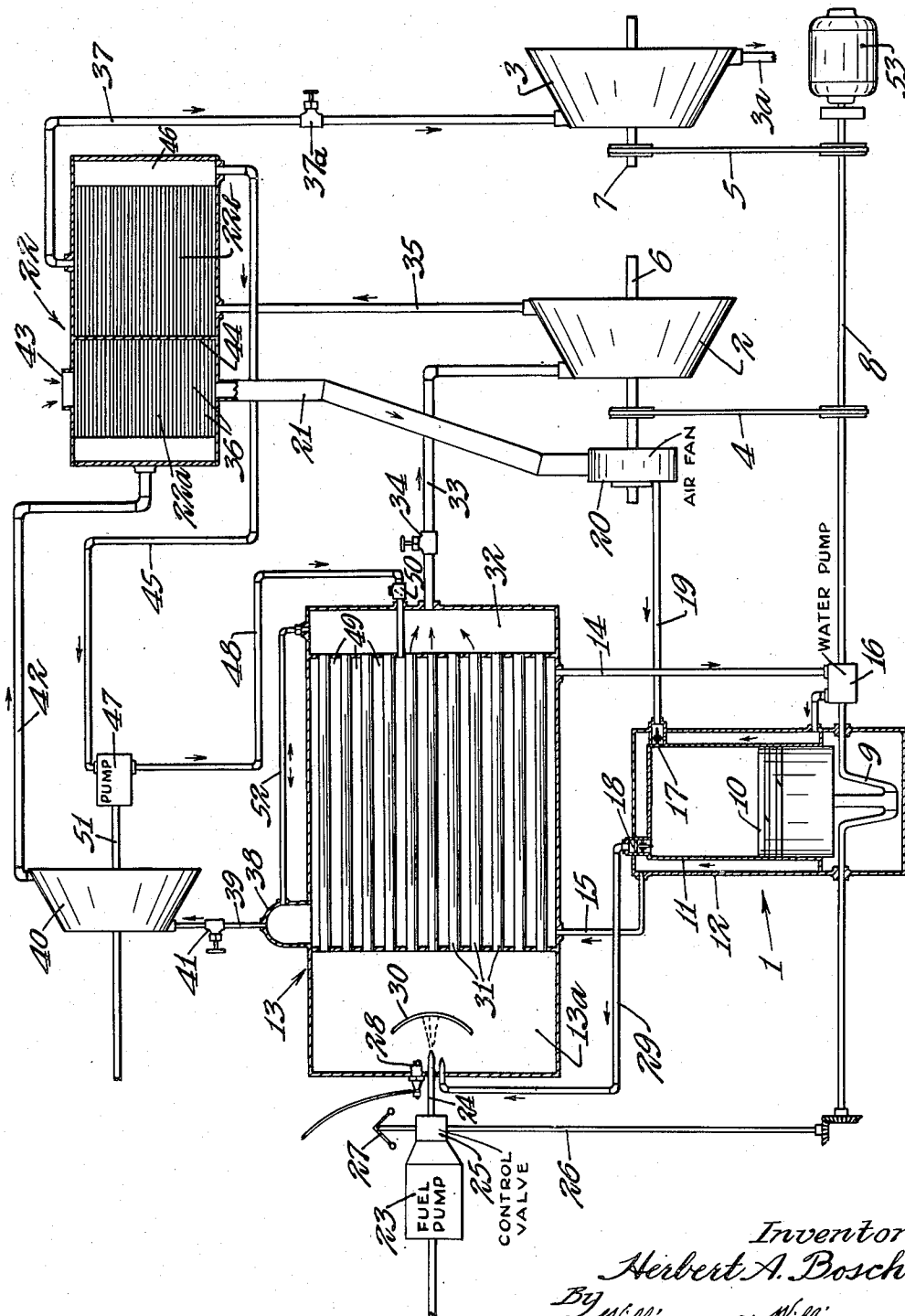


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STEAM POWER PLANT USING EXHAUST FROM AUXILIARY
GAS TURBINE FOR CONDENSING STEAM
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STEAM POWER PLANT USING EXHAUST
FROM AUXILIARY GAS TURBINE FOR
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This invention relates to apparatus for converting the heat energy of fuels into work, particularly wherein the products of combustion are maintained under compression within a steam generator. The invention is adaptable for use as a stationary installation or a power plant in a land, water or air vehicle.

An object of the invention is to provide an apparatus whose construction is relatively low per horse power and to convert into work as much of the heat energy as possible from the fuel.

Generally the method includes burning the fuel and air under a much higher degree of pressure than usual and cooling the gases of combustion by having them pass through or over boiler tubes under pressure in the generation of steam. In so doing the pressure of the steam in the boiler and that of the products of combustion is the same. This permits the use of much thinner and cheaper boiler tubes than used heretofore wherein the tubes have been subjected to a higher pressure only on one side thereof. This condition of equal pressure is maintained by connecting the chamber confining the gases of combustion with the steam chamber in the proper locations and manner hereinafter explained. There is also maintained a counterflow of the gases of combustion or the water and other liquid in the boiler to permit the greatest cooling of the gases of combustion and heating of the boiler liquid in a minimum boiler space. The steam after expanding and doing work is passed through the condenser and condensate returned to the boiler and the heat given off by the steam is recovered. This heat recovered is used to assist combustion.

The gases of combustion because of their relatively high compression are expanded in two or more stages. Since a large range of expansion is provided the products of combustion can be cooled to a considerable extent and still be maintained under relatively high pressure. While in this relatively cool condition the gases are passed through a condenser with a counterflow of exhaust steam wherein the products of combustion are warmed and the steam is condensed. The products of combustion can be expanded to atmospheric pressure at a temperature of approximately 40° F.

The figure in the drawing is a partially diagrammatic layout of a system for practicing my invention, the structure of some of the parts being shown in somewhat detail and in vertical section, other parts being nearly conventionally indicated.

A compressor 1 derives its power from a pair of gas driven turbines 2 and 3 to which the com-

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pressor is connected by belts 4 and 5 which connect the turbine shafts 6 and 7 respectively to a countershaft 8. A crank 9 formed in the countershaft 8 is drivingly connected to the compressor piston 10. The compressor has a cylinder 11 surrounded by a spaced water jacket 12 which is connected to a boiler 13 by pipes 14 and 15. Circulation of water through the jacket 12 is induced by a water pump 16 which pumps water from the relatively cool right hand end section of the boiler 13 into the compressor water jacket 12, and returns it somewhat warmer through the pipe 15 to the left hand end of the boiler which is the high temperature end thereof. The compressor intake and outlet check valves 17 and 18 are operated in a conventional manner.

The valve 18 opens on the compression stroke of the piston 10 and permits air to enter the boiler combustion chamber 13a and the valve 17 opens on the intake stroke of the piston 10 to allow a fresh change of air to enter the compressor cylinder 11 through the pipe 19 which is fed by an air fan 20 which is used to pull air through the pipe 21 and a section 22a of a steam condenser indicated generally at 22, the pressure being approximately 15 pounds per square inch gauge pressure. The fan 20 is mounted on the main shaft 6 of the gas turbine 2.

A fuel pump 23 is mounted at the left hand end of the boiler 13 and has a fuel injection nozzle 24 which extends to the boiler combustion chamber 13a. Interposed in the injection nozzle 24 is a control valve 25 through which extends a shaft 26 having a flyball governor 27 on its upper end. The lower end of the shaft 26 is geared to the main countershaft 8 which drives the compressor 1 and is in turn driven by the gas turbines 2 and 3. The speed of rotation of the turbines 2 and 3 naturally determines the speed of the shafts 8 and 26, and the governor 27 regulates the flow of fuel to the combustion chamber 13a in response to such speeds. A spark plug 28 is provided for ignition of the fuel pumped to the combustion chamber 13a. Air under pressure is supplied from the compressor 1 through a pipe 29 which enters the combustion chamber 13a adjacent the end of the fuel nozzle 24 and the spark plug 28. A shield 30 in the combustion chamber 13a diffuses the burning fuel mixture through the combustion chamber 13a to secure complete combustion before entering the tubes of the boiler 13. The gases of combustion pass through the boiler 13 through tubes 31 to a header 32 at the right hand end of the boiler. A pipe 33 leads from the header 32 to conduct the gases of com-

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bustion to the intake of the turbine 2. A suitable hand valve 34 is interposed in the gas line 33 to assist in maintaining the proper pressure of the combustion gases and regulate their flow.

The combustion gases are partially expanded as they pass through the turbine 2 and are then conducted through a pipe 35 to the section 22b of the condenser 22. The combustion gases pass around the tubes 36 and thence into a pipe 37 which constitutes the intake for the second gas turbine 3. A flow and pressure control valve 37a is interposed in the pipe 37. Turbines 2 and 3 are for the purpose of driving the compressor 1 and the fan 20 respectively and are not for external work.

Mounted on the upper side of the steam boiler 13 is a steam dome or collector 38, and a pipe 39 extends from said dome to the intake of a steam turbine 40. A valve 41 is adapted to permit regulation of steam pressure in the line 39. The steam passing through the turbine 40 is expanded and it passes through the steam outlet pipe 42 and through the tubes 36 of the condenser sections 22a and 22b. The steam is condensed by air entering the inlet 43 of the condenser section 22a under the influence of the pump 20 which is connected to the lower side of the condenser section 22a by the pipe 21. The steam is also condensed by the combustion gases traveling through the condenser section 22b by means of the inlet pipe 35 and outlet pipe 37. A partition 44 separates the condenser sections 22a and 22b to prevent mixture of the air entering the inlet 43 and the combustion gases passing through the condenser sections 22b.

The condensed steam leaves the condenser 22 through a pipe 45 which is connected to a header 46 at the right hand side of the condenser 22. The pipe 45 is connected to a pump 47 and the outlet of the pump is connected by a pipe 48 to the boiler water spaces 49 about the tubes 31 in the boiler. A check valve 50 in the pipe 48 prevents back flow of liquid through said pipe 48. The pump 47 is preferably connected to the shaft 51 of the steam turbine 40.

The steam condenser 22 mentioned above maintains as near as possible a counterflow of the steam fluid and the cooling fluid to permit the greatest efficiency of operation.

A pressure equalizing pipe 52 connects the steam dome 38 with the header 32 which is a portion of the combustion gas chamber in the boiler 13 and said pressure equalizer pipe 52 maintains an equality of pressure on both sides of the tubes 31 in the boiler 13. Consequently, the tubes are not subjected to any unequal pressure and can thereby be made of much lighter material than it has been possible to use heretofore.

A summary of the principal features of the invention is as follows:

A higher compression of the gases of combustion in the boiler tubes to a pressure of 600 pounds per square inch, for example, such pressure being the same on the opposite sides of the boiler tubes; the pressure equalizing conduit connecting the area of the combustion gases with that of the generated steam to secure this equality of pressure; thinner boiler tubes and greater economy of construction as well as greater capacity to exchange heat between the combustion gases and the boiler water; the recovery of the latent heat of vaporization from the condenser 22 for work in a new and simple manner; cooling of the gases of combustion in the first stage of expansion to a point where they can act as a cooling agent in the condenser 22; the conversion of the heat ab-

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sorbed by the combustion gases into work in the second stage of expansion of such gases; and the preheating of air to be used for combustion, said preheating being accomplished in one portion of the condenser 22.

In operation the fan 20 causes a flow of air through the condenser section 22a where the air is warmed somewhat and is preferably at a pressure of 15 pounds per square inch. This air passes from the pump 20 to the compressor 1 and is then pumped from the compressor 1 to the boiler combustion chamber 13a through the pipe 29. Of course, it is understood that the check valve 17 admits air from the pump pipe 19 to the compressor cylinder 11 on the downward stroke of the piston 10, while on the upward stroke of the piston the check valve 17 closes and the valve 18 permits the piston to force air into and through the pipe 29.

At the same time that air is being fed under pressure to the boiler combustion chamber 13a fuel is introduced through the nozzle 24 and is burned with said air under pressure. In normal operation the pressure in the combustion chamber and boiler tubes is approximately 600 pounds per square inch. Because of the high compression the gases of combustion have a higher temperature than would result from combustion without such compression.

Because of the balance of pressures on the inner and outer sides of the boiler tubes 31 they can be made much thinner and need only be constructed to prevent the leakage of liquids and withstand a fairly high temperature. The thickness of the tubes while considerably less than those of a conventional type would necessarily depend upon the material from which they are made and size or diameter, and whether the tubes are to be used in a stationary power plant or built to withstand vibration as in a rapidly moving power plant. The heat exchange capacity of the boiler due to the extreme relative thinness of the boiler tubes is greatly increased beyond the heat exchange capacity of present boilers. The entire boiler could therefore be made smaller and at less expense.

The gases of combustion passing through the tubes 31 are cooled faster by reason of their thinness and as a result a more rapid return of travel through the tubes is possible whereby their capacity is accordingly increased. The pressure of the combustion gases after passing through the tubes is still 600 pounds less of course the small amount necessary to force them to travel through the tubes.

Because the combustion gases are cooled and afford such a large range of expansion they can be expanded to about 100 pounds per square inch and cooled in the process to about 35° to 40° F. The gases passing through the turbine 2 from the boiler 13 are expanded to about 100 pounds per square inch pressure and the valve 34 can be regulated to maintain this pressure. After this expansion the combustion gases are cooled to about 35° to 40° F. and then passed to the condenser section 22b where by reason of a counterflow of condensing steam the combustion gases are considerably warmed. The gases then are conducted to the second gas turbine 3 and are exhausted to atmospheric pressure through the outlet 3a. The valve 37a controls the flow from the condenser section 22b and maintains the proper pressure therein.

The steam generated in the boiler 13 is maintained at about 600 pounds per square inch by a

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proper setting of the valve 41 which controls the rate of flow through the pipe 39. This steam pressure of 600 pounds neutralizes the combustion gas pressure of 600 pounds and relieves the boiler tubes of the necessity of withstanding any pressure. Of course, any differences in pressure are equalized by the pressure equalizing pipe 52. The steam generated in the boiler 13 travels to the steam turbine 40 where it is permitted to expand in operating the turbine. The expanded steam travels through the pipe 42 and through the condenser tubes 36 of the condenser sections 22a and 22b. In passing through those portions of the tubes 36 in the condenser section 22a the steam is cooled by the counterflow of air induced by the fan 20. The steam then passes through those portions of the tubes 36 in the condenser section 22b where it is condensed by a counterflow of the gases of combustion which at that point are relatively cool. The condensed steam is returned to the boiler through the pipes 45 and 48 by the action of the pump 47.

The following might be one method of starting the apparatus. The compressor 1 might be initially started by any suitable means such as an electric motor 53 which also might be used by reason of connection with the main countershaft 8 to start the fan 20 and the fuel pump 23. The fuel mixture is ignited by the spark plug 28 and after ignition electrical energy to said plug is cut off. The steam valve 41 and combustion gas valve 34 would each be closed until the compressor has increased the pressure to approximately 20 pounds per inch. The pressure equalizing pipe 52 will maintain the pressure equal on both sides of the boiler tubes. When the pressure has reached about 20 pounds per inch the valve 34 can be opened whereupon the combustion gases leaving the boiler will operate the turbine 2. The turbine 2 can then be utilized to drive the fan 20, the compressor 1, and the fuel pump 23. As soon as the boiler reaches the correct temperature and pressure the valve 41 can be opened to start the steam turbine 40.

It is evident from the foregoing explanation of the operation of this invention that the entire heat energy of the fuel is converted into work except for unavoidable losses such as radiation, friction, etc. This is evident from the fact that the latent heat of vaporization is recovered from the condenser and converted into work and from the fact that the gases of combustion are released at atmospheric pressure and relatively low temperatures.

It will, of course, be understood that various changes may be made in the form, details, arrangement and proportions of the various parts without departing from the scope of my invention.

I claim:

1. An apparatus of the character described including a combustion chamber having fuel and air inlets, means for delivering fuel and air under pressure to said inlets and burning said fuel under pressure in said combustion chamber, a steam chamber having an inlet for liquid to be vaporized and a steam outlet, said chamber being in heat exchange relationship with said combustion chamber and having conduits therethrough in communication with the combustion chamber for the passage of the products of combustion so that they give off heat to produce steam, a header communicating with the conduits for receiving

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the products of combustion, said header having an outlet for said products, a power unit connected with the steam outlet of the steam chamber for operation by the steam and in which the steam is expanded, a second power unit connected with the outlet of the header for operation by the products of combustion and in which the products are expanded, a heat exchanger including a first section having an air inlet and an air outlet, means affording communication between said outlet and the air inlet of the combustion chamber, a separate, closed heat exchanger section having an inlet and an outlet, through which the partially cooled products of combustion pass, said last mentioned inlet being in communication with said second power unit, conduits passing through both sections of said heat exchanger, inlet and outlet headers in communication with the respective ends of said last mentioned conduits, a conduit extending between said first mentioned power unit and said inlet header for the passage of steam, the steam passing through the conduits in the heat exchanger into the outlet header in successive heat exchange relation with the air flowing through the first section of the heat exchanger and the partially cooled products of combustion flowing through the second section of the heat exchanger so as to preheat the air utilized for combustion, reheat the partially cooled products of combustion and condense the steam to liquid, a conduit extending between and in communication with the outlet header of the heat exchanger and the steam chamber to return the condensed steam and a third power unit connected with the outlet of the second section of the heat exchanger for operation by the reheated products of combustion, said products of combustion being expanded to below atmospheric temperature, said combustion chamber and said conduits being constructed to produce a pressure in said conduit above 600 p. s. i. and said conduits having enough heat transfer surface to produce a low enough temperature in said header to permit said expansion to below atmospheric temperature.

2. An apparatus as defined in and by claim 1 wherein a conduit is provided in communication between the steam chamber and the header that receives the products of combustion for balancing the pressures between the steam chamber and the conduits passing therethrough.

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