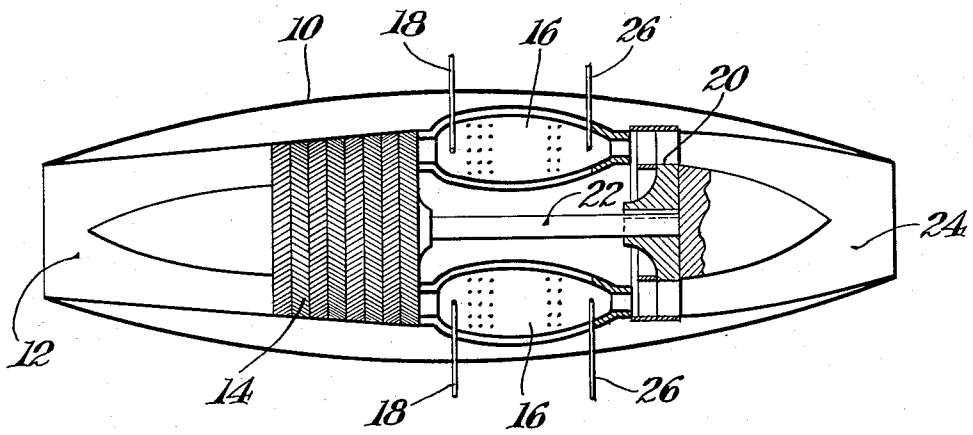
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GAS TURBINE ROTOR COOLING

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GAS TURBINE ROTOR COOLING

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This invention relates to improvements in gas turbines and specifically to an improved apparatus and method of cooling the rotor to permit higher operating efficiency.

It is well-known that a major problem in the development of the gas turbine has been in designing rotor blading which would withstand the high temperatures required for good efficiency under the severe stresses existing in service. It is well known too, that relatively small gas temperature increases, in the order of a few hundred degrees, for example, will materially raise cycle efficiency. Nevertheless in spite of the fact that higher and higher temperature alloys have been developed and costly production methods adopted, service temperatures are still limited by these factors and maintenance problems are severe.

It is the object of this invention to provide a novel means for cooling the rotor blading of gas turbines so that standard materials of construction and methods of manufacture may be safely used at operating temperatures far in excess of those presently possible.

This is based on my prior discovery that the quenching or cooling of very hot gases by direct contact with atomized water droplets is surprisingly difficult. With hot gas temperatures of the order of 1200 to 1300° F. and with short contact time between the atomized water droplets and the gas, I found that the water had to be dispersed to an impossible and actually invisible fineness in order to be completely vaporized at the end of the path of travel with a time interval of the order of 0.25 second. I also found that metal surfaces such as pipe linings and thermocouple wells down stream of the atomized water injection point became coated with a liquid water film and immediately dropped to a temperature corresponding to the water boiling point.

I propose that advantage be taken of this phenomenon to cool the first stage rotors of a hot gas turbine by injection or atomization of a small amount of water into the gases at a point between the combustion zone and the rotor. In this way a small portion of the water would be vaporized by the hot gases prior to contact with the rotor and the remainder of the water would wet the rotor blades; as long as the total water quantity was greater than the heat pickup by radiation and convection by the cooled rotor.

I find that the amount of water required is comparatively small and will have no appreciable cooling effect on the gases themselves. Thus the gas temperature can be materially increased and

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the exposed metal surface will have a temperature below that of boiling water.

Further features of my invention will appear from the following disclosure of a preferred form of embodiment thereof taken in connection with the attached drawing which is a central longitudinal section diagrammatically showing the parts of a gas turbine.

In accordance with the preferred form of embodiment of my invention, the gas turbine generally shown at 10 is provided with a typical air intake 12, and compressor 14 whereby the air is compressed to the desired amount and delivered to the combustion chambers 16. Fuel is conveniently supplied to the combustion chambers 16 by any suitable means such as the fuel line 18 and in accordance with prior practice the products of combustion are partially cooled with secondary air and discharged through the turbine 20 which drives the compressor 14 through the shaft 22. The products of combustion then discharge through the exhaust outlet 24.

The principal feature of my invention relates to the application of non-combustible liquid such as water in finely dispersed droplet or particle form to the rotor and stator blades of the turbine 20. This may be conveniently accomplished by a series of peripherally spaced jets 26 in the form of spray nozzles placed within the combustion chamber whereby the liquid is discharged into the gas stream and against the turbine blades. The film formed on the blades wets the blades and thus keeps them at a temperature below the boiling point of the liquid.

This mechanism is quantitatively analyzed as follows:

In the case of a spherical water particle at a temperature T_2 inside a closed chamber which is at a temperature T_1, if the chamber interior is a black body, the net rate at which the particle of water receives rediant energy is

$$\frac{dq}{dt}=ApK(T_1^4-T_2^4)$$

where A is the area of the particle, K is the Stefan-Boltzman constant, and p the emissivity of the water. The amount of energy dq absorbed in the time dt is used up to vaporize a mass of water SdV where S is the density of water. Therefore, $dq=Ls\ dr$ where L is the latent heat of water at temperature T_2. It follows that the decrease in radius of the water particle is

$$r_1-r_2=\frac{PK}{L_s}(T_1^4-T_2^4)t$$

where

t=time in hours
T_1=° R
T_2=° R
K=0.173×10^{-8}
L=970 B. t. u./pound
S=59.19
p=0.8

For the case where the chamber temperature T_1 is 1600° F., T_2 is 220° F. and the time is 0.1 second; the radial shrinkage of the particle is only 0.000143'' or 3.6 microns. It follows that a very fine mist of atomized water of 60 microns particle size would only be 10 to 15% vaporized in a 0.1 second travel with the 1600° F. hot gases prior to reaching the rotor. Liquid particles having an approximate size of 60 to 100 microns may be used.

The water mist will wet the rotor if the total water quantity is sufficient to provide a heat of evaporation equal to or greater than the heat pickup by the wetted rotor surfaces. This heat pickup per square foot of total rotor surface by radiation will be

$$G=Kp\ (T_1^4-T_2^4)$$
T_1=1600° F.
T_2=220° F.
G=24,600 B. t. u./sq. ft./hr.

Allowing for the small amount of convection heat pickup the total heat quantity to be removed becomes 28,740 B. t. u./hr./sq. ft. This corresponds to a water requirement of 35 pounds per hour or 4.2 gallons per hour per square foot of blade area.

If a higher hot gas temperature than 1600° F. were assumed, this water quantity would increase rather rapidly since we are dealing with temperatures raised to the fourth power. It will be seen however, that temperatures far higher than the present maximum in gas turbine practice may be reached with cooling water quantities in the practical range.

What I claim is:

1. The method of increasing the efficiency and output horsepower of a gas turbine which comprises introducing the motive gas to the turbine at a temperature substantially in excess of a safe operating temperature for the stator and rotor blades of said turbine and simultaneously spraying water into the gas stream adjacent the turbine inlet to form a water film on the rotor and stator blades, said water being in a finely dispersed condition having an approximate size of 60 to 100 microns when it leaves the spray nozzle and sprayed in amounts insufficient to materially lower the gas temperature in the time the gas passes to the blades, and in amounts great enough to keep the outside of the blades wet, whereby the sensible temperature of the blades is at least several hundred degrees Fahrenheit lower than the entering gas temperature.

2. The method of increasing the efficiency and output horsepower of a gas turbine which comprises introducing the gas to the turbine at a temperature substantially in excess of a safe operating temperature for the stator and rotor blades of said turbine and simultaneously depositing a water film on the stator and rotor blades whereby they have a sensible temperature in the order of several hundred degrees Fahrenheit lower than the entering gas, said water film being formed by injecting the water in a particle range of 60 to 100 microns closely adjacent the stator blades and following fuel combustion and at a point in the gas travel such that only about 10% to 15% of the water is vaporized by the gas prior to reaching the rotor blades.

3. The method of increasing the efficiency and output horsepower of a gas turbine which comprises introducing the motive gas to the turbine at a temperature substantially in excess of a safe operating temperature for the stator and rotor blades of said turbine, and simultaneously spraying water into the gas stream adjacent the turbine inlet closely adjacent the stator blades, and at a point in the gas travel such that only a minor portion of the water is vaporized by the gas prior to reaching the stator blades to form a film of water on the rotor and stator blades, the water leaving the spray nozzle being a very fine mist of atomized particles and in amounts insufficient to materially lower the gas temperature in the time the gas passes to the blades, and in amounts great enough to keep the outside of the blades wet under operating conditions, whereby the sensible temperature of the blades is at least several hundred degrees Fahrenheit lower than the entering gas temperature to the blades.

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