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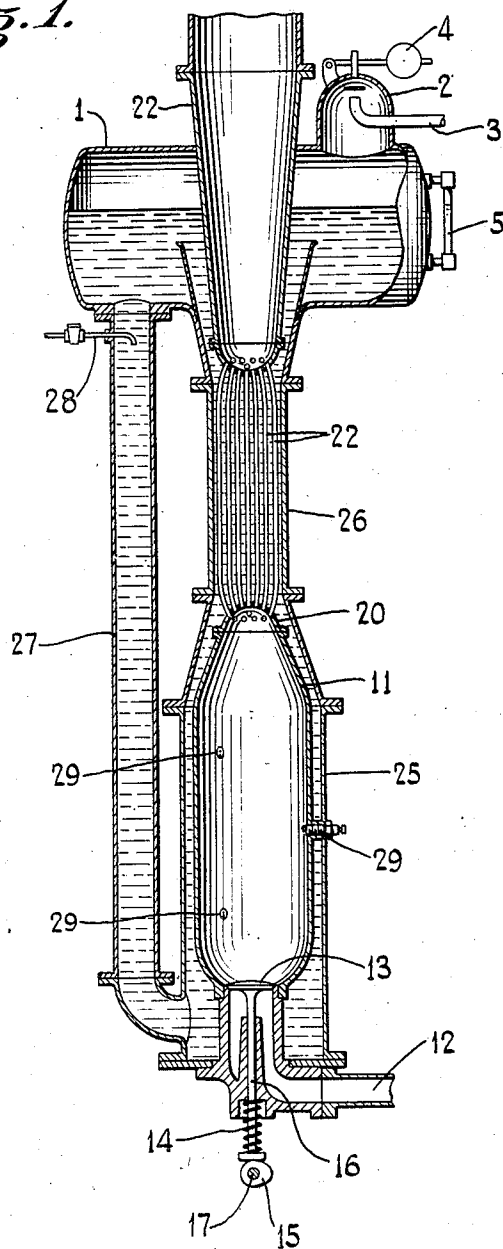
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1,993,748

STEAM GENERATOR

Original Filed Jan. 18, 1929 3 Sheets-Sheet 1

Fig. 1.



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Original Filed Jan. 18, 1929 3 Sheets-Sheet 2

Fig. 2.

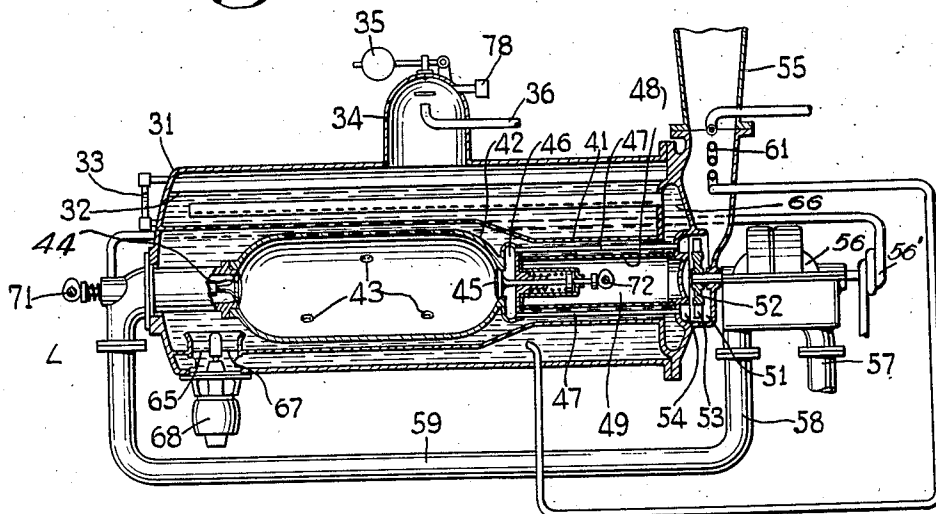
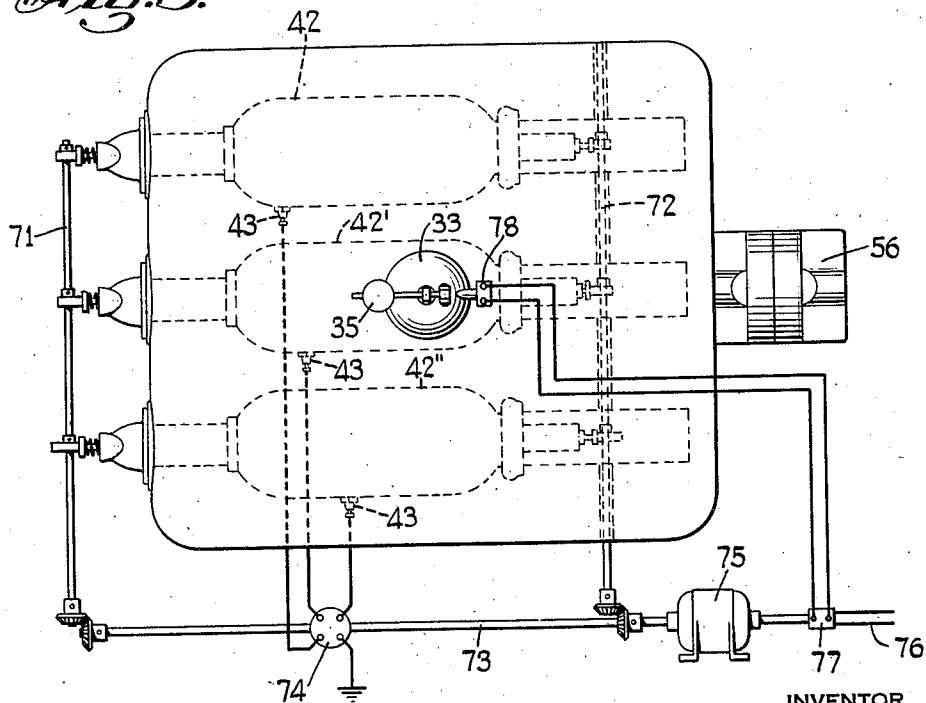


Fig. 3.



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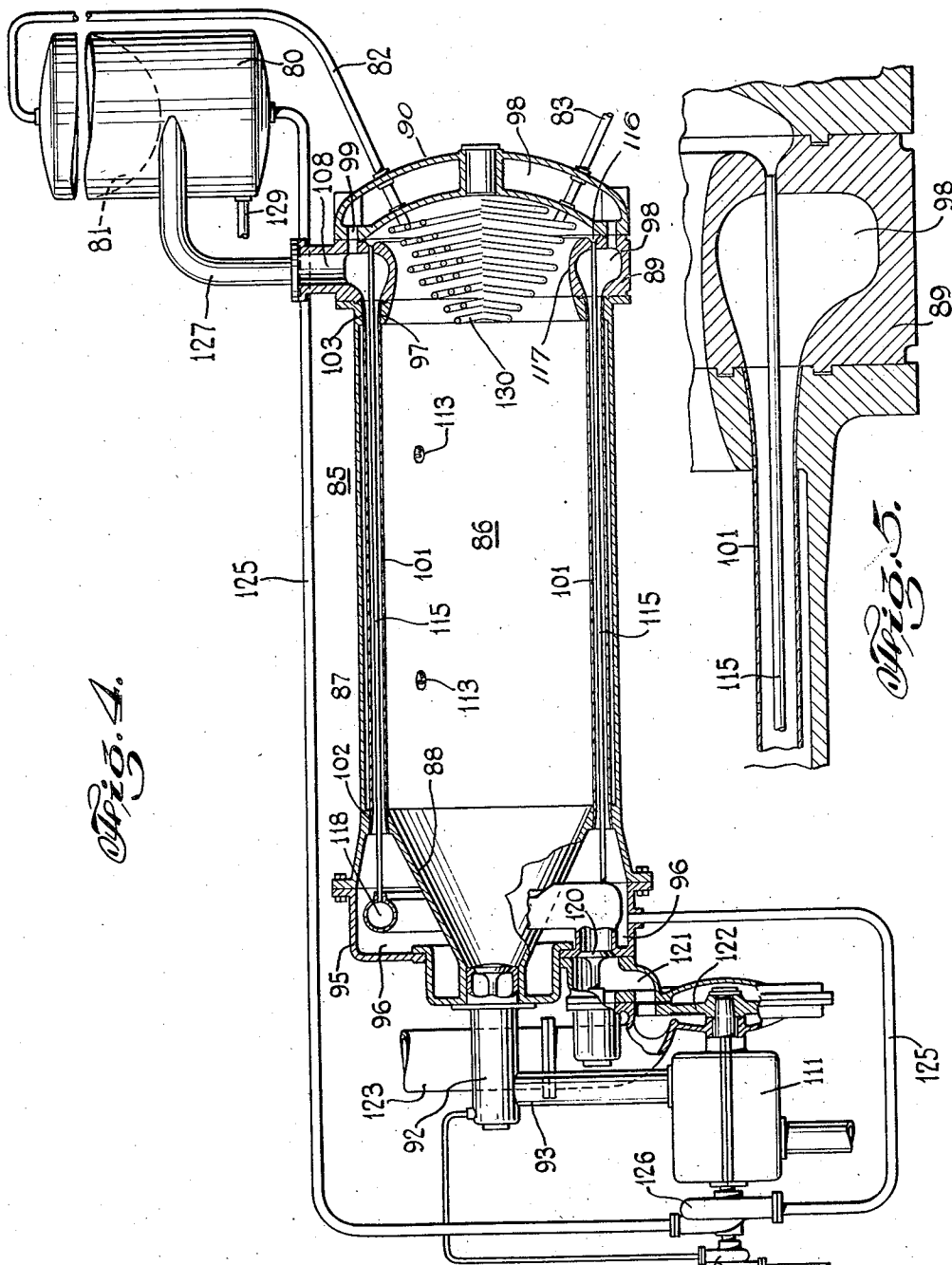
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Original Filed Jan. 18, 1929 3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

1,993,748

STEAM GENERATOR

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Continuation of application Serial No. 333,453, January 18, 1929. This application February 23, 1934, Serial No. 712,573. In Germany December 19, 1928

18 Claims. (Cl. 122-24)

This application is a continuation of my co-pending application, Serial No. 333,453, filed January 18, 1929, and a continuation in part of my applications, Serial No. 343,745 and Serial No. 343,746, filed March 1, 1929, and Serial No. 414,428, filed December 16, 1929, upon which Patents No. 1,948,535, No. 1,948,536 and No. 1,948,537, respectively, were issued on February 27, 1934.

This invention relates to steam generators and it has among its objects the provision of a novel steam generator in which a compressed combustible charge is subjected to explosive combustion in a pressure-proof combustion chamber and the resulting high pressure head is chiefly applied for imparting to the hot combustion gases high velocities through heating ducts of an evaporator holding a steam generating liquid, such as water, to secure by high heat transfer and with small heating duct cross sections a high rate of steam generation.

A further object of the invention is utilization of the remnant pressure and energy of the cooled combustion gases discharged from the heating ducts for impelling a gas turbine and applying the gas turbine for driving a compressor which compresses the charge supplied to combustion chamber.

The boiler plants for modern steam turbine stations cost about 60% of the whole plant. Through the use of high velocity heat exchange and the explosion type combustion, it is possible to reduce all the dimensions of the boiler plant to only a fraction of that required at present, thus effecting an unusually great saving in the space and the costs of boiler plants.

Even greater advantages are obtained through the application of the new steam generator of my invention on board of ships or on locomotives and similar vehicles. On the shipboard, for instance, especially on cruisers or other war ships, the great reductions in the space and weight occupied by the boiler plant have enormous value because they enable increase of the loading capacity, armament, radius of action, etc., to values which heretofore could not be reached.

The foregoing and other objects of 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 vertical sectional view through a steam generator embodying one form of the invention;

Fig. 2 is a view similar to Fig. 1 embodying another form of the invention;

Fig. 3 is a horizontal diagrammatic view of a steam generator as shown in Fig. 2 with automatic control of the combustion cycles;

Fig. 4 is a view similar to Fig. 1 embodying a further form of the invention; and

Fig. 5 is a detail sectional view of the heating nozzle inlet mounting of Fig. 4.

Combustible charges such as mixtures of air and atomized fuel, or mixtures of air and a combustible gas, or a combustible gas, burn or explode much quicker and with greater temperatures in closed vessels under increase of pressure than in open spaces at atmospheric pressure. Thus, for instance, relatively large combustion spaces are required for the open-fire chambers of steam boilers in order to give the mixture the required time for complete combustion and to prevent the escape of unburnt parts of the mixture. On the other hand, fuel, such as gas, oil, coal powder, and similar finely distributed materials, will burn or explode in closed combustion chambers in a fraction of a second. The size of the combustion chamber space in such cases does not depend any more on the time required for effecting complete combustion, but merely on the quantity of the combustible mixture used for each explosive cycle.

The present invention utilizes this phenomenon of quick combustion in a closed space under increase of pressure for steam generators, causing the fuel, such as gas, oil, carbon dust, or the like, to explode or burn in closed combustion chambers and applying the heat released during the combustion in a special way for the generation of steam.

The transfer of heat by a gaseous medium depends to a high degree on its density and its velocity of flow. A much greater heat transfer is obtained if the heat-carrying medium passes across the heat exchange surface at high velocity. According to the invention this is taken advantage of by utilizing the increase of pressure, produced by the combustion in the closed combustion chamber, for imparting to the gases of combustion a high streaming velocity across the heat exchange surfaces of an evaporator so that relatively small heat exchange surfaces are sufficient for transferring the heat set free by the combustion to the water that is to be evaporated.

The increase of the velocity of the gases is made as large as practically feasible and the

gases are discharged with velocities which may even exceed the velocity of sound.

In accordance with the invention the pressure conditions in the combustion chamber, the dimensions of the gas discharge tubes and the entire system are so designed and chosen as to cause the gases of combustion to pass adjacent the heat exchange surfaces of the evaporator tubes with a velocity near 300 meters per second, or, in general, with velocities of about 200 meters per second or more, including velocities above 150 meters per second.

The principles of the invention will be best understood by reference to its exemplifications shown in the drawings.

In Fig. 1 is shown a vertical steam generator comprising a steam collector drum 1 which is filled with water up to the level indicated in the drawings. On the top of the drum is disposed a steam dome 2 from which the steam may be taken off through a steam outlet pipe 3. A safety valve 4 and a water gauge 5 of familiar construction are provided on the drum. Underneath the drum is mounted the heat generation and evaporator apparatus arranged and operating in the novel way pointed out before. This apparatus consists of a closed pressure-proof combustion chamber 11 which is charged with a combustible charge through the feed pipe 12 connected to the bottom of the combustion chamber by an inlet valve 13. This inlet valve, as shown in the drawings, may be automatically held in closed position, as by means of a spring 14, the seat arrangement being such that under higher inner pressure in the combustion chamber 11, the valve is held against its seat in closed position. The inlet valve 13 is arranged to admit fresh combustible mixtures at the end of each explosion or combustion period to the combustion chamber 11, this admission being effected by suitable control of the valve, for instance, through a cam 15 acting on the push rod 16 of the valve, the cam being actuated by a motor driven shaft 17 or in some other suitable way to secure a periodical action of the valve 13.

The combustible charge is suitably supplied to the feed pipe 12, any suitable means being used for this purpose, for instance, any of the usual means for mixing liquid or gaseous fuels with air such as are employed in explosion engines or gas turbines may be applied. A compressor serves to compress the charge and to admit it in compressed condition to the combustion chamber 11. This compression of the charge may by itself be used to control the admission of the charge to the combustion chamber in which case the control of the valve 13 through a cam 15 is omitted, the fuel charge being admitted into the combustion chamber after the charging pressure has risen to a sufficiently high value to overcome the pressure which holds the valve 13 on its seat.

A plurality of nozzle-like heater tubes or nozzles 21 are connected to the tapered outlet portion 20 of the combustion chamber. These heater tubes or nozzles 21 serve as heat exchange surfaces and terminate in the narrow end of a tapered exhaust duct 22 extending through the collector drum 1 for discharging the gases. The combustion chamber 11 and the heater pipes 21 are surrounded throughout their length with tubular water jackets 25, 26, respectively, which lead into the collector drum 1. Water is circulated through the jackets along the walls of the combustion chamber 11 and the heater nozzles 21 by a return duct 27 which is connected between

drum 1 and the lower part of the water jacket 25 surrounding the explosion chamber. Feed water may be admitted through a feed water inlet 28 connected to the return duct 27.

Ignition of the combustible charge in the combustion chamber 11 is effected by spark plugs 29 provided in the chamber. The explosion periods are suitably controlled by familiar means such as used in explosion engines or turbines to ignite the charge.

The operation of the steam generator as shown in Fig. 1 is as follows:

A combustible charge is admitted under an initial pressure into the combustion chamber 11 through the inlet valve 13 and the valve is closed. Thereupon the charge is ignited by the spark plugs 29. The charge undergoes a brief explosion-like combustion and the resulting increase of the pressure of the produced hot combustion gases drives the hot combustion gases with great velocity through the narrow nozzle-like heater tubes 21 into the exhaust duct 22. The hot combustion gases acquire thus great velocity and the internal heat and kinetic energy of the outflowing gases are given up to the heat exchange surfaces of the heater tube walls, the kinetic energy being given up in the form of friction losses or friction heat. Upon the termination of the outflow of the combustion gases, a fresh combustible gas charge is admitted and the process is repeated. Where the fresh charge is admitted in compressed form without the use of a special control of the inlet valve 13 by means of the cam 15, the fresh charge is admitted as soon as its charging pressure exceeds the pressure in the interior of the combustion chamber, thus automatically opening the inlet valve 13, at the appropriate moment, this process likewise repeating itself periodically.

Because of the small cross section of the heater tubes 21 and the resulting high flow resistance, it is possible to maintain a sufficient charging pressure without providing an outlet valve at the outlet end of the tubes 21.

The heat delivered to the walls of the combustion chamber and of the heater tubes 21 is conveyed to the water for steam generation. The heated water passes with high velocity over these heating surfaces, the jackets around the combustion chamber and the heater tubes being shaped to cause the water to flow in a thin layer closely to the surfaces which are heated. The circulation of the water is produced by the difference of the weight of the light body of water filled with steam bubbles flowing upwardly around the system of heater tubes 21 within the jackets 25 and 26, and the colder bubble-free heavier water returning downwardly through the left-hand return pipe 27 to the bottom of the combustion chamber jacket 25. The generated steam separates from the water in the upper drum 1 and accumulates in the top portion thereof.

Figs. 2 and 3 show a modification of the steam generator of the invention. It comprises a large pressure-proof tank 31 filled with water up to level line 32. A water gauge 33 and a steam dome 34 with a safety valve 35 and a steam outlet 36 are arranged on the top portion of the tank.

In the interior of the tank are provided one or more tubular water guiding jackets 41. Within each jacket 41 is mounted a combustion chamber 42 arranged similarly to the combustion chamber 11 of Fig. 1. A plurality of spark plugs 43 mounted on the surface of the combustion chamber serve for igniting the combustible charge. An inlet valve 44 controls the inlet of the combustible

charge into the chamber 42. A set of heater tubes or nozzles 45 surrounded by water extends from the interior of the combustion chamber and may, like in Fig. 1, open directly into the chamber, the flow resistance in the tubes being sufficient to maintain the charging pressure in the chamber.

Where higher charging pressure is desired, a gas outlet chamber 46 may be provided at the outlet end of the chamber, with an outlet valve 47 which is normally closed and opens only to discharge the gases from the chamber. The heater tubes or nozzles 45 extend in an annular row in front of the outlet chamber, being confined between the outer guiding jacket 41 and an inner guiding jacket 48 for guiding the water along the heater tubes. The inner jacket wall 48 forms a chamber 49 for housing the mechanism to close and open the outlet valve 46.

The outlet ends of the heater tubes 47 open into an exhaust space 51 in the form of a gas turbine which has a turbine rotor 52 with a blade system 53 into which the cooled combustion gases discharged from the heater tubes are directed by a stationary blade system 54. From the turbine rotor 52 the exhaust gases are discharged into the stack 55. The turbine rotor 52 is coupled to a compressor 56 by means of which the air with fuel substances admixed thereto or the gas mixture used for combustion is compressed. The compressed air or the gas mixture is received at the inlet 57 of the compressor and is delivered from the outlet 58 through a feed pipe 59 to the inlet valve 44 of the combustion chamber 42.

In some cases enough heat remains in the gases escaping from the exhaust turbine for utilization to preheat the feed water, and suitable water heaters may be arranged for this purpose in the exhaust space as indicated at 61.

In the foregoing arrangement the fuel or fuel mixture may be compressed by the compressor 56 and sent through the pipe 59 to the inlet valve 44 of the combustion chamber 42; or, only compressed air may be delivered through the pipe 59, and the fuel, such as oil, injected into the compressed air while or after it is discharged into the combustion chamber 42, by providing, for instance, a fuel pump which delivers the fuel at the inlet valve 44 into the combustion chamber.

The use of a gas turbine for driving the compressor is extremely economical because the gas turbine is driven by gases, which have already given up the greatest part of their heat, but still retain a substantial amount of energy in the form of velocity, heat and pressure. By the expansion of these gases and delivering their power in the gas turbine, the gases are deprived of their entire energy content. The energy (heat) which is converted by the gas turbine into compression work goes, but for the small losses due to bearing friction, back to the heat cycle of the steam generator in the form of compression heat. Through the expansion, and the working in the gas turbine, the hot gases are cooled to a very low temperature. If any heat is still left in the gases, additional heater surfaces 61 may be provided which deliver the remnant heat to the feed water of the generator.

The gas turbine may be operated as an explosion gas turbine in which the gases are discharged against the wheel in the form of a series of impulses, that is, with variable pressure and heat drops, or it may also be arranged for operation as a constant pressure turbine by accumulating the gases in the space in front of the turbine

inlet blade system 54, to equalize their pressure and then discharging the gases with constant pressure into the blades.

To secure effective heat transfer from the high velocity gases flowing at high velocity through heater tubes 45, the outer guiding jacket 41 and the inner guiding jacket 48 are shaped to cause the water to flow in a thin layer along the heated surfaces. Sufficient water circulation is maintained by providing in an opening 65 in the lower front portion of guide jacket 41 a pump 67 which pumps water from the bottom of tank 31 and drives it in a thin layer along the outer heat exchange surfaces of the combustion chamber 42 and the heater tubes 45, discharging the water with the steam admixed thereto into a drum 66 from which the water steam mixture is returned through pipes 21 into the upper space of tank 31 where the steam separates from the water. The circulation pump 67 may be driven by an electric motor 68, or in some other suitable way.

The operation of the steam generator is similar to that shown in Fig. 1. The inlet valve 44 is opened to admit the combustible charge. Thereupon the valve closes and the charge is ignited by the spark plugs 43, producing hot combustion gases of high pressure. Thereupon the outlet valve 47 is opened and under the action of the high pressure, the hot combustion gases stream out through the heater tubes 45 giving up to the surrounding water the energy produced by combustion and compression. A part of the energy is used for driving the compressor by means of which the charge is compressed. The water which is highly heated in a thin circulating layer adjacent to the heating surfaces of the combustion chamber and the heater tubes, with the steam formed therein, passes into the tank, the steam separating and accumulating at the top portion of the latter.

The explosions of the combustion charge are repeated periodically, and after each explosion, the hot combustion gases are discharged under the action of the generated pressure at high velocity through the heater tubes. Since the pressure in the combustion chamber is highest at the beginning of each discharge period, the velocity of the gases through the heater tubes 21 is greater at the beginning of the discharge period than at its end. Toward the end of the discharge period the velocity may drop down to about 200 meters per second, although satisfactory operation may be obtained even in case the gas velocity in the heater tubes drops down to about 150 meters per second at the end of the discharge period.

The control of the valves may be effected in the same way as in the arrangement shown in Fig. 1. Where an outlet valve is provided as well as an inlet valve, it is preferable to use a common control of the two valves as well as of the ignition. This may be effected, for instance, by a cam shaft that is driven by a special motor. As an alternative arrangement for operating the valves and the ignition, other well known controlling and operating devices may be used.

The control of the valves and of the ignition enables a very close regulation of the steam generation since the number of the combustion cycles, that is, the number of the explosions, may be changed by varying the speed of the control sequence. A number of such explosion-type combustion chambers may with advantage be combined with such regulating system. The time sequence of the explosions in the several

chambers may readily be controlled through the valves of the individual chambers.

By controlling the valves, the compressor, and the feed water flow, the generator of the steam may be controlled directly in accordance with the variations of the steam demand, making possible the use of small water spaces.

Such automatic control of the valves is shown diagrammatically in Fig. 3. The boiler, of a construction such as illustrated in Fig. 2 but viewed from the top, is shown provided with three explosion chambers 42, 42' and 42''. The inlet valves 44 are controlled by a cam shaft 71. The outlet valves 47 are controlled by a cam shaft 72, the two cam shafts being driven by a main control shaft 73 which also drives the ignition device and distributor 74. The control shaft 73 is arranged to be driven by an electric motor 75 that is supplied from a line 76, the operation of the motor being controlled by a controlling device 77 in accordance with the variation of the pressure conditions in the boiler as determined by a regulating device 78 connected to the boiler dome. The cams on the two cam shafts 71, 72 are so arranged that the explosions in the three combustion chambers 42, 42', 42'' follow each other in sequence, like the strokes of a three-cylinder engine, and the speed of the cycle may be varied by varying the speed of the control shaft, the latter being controlled through the control device 77 of the electric motor 75 by the regulator 78. This regulator 78 and the arrangement for varying the speed of the motor 75 in accordance with the conditions of the pressure, or some other property of the steam, may be of any well known kind, any standard regulator used in the various electrical applications for varying the speed of a driving motor depending on some given condition being applicable.

Instead of the direct vaporization of the water by its direct contact with the heating surfaces, other systems known in the art may be used.

A part of the heat exchange surfaces of the combustion chamber or of the heater tubes may also be used as a superheater for the steam.

In Fig. 4 is shown a steam generator plant embodying my invention in another form. It comprises a steam separating drum 80 holding in its lower portion water to be evaporized and having in its upper part a steam space 81 with a dome 82 in which the steam separating from the water accumulates to be conveyed to the steam load by steam pipe 83.

The steam generator 85 for generation of the steam comprises a combustion chamber 86 formed of a cylindrical shell 87 enclosed on one end by a conical inlet head 88 and on the other end by a detachable cylindrical closure member 89 having a detachable rear cover 90. Over the forward end of the inlet head 88 is mounted an inlet valve 92 which is supplied with a combustible charge through inlet pipe 93. The conical inlet head 88 has mounted thereover an enclosure member 95 which forms a water inlet duct 96 around the inlet head for receiving the water that is to be vaporized. The rear closure member 89 of the chamber is attached to a rear flange 97 of the chamber shell 87, and has in its interior a hollow water outlet duct 98 for receiving the vaporized mixture of water and steam. The rear cover 90 is also hollow and has a water circulating chamber 98 which is in communication through channels 99 with the water outlet duct 98.

Along the cylindrical inner walls of the combustion chamber shell 87 is mounted a layer of water tubes 101. The front ends of these tubes are firmly mounted within a series of annularly disposed holes 102 in the base of the conical head. The rear ends of the water tubes 25 are similarly mounted within holes 103 of the inwardly projecting portion of the rear flange 97 of the shell, these holes opening into the adjacent outlet duct 98 of the rear closure member 89.

The combustible charge is compressed and supplied by means of a compressor 111 under pressure to the inlet pipe 93 of the inlet valve 92 of the combustion chamber. Any of the combustible mixtures employed in explosion-type engines and gas turbines may be used as combustible charge, the charge being preferably supplied, for instance, by a compressor supplying compressed air, and an auxiliary fuel pump 111a associated with the compressor which injects the fuel into the compressed air.

The initially compressed charge delivered by opening the inlet valve 92 to the combustion chamber 86 to spark plugs 113 are mounted on the interior wall of the chamber.

Through each of the water tubes 25 extends a gas-discharge nozzle-like heater tube 115 of small cross section. The rear ends of the nozzle tubes 115 are secured within a series of annularly disposed nozzle-shaped inlet holes 116 in the inner wall 117 of the closure member 89 in alignment with the holes on its front side that hold the open ends of the water tubes 25. Through these inlet nozzle openings 116 the hot combustion gases within the combustion chamber enter directly from the chamber into the heater tubes 115. The heater tubes 115 extend through the water tubes 102 and the water inlet duct 96 into a gas outlet duct 118, into which they release the combustion gases flowing from the chamber. The gas outlet duct has an outlet valve 120 which releases the gases through the nozzle duct 121 into the blades of a gas turbine 122, imparting driving energy to the turbine wheel, the exhaust gases from the gas turbine passing into the exhaust duct 123 where they may serve for preheating the feed water before being discharged into the atmosphere. The gas turbine 122 is coupled to the compressor 111, and supplies thereto the driving power required to initially compress the combustible charge delivered to the combustion chamber.

Water is circulated between the water space of the separator drum 80 and the water tubes 101 of the combustion chamber by pipe 125 leading from the drum 80 through a circulating pump 126 driven by the gas turbine 122 to the water inlet duct 96 of the chamber, the water flowing then by way of the water tubes 101 into the water outlet duct 98 and therefrom through return tube 127 into the distributor duct 128 within the collector drum 86 where the steam separates from the water and collects in the top of the separator drum 80. Feed water may be supplied to the separator drum 80 by feed water pipe 129.

The operation of the steam generator shown in Fig. 4 is as follows: A combustible gaseous charge is admitted under an initial charging pressure to the interior space of the combustion chamber 86 through inlet valve 92. When charging is completed, the charge is exploded by means of spark plugs 113 within the chamber. Rapid combustion of the charge follows, and at the completion of the combustion the outlet valve 120 of

the outlet duct 118 is opened. Because of the great pressure produced by the combustion in the chamber, the hot combustion gases are discharged through the heating tubes 115 at very high velocity giving up the greater part of their energy in the form of heat to the water in the surrounding water tubes 25. After having passed through the heater tubes 115 the gases still retain a certain part of their pressure and energy and are discharged over valve 120 through nozzle duct 121 into the gas turbine 122 driving the latter, passing therefrom into the exhaust duct 123 where they may be used for preheating feed water as in Fig. 2. Thereupon, a fresh charge is admitted into the combustion chamber 86 through inlet valve 92 and the process thus continuously repeated.

Efficient steam generation is obtained by circulating with the water pump 126 the water through the water tubes 101, the water flowing in a thin layer adjacent the surfaces of the heater tubes 115 along which the hot combustion gases pass with great velocity. The water tubes 101 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. The parts of the combustion chamber which are not covered by the water tubes, namely the front and rear ends, are protected against overheating by making their walls hollow and passing the circulating water there-through. The heat of the gases in the combustion chamber may also be utilized for superheating the steam, and to this end the steam pipe 82 leading the steam from the separator 80 to the load may be connected to a set of superheater tubes 130 carried on the rear cover 90 of the combustion chamber. The superheater tubes 130 superheat the received steam and deliver it over the extension of the steam supply pipe 83 to the load.

The steam generator of Fig. 4 may have several combustion-chamber-evaporator units operate with a single gas turbine, and automatic control and regulation of the valves, ignition, number of cycles, compression and feed-water supply, as described in connection with the steam generator plant of Figs. 2 and 3.

In all embodiments of the steam generators described above, the great heat transfer and the resultant unusually high capacity and responsiveness of the steam generation is made possible by connecting the inlet nozzle openings of the water surrounded nozzle-like heater ducts directly to the combustion chamber, and by the utilization of the high pressure in the combustion chamber to impart to the hot combustion gases their highest velocity at the moment of their entrance into the water-immersed heater tubes when they are at their highest temperature and density, thereby securing maximum obtainable heat transference and steam generation.

The invention is not limited to the details of construction and operation described above, and modifications thereof will suggest themselves to those skilled in the art. I desire, accordingly, that the appended claims be given a broad construction commensurate with the scope of the invention within the art.

I claim:

1. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said

chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of substantially higher pressure of a predetermined range in said chamber, evaporator means for holding a vaporizable liquid having heating surfaces in contact with said liquid and constituting a set of ducts having inlet nozzles opening into said chamber, said inlet nozzles being proportioned to apply a substantial part of said higher pressure of the hot combustion gases in the chamber for imparting to said hot gases a high velocity through said heating ducts to heat said liquid and generate vapor, and means for applying the energy available in the gases not utilized in the evaporator means for the heat cycle of said generator.

2. In a vapor generator, a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means comprising heating surfaces constituting a set of ducts having at one end inlet nozzles opening into said chamber and being of a cross section and length at which the larger part of said pressure head of the hot combustion gases in said chamber imparts to said compressed hot gases a high velocity at said inlet nozzles driving said gases through said ducts, and enclosure means for passing a flowing vaporizable liquid in contact with the entire surface of said ducts heated by the hot gases discharged from said chamber to deprive said flowing gases of heat and generate vapor, and means for applying the energy available in the gases not utilized in the evaporator means for the heat cycle of said generator.

3. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means for holding a vaporizable liquid having heating surfaces in contact with said liquid and constituting a set of ducts having inlet nozzles opening into said chamber and being of a cross section and length constructed and proportioned to apply a substantial portion of the high pressure of the hot combustion gases in the chamber for driving the hot gases at a high velocity through said inlet openings into said heating ducts to heat said liquid and generate vapor, and a gas turbine impelled by the remaining portion of the pressure of the gases not utilized in the evaporator means for driving said compressor to supply initial pressure to the charge.

4. In a vapor generator, a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head within a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means comprising heating surfaces constituting a set of ducts having at one end inlet nozzles opening into said chamber and being of a cross section and length at which the larger part of

said pressure head of the hot combustion gases in said chamber imparts to said compressed hot gases a high velocity at said inlet nozzles driving said gases through said ducts, and enclosure means for passing a flowing vaporizable liquid in contact with the entire surface of said ducts heated by the hot gases discharged from said chamber to deprive said flowing gases of heat and generate vapor, and a gas turbine impelled by the remaining portion of the pressure of the gases not utilized in the evaporator means for driving said compressor to supply initial pressure to the charge.

5. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head within a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means for holding a vaporizable liquid having heating surfaces in contact with said liquid and constituting a set of ducts having inlet nozzles opening into said chamber and being of a cross section and length constructed and proportioned to apply the larger part of said high pressure head of the hot combustion gases in the chamber for driving the hot gases at a high velocity through said inlet openings into said heating ducts to heat said liquid and generate vapor, and a gas turbine impelled by the remaining portion of the pressure head of the gases discharged from the evaporator ducts for driving said compressor to supply initial pressure to the charge.

6. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means comprising heating surfaces constituting a set of ducts having at one end inlet nozzles opening into said chamber and being of a cross section and length at which the larger part of said high pressure head of the hot combustion gases in said chamber imparts to said compressed hot gases a high velocity at said inlet nozzles driving said gases through said ducts, and enclosure means for passing a flowing vaporizable liquid in contact with the entire surface of said ducts heated by the hot gases discharged from said chamber to deprive said flowing gases of heat and generate vapor, and a gas turbine impelled by the remaining portion of the pressure head of the gases discharged from the evaporator ducts for driving said compressor to supply initial pressure to the charge.

7. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a substantially higher pressure of a predetermined range in said chamber, evaporator means for holding a vaporizable liquid having heating surfaces in contact with said liquid and constituting a set of ducts having inlet nozzles opening into said chamber and being of a cross section and length constructed and proportioned to apply said higher pressure of the hot combustion gases in the chamber for driving the hot gases at a velocity of 150 meters per sec-

ond or more through said inlet openings into said heating ducts to heat said liquid and generate vapor, and means for applying the energy available in the gases not utilized in the evaporator means for the heat cycle of said generator.

8. In a vapor generator, a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means comprising heating surfaces constituting a set of ducts having at one end inlet nozzles opening into said chamber and being of a cross section and length at which the larger part of said pressure head of the hot combustion gases in said chamber imparts to said compressed hot gases a velocity of 150 meters per second or more at said inlet nozzles driving said gases through said ducts, and enclosure means for passing a flowing vaporizable liquid in contact with the entire surface of said ducts heated by the high-velocity hot gases flowing from said chamber to deprive said flowing gases of heat and generate vapor, and means for applying the energy available in the gases not utilized in the evaporator means for the heat cycle of said generator.

9. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means for holding a vaporizable liquid having heating surfaces in contact with said liquid and constituting a set of ducts having inlet nozzles opening into said chamber and being of a cross section and length constructed and proportioned to apply said high pressure of the hot combustion gases in the chamber for driving the hot gases at a velocity of 150 meters per second or more through said inlet openings into said heating ducts to heat said liquid and generate vapor, and a gas turbine impelled by the remaining portion of the pressure of the gases not utilized in the evaporator means for driving said compressor to supply initial pressure to the charge.

10. In a vapor generator, a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means comprising heating surfaces constituting a set of ducts having at one end inlet nozzles opening into said chamber and being of a cross section and length at which the larger part of said pressure head of the hot combustion gases in said chamber imparts to said compressed hot gases a velocity of 150 meters per second or more at said inlet nozzles driving said gases through said ducts, and enclosure means for passing a flowing vaporizable liquid in contact with the full length of said ducts heated by the high-velocity hot gases flowing from said chamber to deprive said flowing gases of heat and generate vapor, and a gas turbine impelled by the remaining portion of the pressure of the gases not utilized

in the evaporator means for driving said compressor to supply initial pressure to the charge.

11. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means for holding a vaporizable liquid having heating surfaces in contact with said liquid and constituting a set of ducts having inlet nozzles opening into said chamber and being of a cross section and length constructed and proportioned to apply the larger part of said high pressure head of the hot combustion gases in the chamber for driving the hot gases at a velocity of about 200 meters per second or more through said inlet openings into said heating ducts to heat said liquid and generate vapor, and a gas turbine impelled by the remaining portion of the pressure head of the gases discharged from the evaporator ducts for driving said compressor to supply initial pressure to the charge.

12. A vapor generator comprising a pressure-proof combustion chamber, means including a compressor for periodically supplying to said chamber a combustible charge under pressure and exploding said charge to periodically produce hot combustion gases of a high pressure head of a predetermined range substantially in excess of the charge pressure in said chamber, evaporator means comprising heating surfaces constituting a set of ducts having at one end inlet nozzles opening into said chamber and being of a cross section and length at which the larger part of said high pressure head of the hot combustion gases in said chamber imparts to said compressed hot gases a velocity of about 200 meters per second or more at said inlet nozzles driving said gases through said ducts, and enclosure means for passing a flowing vaporizable liquid in contact with the full length of said ducts heated by the high-velocity hot gases flowing from said chamber to deprive said flowing gases of heat and generate vapor, and a gas turbine impelled by the remaining portion of the pressure head of the gases discharged from the evaporator ducts for driving said compressor to supply initial pressure to the charge.

13. The process of generating vapor comprising initially compressing a gaseous body in a compressor and periodically supplying therefrom a combustible charge under pressure to a pressure-proof combustion chamber, periodically exploding said charge in said combustion chamber producing therein high-temperature combustion gases of a pressure head substantially higher than the pressure of the charge, applying a substantial part of said high pressure head at nozzle inlets of narrow evaporator ducts opening into said chamber to impart to said hot gases a high velocity at said inlets driving said gases through said ducts, passing vaporizable liquid in contact with the length of said ducts traversed by said high velocity gases for heating said liquid and generating vapor, and applying the energy of said gases not utilized in said evaporator ducts for supporting generation of heat in said process.

14. The process of generating vapor comprising initially compressing a gaseous body in a compressor and periodically supplying therefrom a combustible charge under pressure to a pressure-proof combustion chamber, periodically ex-

ploding said charge in said combustion chamber producing therein high-temperature combustion gases of a pressure head substantially higher than the pressure of the charge, applying most of said high pressure head at nozzle inlets of narrow evaporator ducts opening into said chamber to impart to said hot gases a high velocity at said inlets driving said gases through said ducts, passing vaporizable liquid in contact with the full length of said ducts traversed by said high velocity gases for heating said liquid and generating vapor, and applying the energy of said gases not utilized in said evaporator ducts for impelling a gas turbine driving said compressor to compress the gaseous body of the charge.

15. The process of generating vapor comprising initially compressing a gaseous body in a compressor and periodically supplying therefrom a combustible charge under pressure to a pressure-proof combustion chamber, periodically exploding said charge in said combustion chamber producing therein high-temperature combustion gases of a pressure head substantially higher than the pressure of the charge, applying most of said high pressure head at nozzle inlets of narrow evaporator ducts opening into said chamber to impart to said hot gases a velocity at said inlets driving said gases through said ducts, passing vaporizable liquid in contact with the full length of said ducts traversed by said high velocity gases for heating said liquid and generating vapor, and applying the remaining portion of the pressure head of said gases leaving said evaporator ducts for impelling a gas turbine driving said compressor to compress the gaseous body of the charge.

16. The process of generating vapor comprising initially compressing a gaseous body in a compressor and periodically supplying therefrom a combustible charge under pressure to a pressure-proof combustion chamber, periodically exploding said charge in said combustion chamber producing therein high-temperature combustion gases of a pressure head substantially higher than the pressure of the charge, applying said high pressure head at nozzle inlets of narrow evaporator ducts opening into said chamber to impart to said hot gases a velocity of 150 meters per second or more at said inlets driving said gases through said ducts, passing vaporizable liquid in contact with the length of said ducts traversed by said high velocity gases for heating said liquid and generating vapor, and applying the energy of said gases not utilized in said evaporator ducts for supporting generation of heat in said process.

17. The process of generating vapor comprising initially compressing a gaseous body in a compressor and periodically supplying therefrom a combustible charge under pressure to a pressure-proof combustion chamber, periodically exploding said charge in said combustion chamber producing therein high-temperature combustion gases of a pressure head substantially higher than the pressure of the charge, applying most of said high pressure head at nozzle inlets of narrow evaporator ducts opening into said chamber to impart to said hot gases a velocity of 150 meters per second or more at said inlets driving said gases through said ducts, passing vaporizable liquid in contact with the full length of said ducts traversed by said high velocity gases for heating said liquid and generating vapor, and applying the energy of said gases not utilized in said evaporator ducts for impelling a gas turbine

driving said compressor to compress the gaseous body of the charge.

18. The process of generating vapor comprising initially compressing a gaseous body in a compressor and periodically supplying therefrom a combustible charge under pressure to a pressure-proof combustion chamber, periodically exploding said charge in said combustion chamber producing therein high-temperature combustion gases of a pressure head substantially higher than the pressure of the charge, applying most of said high pressure head at nozzle inlets of narrow evaporator ducts opening into said chamber to

impart to said hot gases a velocity of about 200 meters per second or more at said inlets driving said gases through said ducts, passing vaporizable liquid in contact with the full length of said ducts traversed by said high velocity gases for heating said liquid and generating vapor, and applying the remaining portion of the pressure head of said gases leaving said evaporator ducts for impelling a gas turbine driving said compressor to compress the gaseous body of the charge.

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