

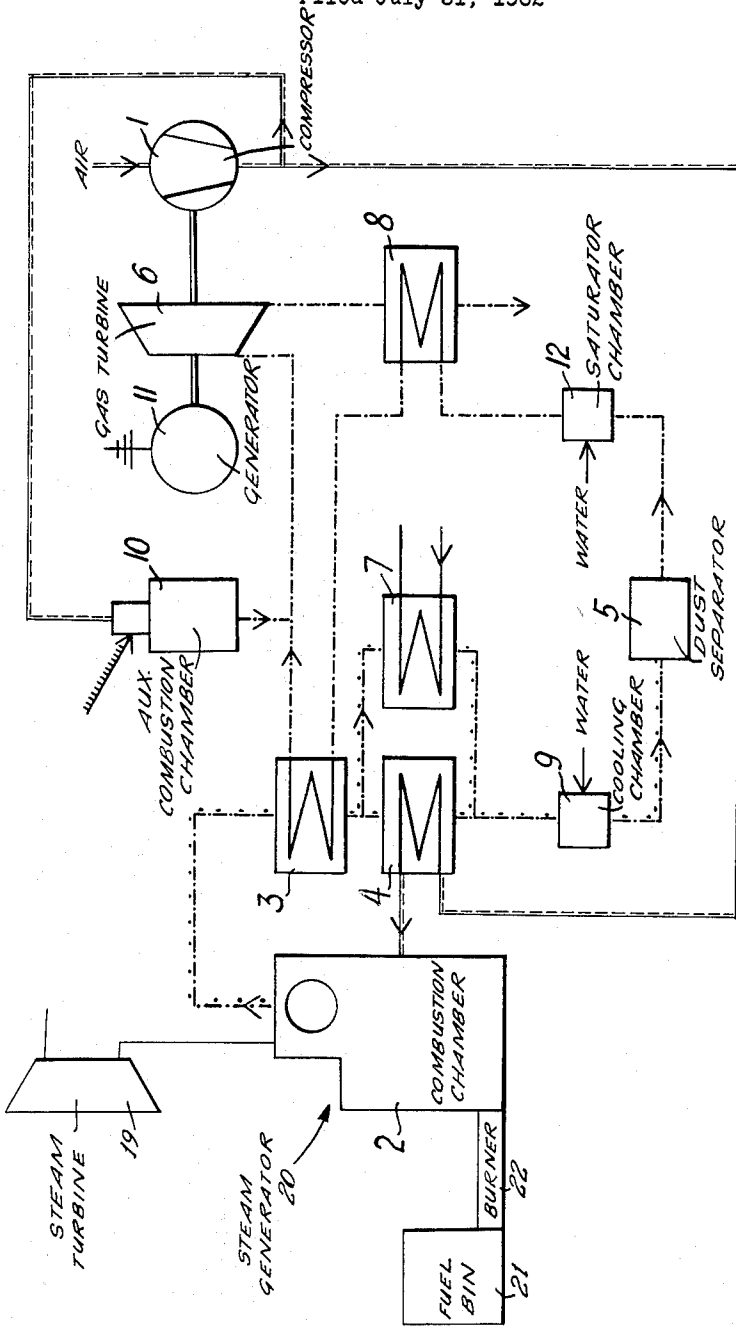
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CHAMBER FOR SOLID FUEL
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SYSTEM OF OPERATION OF A STEAM-GAS CIRCUIT OR OF A GAS CIRCUIT FOR GAS TURBINES COMPRISING A COMBUSTION CHAMBER FOR SOLID FUEL

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This invention relates to an improved operating system of a steam-gas or gas circuit of gas turbines with a combustion chamber for solid fuel, where the combustion products at elevated pressure are separated after burning from the solid remnants of burning, whereas they are at admission temperature and pressure supplied as driving gases into the gas turbine, where they expand and render mechanical energy.

There have been repeated attempts to use solid fuel for the gas turbine circuits. Proposals have been made for instance to burn coal at elevated pressure in a heating chamber and to use a direct passage of the combustion products through the turbine. A substantial drawback, which has not yet been removed is the separation of solid remnants from the combustion products, which remnants cause erosion of the turbine blades or form deposits in the turbine.

Other proposed solutions rely on the heating of clean compressed air prior to the entrance into the turbine by means of a high temperature heat exchanger heated by coal combustion products at approximately atmospheric pressure. As combustion air hot air leaving the turbine after expansion is used. A drawback of this solution is the need of a large and expensive heat exchanger made of alloyed material. A further proposed solution is the gasifying of coal under pressure, cleaning of the gas and its burning in a combustion chamber of the gas turbine. A drawback of this system is however the complexity of the arrangement, a worse effectiveness namely of the gas generator and its relatively small output.

The said drawbacks cause that solid fuel is used for the drive of gas turbines only in sporadic cases. The same holds true about steam-gas devices.

It is commonly known that it is possible to achieve at steam-gas cycles a better thermal effect and in addition, namely for cycles with steam generators heated at elevated pressures, also a reduction of the size and weight of the steam generator. At increased pressure of the combustion products the heat transmission coefficient from the combustion products to the wall increases, so that the required heat transmitting surface is reduced. The hot compressed combustion products expand after leaving the combustion chamber of the steam generator in the gas turbine. The actual drawback is however, that solid fuel cannot be used in this case due to the above mentioned difficulties with the separation of solid remnants from the combustion products.

It is an object of this invention to eliminate this drawback. In accordance with this invention, solid fuel is burnt at elevated pressure and the hot compressed combustion products expand in the gas turbine, but contrary to presently known arrangements of this kind the separation of the solid remnants after burning from the stream of combustion products takes place at a lower temperature than the supply temperature of the combustion products into the gas turbine. As the removal of dust is substantially easier and more effective at low temperature, it is possible to achieve in accordance with this invention the required degree of purity of the combustion products.

The cooling of the compressed combustion products in order to ease the removal of dust is carried out in a

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system of two or more heat exchangers arranged in the stream of not cleaned combustion products, the first of which heat exchangers, arranged behind the pressure combustion chamber, serves for the reheating of the driving gases, i.e. of the cleaned compressed combustion products, to the admission temperature of the gas turbine, while the following one or more heat exchangers serve for other purposes of the cycle as heating device of the advantageously regenerating type, serving for heating the compressed combustion air, supplied by a compressor to the combustion chamber, or eventually also as an auxiliary economiser, serving for preheating the supply water or the condensate for the steam generator, or further coolers serving other technological purposes of the cycle and similar.

In accordance with the invention the injection of suitably prepared water into the stream of combustion products is used prior or after their cleaning from dust or prior and after their cleaning, or in case the separation of the solid remnants is carried out after burning, directly in the wet separator.

The reheating of the pressure combustion products separated from dust to the admission temperature of the gas turbine is carried out in accordance with this invention so that the cooled and cleaned pressure combustion products are first carried over a heat exchanger, arranged in the exhaust of the gas turbine, in which they are heated by the heat of the expanded driving gases, whereafter they pass over the already mentioned heat exchanger, arranged behind the pressure combustion chamber in the stream of the hot not cleaned pressure combustion products, by the heat of which they are heated to the admission temperature, at which they are thereafter brought as driving gases into the gas turbine.

The steam-gas cycle has considerable requirements to the economical regulation and operation. This pretentious requirement is met in accordance with this invention so that the starting of the gas cycle and eventually also the regulation of the admission temperature of the driving gases, i.e. of the cleaned and reheated pressure combustion products, is carried out by means of an auxiliary combustion chamber for fluid or gaseous fuel arranged in front of the gas turbine, into which chamber compressed combustion air is supplied from a tap of the compressor output and the combustion products of which are mixed with the driving gases supplied to the gas turbine.

In the course of burning of solid fuel in the steam-gas cycle according to this invention, it is possible to supply prior prepared, i.e. dried and comminuted fuel from an auxiliary storage vessel to the stream of compressed primary air, with which it is brought into the pressure combustion chamber.

At the elevated pressure of the combustion products in the combustion chamber and in the channels of the steam-gas cycle it is also possible to carry out the system according to this invention in combination with a pressure circuit for the preparation, i.e. the drying and possibly also the disintegration of the fuel, where the fuel is dried and comminuted by the pressure combustion products or by the pressure combustion air. If pressure combustion products are used as drying medium, it is possible to clean the drying medium from this circuit (the vapours) from dust and use it together with the other pressure combustion products after reheating to the admission temperature for the drive of the gas turbine.

An example of an embodiment of the system according to this invention is shown schematically as a steam-gas arrangement in the accompanying drawing.

The compressor 1 driven by the gas turbine 6 sucks air from the atmosphere, compresses it and supplies it over the heat exchanger 4 to the combustion chamber 2 of a steam generator 20, into which simultaneously solid

fuel is supplied under pressure from a storage bin 21 by a burner 22.

The pressure combustion chamber 2 for solid fuel is in this case a part of a steam generator, from which steam, generated by heat of the combustion products, passes into the steam turbines 13 through a circuit of customary design, which is not shown in detail in the drawing. The pressure combustion products generated in the combustion chamber 2 containing solid remnants after combustion are cooled in a heat exchanger 3 for heating clean driving gases, in a heat exchanger 4 for heating combustion air and alternatively also in a heat exchanger 7 provided as an auxiliary economiser for preheating water for the steam generator. In the stream of the not cleaned combustion products one or more coolers can be provided, serving for other purposes of the circuit as for instance for the regeneration of the solution for washing out sulphur compounds and similar. In this case the further cooling of the combustion products is carried out by water injection in a cooling chamber 9. The cooled pressure combustion products pass thereafter through a dust separator 5, where they are at reduced temperatures easily deprived of the solid remnants after combustion. A wet separator can be also used advantageously for this purpose. In this case a further saturator chamber 12 is provided behind the dust separator 5 where the combustion products relieved of the dust are saturated by water injection. The combustion products cooled down and relieved of dust are thereafter heated in a heat exchanger 8 by the heat contained in the expanded driving gases from the gas turbine 6 whereafter they finally pass the already mentioned heat exchanger 3 where the combustion products relieved of dust are again heated by hot combustion products still containing dust to the admission temperature, at which they are fed to the gas turbine 6. The gas turbine 6 drives the compressor 1 and the generator 11. The already mentioned heat exchanger 4 where the compressed combustion air is heated by means of compressed combustion products not yet relieved of dust, can be advantageously of the regenerating type.

From the tap of the output of the compressor 1 air is also supplied to an auxiliary combustion chamber 10 for fluid or gaseous fuel and the combustion products from this chamber are mixed with the combustion products from the main combustion chamber 2 relieved of dust and heated again, with which they are supplied as driving gases to the gas turbine 6.

It is self understood that the object of this invention in its fundamental arrangement includes also other characteristic arrangements of the steam-gas or gas circuits using the technology of preparation of not aggressive driving gases for a gas turbine from combustion products on the described fundamental principle.

An advantage of the described system of operation of the steam-gas, or gas circuit according to this invention is, that the removal of dust from the combustion products is carried out at low temperature, where in case a suitable dust cleaning device is used, a high degree of cleanliness of the combustion products, required for the gas turbine, can be achieved. The heating of the pressure air by pressure combustion products is advantageous as at a relatively high specific weight of the air there is a good heat transmission coefficient. A regenerating heat exchanger is especially advantageous regarding price and operation. The well known drawback of the regenerating heat exchanger, that it is not tight does not matter as the penetration of air into the combustion products increases the surplus of air, it increases however the output of the gas part of the steam-gas circuit, what is advantageous. A possible pollution of the combustion air by the not cleaned combustion products is equally not damaging as the air is supplied into the combustion chamber where fuel with an ash content is burnt.

The cooling of the combustion products by water in-

jection leads to an increase of the output of the gas turbine and in a certain degree contributes even to an increase of the efficiency of the whole arrangement. The combustion products relieved of dust are advantageously heated in recuperating heat exchangers in order to prevent a repeated pollution. The heating takes place in a heat exchanger by combustion products from the gas turbine at normal pressure in order to reduce the loss of heat in the exhaust combustion products and furthermore by combustion products not yet relieved of dust of high temperature. This second heat exchanger must be made of a material which withstands high temperatures, which is expensive. It is therefore advantageous, that the heated and cooled medium have high pressure, what influences advantageously the heat transmission coefficient and reduces the size of the heat exchanger.

The auxiliary combustion chamber for fluid or gaseous fuel enables a flexible start and regulation. It is necessary to supply to this chamber pressure air advantageously directly from the compressor and to mix the combustion products from this chamber with the cleaned and heated combustion products supplied by the main combustion chamber. Thus the temperature of the combustion products prior to their entrance into the gas turbine is regulated.

It is advantageous to supply the comminuted solid fuel for a combined steam/gas circuit or for a gas circuit from an auxiliary storage vessel into the compressed primary air, with which it is brought into the pressure combustion chamber. This enables an independent operation of the fuel grinder and of the boiler without mutual influencing. The need of fuel for large energetic arrangements is large, what leads not only to the use of large fuel grinders, but also to large cross sections of all conduits and other devices of the grinder circuit. It is therefore advantageous to choose a high pressure in the grinder circuit in order to reduce the cross sections for the passage. The combustion products used as drying medium in the grinder circuit (vapours) have to be perfectly relieved of dust and they can be thereafter supplied together with the other combustion products into the gas turbine.

What we claim is:

1. A method of operating a gas turbine which comprises:

- (a) feeding a solid fuel and air under pressure higher than atmospheric pressure to a combustion zone;
- (b) burning said fuel with said air in said zone, whereby a hot gas of combustion having solid material suspended therein is formed;
- (c) cooling said gas and the suspended material to a lower temperature;
- (d) separating the suspended material from the cooled gas;
- (e) heating the separated gas first by heat exchange with an expanded gas and thereafter by heat exchange with said hot gas of combustion, whereby said hot gas of combustion is cooled to said lower temperature, said higher pressure being maintained during said burning, said cooling, said separating, and said heating; and
- (f) expanding said heated gas in a gas turbine, whereby said turbine is driven, and the expanded gas for said heat exchange with said separated gas is obtained.

2. A method as set forth in claim 1, wherein said gas and the suspended material are cooled by admixing water thereto.

3. A method as set forth in claim 1, wherein water is admixed to said separated gas prior to said expanding thereof.

4. A gas turbine arrangement comprising, in combination:

- (a) a combustion chamber sealed from the atmosphere;

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- (b) first feeding means for feeding a solid fuel to said chamber at a pressure higher than atmospheric pressure;
- (c) second feeding means for feeding air of combustion to said chamber under said pressure for combustion of said fuel, whereby a hot combustion gas under said pressure having solid material suspended therein is generated;
- (d) heat exchanger means communicating with said chamber for receiving said hot combustion gas and the suspended solid material, said heat exchanger means being adapted to cool the received gas and solid material to a lower temperature by heat exchange with another gas;
- (e) separator means for separating said combustion gas from said solid material;
- (f) a first conduit connecting said heat exchanger means with said separator means for conveying said gas and said solid material at said lower temperature to said separator means;
- (g) a second conduit connecting said separator means with said heat exchanger means for conveying the separated combustion gas at said lower temperature to said heat exchanger means for heat exchange with said hot combustion gas and solid material, whereby the hot combustion gas and solid material are cooled to said lower temperature, and said separated gas is heated to a higher temperature;
- (h) a gas turbine;
- (i) a third conduit connecting said heat exchanger means to said gas turbine for operating the same by the expansion of said heated separated gas;
- (j) additional heat exchanger means arranged in said second conduit for passage of said separated gas therethrough; and
- (k) a third conduit connecting said additional heat exchanger means to said gas turbine for heat exchange of the expanded gas passing through said additional heat exchanger means.
5. An arrangement as set forth in claim 4, wherein said second conduit includes saturator means for admixing water to said separated gas.
6. A gas turbine arrangement comprising, in combination:
- (a) a combustion chamber sealed from the atmosphere;
- (b) feeding means for feeding a comminuted solid fuel to said chamber at a pressure higher than atmospheric pressure;
- (c) an air compressor;
- (d) a first heat exchanger communicating with said compressor and said chamber for preheating air compressed by said compressor, and for feeding the preheated compressed air to said chamber for combination with said fuel, whereby a hot gas of combustion carrying solid material is formed;
- (e) a second heat exchanger interposed between said chamber and said first heat exchanger for cooling said gas of combustion and the carried solid material, and for transmitting the cooled gas of com-

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- bustion and solid material to said first heat exchanger for thereby preheating said compressed air and further cooling said gas of combustion and solid material;
- (f) separator means communicating with said first heat exchanger for separating said further cooled gas from the solid material carried thereby;
- (g) a third heat exchanger interposed between said separator means and said second heat exchanger for reheating said separated gas in said third heat exchanger, and for heat exchange of the reheated separated gas in said second heat exchanger with said hot gas of combustion and the solid material carried, whereby said separated gas is further reheated and said hot gas of combustion and said solid material carried thereby are cooled;
- (h) a gas turbine connected to said third heat exchanger for receiving said further preheated gas, the expansion of said gas driving said turbine;
- (i) a conduit connecting said turbine to said third heat exchanger for conveying the expanded gas to said third heat exchanger, and for heat exchange between said expanded gas and said separated gas;
- (j) motion transmitting means interposed between said turbine and said compressor; and
- (k) power-consuming apparatus connected to said turbine.
7. An arrangement as set forth in claim 6, further comprising cooling means interposed between said first heat exchanger and said separator means for additionally cooling said further cooled gas.
8. An arrangement as set forth in claim 7, wherein said cooling means include means for admixing water to said further cooled gas.
9. An arrangement as set forth in claim 6, further comprising saturator means interposed between said separator means and said third heat exchanger for admixing additional water to said separated gas.
10. An arrangement as set forth in claim 6, further comprising auxiliary combustion means communicating with said turbine for burning a fuel substantially free from solid matter, whereby a fluid combustion product is formed, and for conveying said combustion product to said turbine.

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