2 Sheets-Sheet 1

Fig. 1.



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Feb. 27, 1934. W. G. NOACK 1,948,537

STEAM GENERATOR

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Fig. 3.

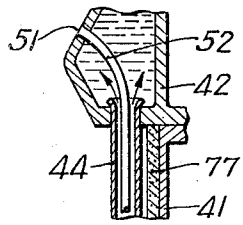


Fig. 4.

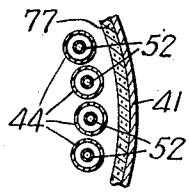


Fig. 2.

Fig. 9.

Fig. 7.



Fig. 5.

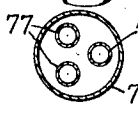


Fig. 6.

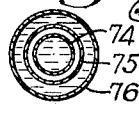


Fig. 8.



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UNITED STATES PATENT OFFICE

1,948,537

STEAM GENERATOR

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Application December 16, 1929, Serial No. 414,428, and in Germany December 19, 1928

17 Claims. (Cl. 122—24)

This invention relates to steam generators and is a continuation in part of my copending applications S. No. 333,453 filed January 18th, 1929, S. No. 343,745 filed March 1st, 1929, S. No. 343,746 filed March 1st, 1929 and S. No. 375,138 filed July 1st, 1929. Among the objects of the invention is the provision of a novel steam generator of the continuous combustion type, in which the combustion mixture is burned under high pressure, and the pressure is utilized to discharge the combustion gases at high velocity along heat exchanger surfaces holding a steam generating fluid, thereby securing higher efficiency, economy in construction, space and operation, and better control.

The invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings wherein,

Fig. 1 is a diagrammatic view of a boiler system exemplifying one form of the invention;

Fig. 2 is a diagrammatic view of a boiler system embodying another form of the invention;

Fig. 3 is a detail sectional view of a portion of the boiler unit of Fig. 2 illustrating the arrangement of the water tubes and of the gas discharge tubes;

Fig. 4 is a horizontal sectional detail view through the boiler of Fig. 2 along line IV—IV of Fig. 2;

Figs. 5 and 6 are horizontal sectional views through the water tubes and gas discharge tubes of boiler unit, such as shown in Fig. 2, illustrating modified construction details;

Fig. 7 is an elevational view of a gas discharge tube of boiler as shown in Fig. 2;

Fig. 8 is a horizontal sectional view of one end of the gas discharge tube of Fig. 7;

Fig. 9 is a view similar to Fig. 8 of the other end of the gas discharge tube of Fig. 7.

In my prior applications referred to above, I have described novel steam generators in which a combustible mixture was delivered to a closed combustion chamber and there subjected to explosion-like combustion, like in explosion type combustion engines, the pressure increase produced by the explosion combustion being utilized to impart to the gases a very high velocity near the sound velocity along heat exchange surfaces for vaporizing water circulated thereacross. In the preferred type of steam generator of the present invention, a combustible charge is continuously supplied under raised pressure to a pressure-proof combustion chamber, and therein subjected to continuous combustion, the pressure in the combustion chamber being applied to impart to the combustion gases a similar high velocity through heater tubes of a heat exchanger for heating a steam generating fluid.

In accordance with the invention the pressure conditions in the combustion chamber, the dimensions of the gas discharge tubes, and the entire system of the boiler are so designed and chosen as to cause the gases of combustion to stream adjacent the heat exchange surfaces or boiler tubes, with a velocity near 300 meters per second or more. In order to impart to the combustion gases this velocity, a certain pressure drop must take place in the discharge conduits, that is, the pressure within the combustion chamber must be a multiple of the pressure in the flue or exhaust. If the loss of pressure on account of tube friction and the other factors governing the operation are taken into consideration, and if in addition, the lower value of the velocity of the combustion gases is taken as about 200 meters per second, there is obtained the value approximately 1.7 as a minimum pressure ratio, for which the above described higher rate of heat transmission will take place, although favorable results will be obtained even with ratios which are somewhat smaller.

To secure such conditions, the continuous combustion boilers of my invention have the combustion carried out in a pressure tight chamber, such as is used, for example, in constant pressure gas turbines, and the combustion air and the fuel are supplied to the chamber under pressure, as by a compressor. The combustion gases are of increased pressure, and are discharged from the combustion chamber, through suitably dimensioned heater tubes at a velocity of about 200 meters per second or more to secure the high rate of heat transmission across the heat exchange surfaces.

I shall now describe, for purposes of illustration, embodiments of my invention in which the advantages resulting from the high velocity flow of the combustion gases along the heat exchange surfaces are secured in boilers in which the combustion process is carried on continuously under substantially constant pressure, as in constant pressure combustion turbines.

The exemplification of the invention shown in Fig. 1 comprises a boiler plant having a combustion chamber 1, a heat exchanger 2, a steam separator drum 3, and associated and auxiliary control apparatus.

Water from the drum 3 is supplied through supply pipes 4 by means of a circulating water

pump 5 to the heat exchanger 2. In passing through the heat exchanger, part of the water is vaporized and water with the steam comingled with it is then returned through the pipe 6 to the steam separator drum 3 where the steam separates and collects in the collector dome 7. The wet steam from the dome 7 is then led through the superheater 9 mounted within the combustion chamber 1 and pipes 10 to the apparatus where it is to be utilized, such as steam turbines, not shown. Fresh feed water is supplied to the boiler system by means of feed water pipe 11 connected to the drum 2, for instance.

The combustion chamber 1 and the heat exchanger 2 are constructed generally in a way similar to the construction of the explosion type boiler illustrated in Figs. 2 to 4 of my application, Serial No. 375,138, suitably modified for use in a continuous combustion process instead of an explosion type combustion process. The combustion chamber is shown in the form of a pressure-tight sheet-metal chamber of steel or similar material having its walls lined with a heat insulating layer 15, of a suitable clay for instance. The lower end of the combustion chamber tapers down to a central inlet opening 16 at which is mounted a burner 17. To this burner, there is supplied a combustible mixture to secure combustion under substantially constant pressure conditions.

The combustible mixture is obtained by admitting to the burner compressed air and fuel. The air may be supplied by a compressor 18 and the fuel may be in the form of a liquid that is supplied by means of a fuel pump 19. The compressor 18 and the fuel pump 19 may be driven either separately or in common as by means of an electric motor 20, which may also serve to operate the water circulating pump 5 referred to before. The compressor 18 is connected directly to the inlet 16 of the combustion chamber 1, so that the compressed air delivered to the chamber to form the combustion mixture carries with it the heat of compression imparted to it in the compressor 18.

The combustion chamber 1 is provided with a gas outlet duct 23 by means of which the hot gases of combustion developed under pressure in the closed combustion chamber 1 are conveyed to the heat exchanger 2. The combustion chamber 1 is arranged to cooperate with one or more heat exchangers 2 in the same way as described in my above mentioned prior applications. The heat exchanger is shown in the form of an elongated cylindrical vessel of sheet metal having longitudinally mounted therein a large number of gas discharge tubes 25. In the upper end of the heat exchanger, there is provided an annular gas inlet chamber 26 and at the lower end of the heat exchanger, there is provided a gas outlet chamber 27. The gas discharge tubes 25 have their upper ends connected to the gas inlet chamber 26 and their lower ends to the gas outlet chamber 27. The gases of combustion discharged from the combustion chamber 1 through the gas outlet duct 23 pass into the inlet chamber 26 of the heat exchanger, wherefrom they are discharged at high velocity through the gas discharge pipes 25 into the outlet chamber 27 whence they pass through the exhaust outlet 28.

By a suitable choice of the dimensions of the gas discharge tubes 25, the combustion chamber 1, the pressure with which the combustion mixture is admitted to the combustion chamber, and the other details of construction, the combustion may be carried out in such manner as to impart to the gases of combustion developed in chamber 1 a pressure sufficiently high above the pressure at the exhaust end of the heat exchanger as to cause the combustion gases to flow through the gas discharge pipes 25 with a velocity of about 200 meters per second or more. In this way, a very high rate of heat exchange between the streaming combustion gases and the water surrounding the gas discharge pipes 25 is obtained as explained before, and efficient boiler operation is secured. By maintaining the water flowing through the heat exchanger in rapid circulation, the rate of steam generation is still further increased.

The superheater 9 may be arranged in the form of a pipe coil disposed near the outlet duct on the top of the combustion chamber 1, as shown in the drawings, or the superheater pipes may be distributed adjacent to the walls of the combustion chamber as in the construction shown in Figs 2 to 4 of my application, Ser. No. 375,138. The compressor 18, for supplying the combustible mixture to the combustion chamber under pressure may be driven, as shown, by electromotor 20 or it may, preferably, be arranged for drive by a steam turbine or by a combustion engine, in the manner illustrated in my prior applications referred to above.

The size of such combustion engine for driving the compressor may be materially decreased if such engine is operated with supercharging, that is, if the combustion air and fuel are supplied in compressed form. In such case, I preferably utilize the compressor which supplies the compressed combustible mixture to the combustion chamber of the boiler system, also for supplying the combustible mixture under pressure to the engine. This is illustrated in the drawings where a combustion engine 29 is shown arranged to be coupled to the compressor aggregate 18. The combustible mixture for the engine 29 is supplied by a pipe 30 branching off from the compressed air supply line leading to the combustion chamber 1 and fuel supply line 31 branching from the fuel supply line leading to the burner 17 of the combustion chamber 1. Any other arrangement, such as those shown in my previous applications referred to above, may, of course, likewise be utilized.

Instead of separate heat exchangers or vaporizers 2, I may provide a plurality of individual tube members or boiler tubes to serve as vaporizers. Such vaporizer may be made in the form of a tube having one or more pipes extending through its center for carrying the hot combustion gases at high velocity. The water which is to be vaporized is circulated through the enclosing tube in the direction opposite to the flow of the gases.

If a steam turbine is used for driving the compressor, it may, with advantage, be constructed and operated as a back pressure or bleeder turbine under utilization of its bleeder and exhaust steam for preheating the feed water for the steam generator.

According to my invention, the compressor load is so chosen that the steam required by the back pressure turbine for driving the compressor is approximately sufficient to preheat the feed water to near the temperature of vaporization.

If an internal combustion chamber, such as a gas machine, Diesel engine, or the like, is used for driving the compressor, I preferably utilize the exhaust gases of such driving engine for pre-

heating the boiler water. In such case, I may admix the exhaust gases of the driving engine with the exhaust gases coming from the heat exchanger and utilize the mixture of these gases for preheating purposes in economizers or the like.

A steam generator embodying these features is shown in Figs. 2 to 6. The generator comprises a pressure-proof combustion chamber casing 41 of steel or similar pressure proof material. The upper end of the combustion chamber casing 41 is provided with a water outlet head 42 and the lower end of the combustion chamber casing is provided with a water inlet head 43. The chamber 41 is lined along its circumference with a layer of longitudinally extending water tubes 44 having their upper and lower ends tightly secured within suitable openings in the water outlet chamber 42 and water inlet chamber 43, respectively. The water tubes 44 are preferably slightly bent so as to flex and adjust themselves in place in accordance with temperature conditions without introducing excessive strains into the construction and without breaking loose from their connections.

The water inlet chamber 43 is of annular shape and has its inner wall arranged to form an upwardly tapering inlet 45 into the combustion chamber 41. At the lower end of the inlet there is mounted a burner 46 at which the combustible mixture is subjected to combustion. The combustion mixture may, for instance, be provided by a mixture of compressed air supplied from a compressor 47 and fuel supplied by a fuel pump 48. As in the structure shown in Fig. 1, the burner 46 may be constructed in the form of the burners developed for use in constant pressure combustion turbines, as described, for instance in the book of A. Stodola on "Steam and Combustion Turbines", published in 1927 by McGraw-Hill Company, New York.

The water outlet chamber 42 may likewise be of annular form and is provided at the lower end of inner wall with a row of openings 51 to which are tightly secured the upper ends of a series of gas discharge pipes or nozzles 52. These gas discharge pipes or nozzles extend downwardly through the water tubes 44 and are connected at their lower ends to an annular gas outlet chamber 53, having an exhaust opening 54 leading to an exhaust duct 55. Over the center opening of the annular water outlet chamber is mounted a superheater head 56 which carries a system of superheater pipes 57 to which steam that is to be superheated is admitted through the inlet chamber 58 and from which superheated steam flows through the outlet chamber 59 into the supply line 60 which delivers it to the load, such as steam turbines of a power plant.

The interior of the water outlet head 42 is connected to a steam collecting vessel, such as a separator drum 61. Water that is near the vaporizing temperature is circulated by pump 62 through pipe 63 by way of the water inlet chamber 43 and caused to flow upwardly through the water tubes 44 and then through the water outlet chamber 42 by way of pipe 64 into the drum 61. Feed water may be directly admitted to drum 61 by feed water pipe 65. The combustion gases which are developed under pressure within the enclosed combustion chamber 41 are discharged through gas outlet pipes 52 in the direction opposite to the direction of the flow of the water in the water tubes 44, the gases being discharged at high velocity to secure the high rate of heat exchange as explained before. The exhaust gases leave the boiler through the exhaust opening 54 and are used for preheating the feed water.

The water tubes with the gas discharge pipes extending therethrough may be arranged in the form as shown in Fig. 4 where a single gas discharge pipe extends through the length of the water tube; or they may be arranged as shown in Fig. 5 where several gas discharge tubes 71 are nested in a single water tube 72, thereby forcing the water to circulate in thin layers and increasing the rate of steam generation. Another advantageous arrangement is shown in Fig. 6 wherein three concentric tubes 74, 75, 76 are arranged one within the other, the water being circulated through the inner tube 74 and the space between the outer tube 76 and the intermediate tube 75, while the gas is discharged through the concentric space between the inner tube 74 and the intermediate tube 75.

The gas discharge tubes of the arrangements described above have their cross-sections suitably designed so as to secure the desired velocity of gas flow in order to give the most favorable conditions of heat exchange. The different portions of the gas discharge tubes may be of different cross-section in accordance with the specific volume of the exhaust gases and the different values of the flow velocities. This may be secured either by connecting tubes of different cross-section to each other or by restricting the cross-section of a given tube, as by pressing it flat, so that one end assumes an oval cross-section, as shown in Figs. 7 to 9.

The utilization of individual boiler tubes or vaporizers, as illustrated in Fig. 2, makes it possible to employ these tubes as a lining for the combustion chamber so as to make it altogether unnecessary to provide a separate fire-proof insulating lining for the combustion chamber or to permit the utilization of a thinner insulating lining 77.

The compressor 47 for supplying the combustion air at a high pressure and impart to the combustion gases a high velocity through the heater tubes 52 for securing a high rate of steam generation may be driven by an auxiliary steam turbine 81. The turbine 81 may be arranged to receive driving steam through pipe 84 from the supply pipe 60. The steam turbine 81 is preferably operated as an extraction and back pressure turbine, and may be utilized also for driving the water pump 62 and the fuel pump 48. The feed water from supply pipe 85 is heated in the preheater 86 by steam extracted from turbine 81 through tap 87, and then again preheated in the second preheater 88 by the exhaust steam coming from the turbine through exhaust pipe 89. The steam is condensed by the water in the preheaters 86, 88 and the preheated water is led through pipe 90 to the water pump 62 and admixed to the water circulated by the pump. In this way all the heat of the supplied steam that is not utilized in compressing the air by the compressor is returned to the feed water and applied for steam generation.

The compressor 47 may also be driven by an auxiliary piston-type explosion motor 91. The exhaust gases of the explosion motor 91 are led through pipe 92 to the exhaust duct 55 and admixed with the exhaust gases from the heat exchanger gas tubes 52. A feed water preheater 93 provided in the outlet duct 55 conveys the remnant heat in the exhaust gases from the heater tubes 52 and the explosion motor 91 to the feed

water which flows from the supply pipe 85, through pipe 94, the preheater 93 and pipe 95 to the water pump 62, being admitted to the water circulated through the water tubes 44. The explosion motor 91 is preferably arranged to be charged under pressure, being supplied with compressed air through pipe 99 leading from compressor 47 and with fuel through pipe 100 leading from fuel pump 48. The heat cycle of the explosion motor 82 is thus likewise interlinked with the heat cycle of the steam generator, the heat not utilized in the motor being applied for raising the temperature of the water that is evaporated.

The invention of the present application is directed to the features disclosed and claimed herein involving the utilization of compressed high-temperature combustion gases for imparting to the gases a high velocity and thereby securing high transfer of heat to a vaporizable substance and generation of vapor, and more particularly the use of continuous compression and combustion for the operation of the generator. The steam generator apparatus and operation disclosed above in connection with the exemplification of the foregoing invention embodies many other novel features relating to the utilization of high velocity compressed combustion 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 Serial No. 419,026 filed January 7, 1930.

The various apparatus and mechanisms and the details of operation to which I referred above in describing my invention are intended only as exemplifications, as many modifications and variations thereof may be utilized in carrying out the principles of my invention. I accordingly desire 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 generation as used in describing the 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 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-proof combustion chamber, means including compressor means for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having gas discharge ducts connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, and means for passing a steam generating fluid to be heated around said ducts.

2. A steam generator comprising a pressure-proof combustion chamber, a gas outlet member, a heat exchanger having ducts connected between said combustion chamber and said outlet member to discharge hot gases of combustion from said chamber, means for passing a steam generating fluid to be heated around said ducts, and means including compressor means for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, the pressure of the hot combustion gases in said chamber and said ducts being proportioned and constructed in such relation to the pressure conditions in said outlet member as to cause said combustion gases to be driven by their pressure through said ducts at a velocity of about 200 meters per second or higher.

3. A steam generator comprising a pressure-proof combustion chamber, means including a compressor for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having gas discharge ducts connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, means for passing a steam generating fluid to be heated around said ducts, heat-energized motor means for driving said compressor, and means interlinking the heat cycle of said motor means with the heat cycle of said steam generator delivering thereto heat from said motor means not utilized in compressing work.

4. A steam generator comprising a pressure-proof combustion chamber, means including compressor means for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having gas discharge ducts connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, and means for passing a steam generating fluid to be heated around said ducts in a direction opposite to the direction of the gas flow in said ducts.

5. A steam generator comprising a pressure-proof combustion chamber, means including compressor means for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having gas discharge ducts connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, a steam separator vessel, tubular enclosure means surrounding said ducts connected to said separator, and means for driving a preheated steam generating fluid through said enclosure means to said separator.

6. A steam generator comprising a pressure-proof combustion chamber, means including compressor means for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having a plurality of gas discharge tubes connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, a steam separator vessel, a plurality of fluid tubes sur-

rounding said gas tubes and connected to said separator, and means for driving a preheated steam generating fluid through said fluid tubes to said separator, said fluid tubes with the gas tubes in the interior thereof being disposed within said combustion chamber along the walls thereof as heat protection therefor.

7. A steam generator comprising a pressure-proof combustion chamber, means including a compressor for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having gas discharge ducts connected to said combustion chamber and arranged to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, a steam separator vessel, tubular enclosure means surrounding said ducts connected to said separator, means for driving a preheated steam generating fluid through said enclosure to said separator, heat-energized motor means for driving said compressor, and means interlinking the heat cycle of said motor means with the heat cycle of said steam generator delivering to the fluid driven through said enclosure means heat supplied to said motor means but not utilized in compressing work.

8. A steam generator comprising a pressure-proof combustion chamber, a gas outlet member, a heat exchanger having ducts connected between said combustion chamber and said outlet member to discharge hot gases of combustion from said chamber, means for passing a steam generating fluid to be heated around said ducts, and means including compressor means for continuously supplying to said chamber a combustible charge of a predetermined pressure range at least 1.7 times greater than the pressure in said outlet member and for subjecting said charge to combustion in said chamber at the supplied pressure, said ducts being constructed and proportioned to cause the pressure of the combustion gases in said chamber to drive the gases through said ducts at a velocity of about 200 meters per second or higher.

9. A steam generator comprising a pressure-proof combustion chamber, means including compressor means supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to combustion at the supplied pressure in said chamber, and heat exchanger means for holding a steam generating fluid and having heating surfaces constituting gas discharge ducts connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more.

10. A steam generator comprising a pressure-proof combustion chamber, means including a compressor supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to combustion under pressure in said chamber, a heat exchanger means for holding a steam generating fluid and having heating surfaces constituting gas discharge ducts connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, heat-energized motor means for driving said compressor, and means interlinking the heat cycle of said motor means with the heat cycle of said steam generator delivering thereto heat supplied to said motor means but not utilized in compressing work.

11. A steam generator comprising a pressure-proof combustion chamber, means including compressor means for continuously supplying a combustible charge of a predetermined pressure range to said chamber and for subjecting said charge to continuous combustion therein at the supplied pressure, a heat exchanger having a plurality of gas discharge tubes connected to said combustion chamber proportioned and constructed to cause the pressure of the hot combustion gases in said chamber to drive said combustion gases through said ducts at a velocity of about 200 meters per second or more, a steam separator vessel, a plurality of fluid tubes surrounding said gas tubes and connected to said separator, means for driving a preheated steam generating fluid through said fluid tubes to said separator, said fluid tubes with the gas tubes in the interior thereof being disposed within said combustion chamber along the walls thereof as heat protection therefor, and superheater tubes extending through said chamber for superheating steam from said separator vessel.

12. The method of generating steam for supplying a steam consuming load which comprises compressing a gaseous body and forming therewith a combustible charge of substantial raised pressure, subjecting said combustible charge to combustion under raised pressure, and applying the pressure of the compressed hot combustion gases for imparting to said gases a velocity of about 200 meters per second or more along a heat exchange surface separating the gases from a steam generating fluid to transfer heat thereto and generate steam.

13. The method of generating steam for supplying a steam consuming load which comprises applying heat energy for compressing a gaseous body and forming therewith a combustible charge of substantial raised pressure, subjecting said combustible charge to combustion under raised pressure, applying the pressure of the compressed hot combustion gases for imparting to said gases a velocity of about 200 meters per second or more along heat exchange surfaces separating the gases from a steam generating fluid to transfer heat thereto and generate steam, and delivering part of the heat applied to compressing said charge but not utilized in compressing work to the steam generating fluid for preheating the same.

14. The method of generating steam for supplying a steam consuming load which comprises applying a heat motor for driving a compressor to compress a gaseous body and form therewith a combustible charge of substantial raised pressure, subjecting said combustible charge to combustion under raised pressure, applying the pressure of the compressed hot combustion gases for imparting to said gases a velocity of about 200 meters per second or more along heat exchange surfaces separating the gases from a steam generating fluid to transfer heat thereto and generate steam, and delivering part of the heat supplied to said heat motor but not utilized in compressing work to the steam generating fluid for preheating the same.

15. The method of generating steam for supplying a steam consuming load which comprises

continuously compressing a gaseous body and forming therewith a combustible charge of substantial raised pressure, continuously subjecting said combustible charge to combustion under raised pressure, and applying the pressure of the compressed hot combustion gases for imparting to said gases a velocity of about 200 meters per second or more along heat exchange surfaces separating said gases from a steam generating fluid to transfer heat thereto and generate steam.

16. The method of generating steam for supplying a steam consuming load which comprises applying heat energy for continuously compressing a gaseous body and forming therewith a combustible charge of substantial raised pressure, continuously subjecting said combustible charge to combustion under raised pressure, applying the pressure of the compressed hot combustion gases for imparting to said gases a velocity of about 200 meters per second or more along heat exchange surfaces separating said gases from a steam generating fluid to transfer heat thereto and generate steam, and delivering part of the heat applied to compressing said charge but not utilized in compressing work to the steam generating fluid for preheating the same.

17. The method of generating steam for supplying a steam consuming load which comprises applying a heat motor for driving a compressor to continuously compress a gaseous body and form therewith a combustible charge of substantial raised pressure, continuously subjecting said combustible charge to combustion under raised pressure, applying the pressure of the compressed hot combustion gases for imparting to said gases a velocity of about 200 meters per second or more along a set of heat exchange surfaces separating said gases from a steam generating fluid to transfer heat thereto and generate steam, and delivering part of the heat supplied to said heat motor but not utilized in compressing work to the steam generating fluid for preheating the same.

WALTER GUSTAV NOACK.