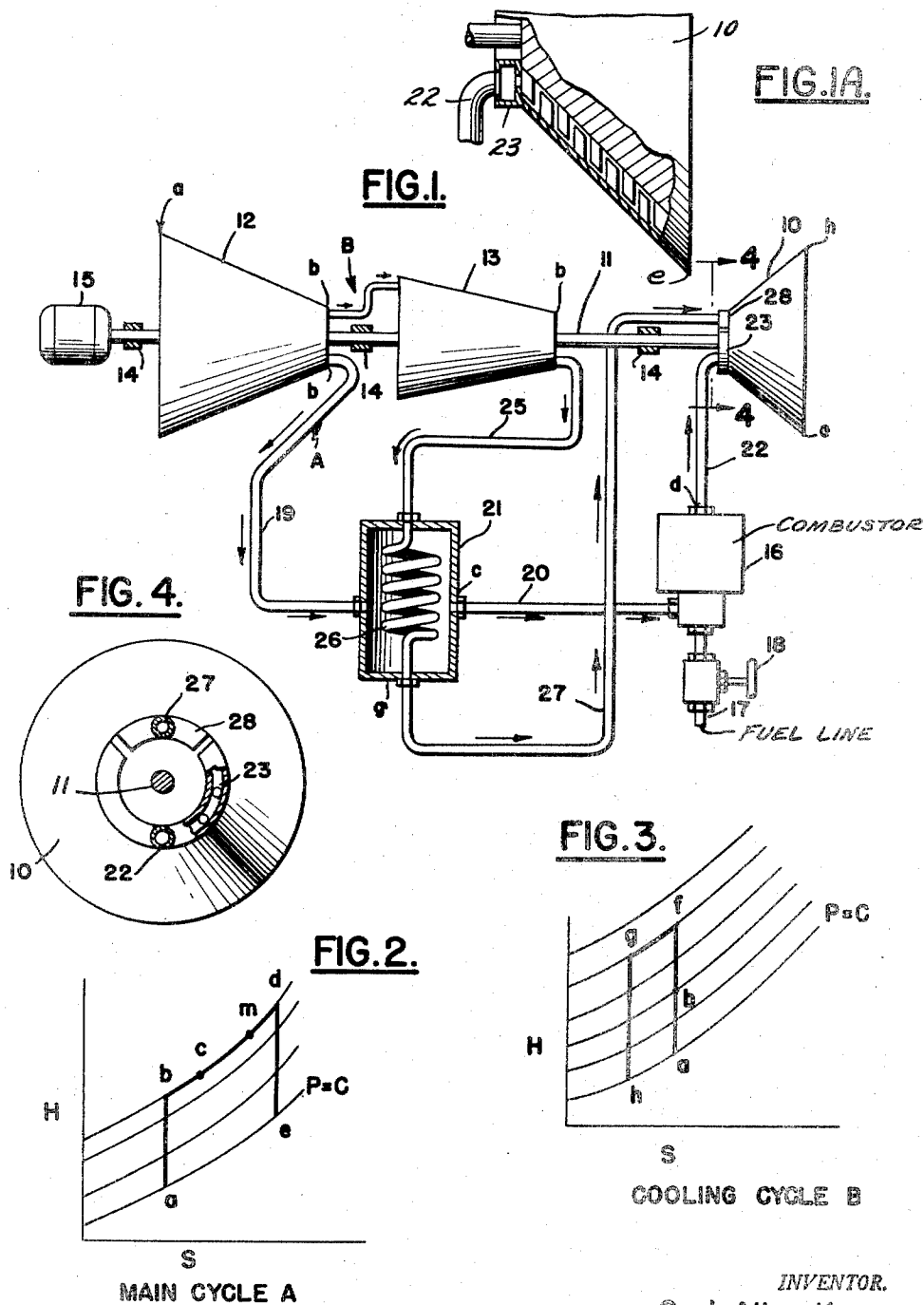


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S. A. KANE
SYSTEM OF BLADE COOLING AND POWER
SUPPLY FOR GAS TURBINES
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INVENTOR.
Saul Allan Kane
BY *[Signature]*
Attorney

UNITED STATES PATENT OFFICE

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SYSTEM OF BLADE COOLING AND POWER
SUPPLY FOR GAS TURBINES

Saul Allan Kane, Washington, D. C.

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This invention relates generally to gas turbine systems and more particularly to use of a part of the system for turbine blade cooling.

In gas turbine systems it is of importance from the viewpoint of thermodynamic efficiency that the temperature of the expanding gas at the rotor blades be as high as possible. In prior art systems this end has been sought by making the turbine rotor blades of heat resistant material and by passing a cooling fluid through or over the rotor or rotor blades so that the average blade temperature may be reduced over that of the heated gas alone while maintaining a high operating temperature for the working fluid.

A defect in the turbine system of this prior type lies in the marked loss of energy required to pump the coolant through the system.

It is proposed to reduce this loss of energy by utilizing the coolant not only for rotor blade cooling but also as an active power agent. It is proposed also to increase the cooling effect of the coolant by direct contact means.

Generally stated, the invention comprises a turbine system wherein the cooling air is subjected to additional compression over air supplied the combustion unit and this highly compressed air is cooled in a heat exchanger and delivered to the turbine at a high pressure and a moderate temperature where it is expanded at a velocity equivalent to that of the heated but moderately pressurized gases when expanded through the nozzle sector. The coolant is super-cooled and utilized both as a cooling medium and for contributing power to the turbine rotor.

The objects of the invention include provision of means for stepping up the normal compression of cooling gases; the provision of means for cooling said super-compressed coolant prior to application to the turbine nozzles; the provision of means for obtaining the same velocity for the coolant at the rotor blades as that obtained from the heated gases following the expansion thereof.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein—

Figure 1 is a schematic drawing showing the turbine system;

Fig. 1A is a fragmentary view, with parts broken away, illustrating structure of gas turbine and nozzle chest combination.

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Figure 2 is an enthalpy-entropy diagram of the turbine system showing the main heating cycle;

Fig. 3 is a similar type diagram showing the cooling cycle; and

Fig. 4 is a view showing the nozzle chests for the heating and cooling cycles, the same being a section taken on line 4—4 of Fig. 1.

The gas turbine which is indicated by the numeral 10, is mechanically connected by shaft 11 to compressors 12 and 13 which may be respectively of the axial and radial type. Supports 14 are also indicated on which the unit is rotatably mounted. Motor 15 is provided for starting the unit.

A combustor 16 having a fuel line 17 controlled by valve 18 supplies fuel to the combustor. Air is supplied the combustor from compressor 12 by means of pipe sections 19 and 20, a heat exchanger 21 being interposed between these pipe sections. From the combustor, heated gases are led by pipe 22 into the main nozzle chest 23 of the turbine. The branch pipe system including pipe sections 19, 20 and 22, heat exchanger 21 and combustor 16 will be referred to hereinafter as branch A.

A fraction of the compressed air output of compressor 12 is led to the compressor 13 where the pressure is increased. Accompanying this pressure increase is a rise in temperature which is removed in heat exchanger 21 to which connection is made by pipe section 25. This relatively cool and highly compressed air is led by pipe 25 through heat exchanger coil 26 and pipe 27 to the nozzle chest 28 of the turbine, where it is expanded and directed against the rotor blades supplementing the gas supply from branch A. The branch including compressor 13, heat exchanger 21 and pipe sections 25 and 27 will be referred to hereinafter as branch B.

It will now appear that power is supplied to the turbine through the two branches A and B, the heated gas at lower compression through branch A and the cooled gas at higher compression through branch B. The two branch gas streams are expanded through nozzles to approximately the same velocity and since the work converted by an impulse turbine is a function of mass and velocity a single optimum combination of design characteristics will be satisfied by both hot and cold gas streams.

The thermodynamics involved in the system operation may best be understood by reference to the enthalpy-entropy diagrams of Figures 2 and 3. It is understood that the end sought is

the utilization at the turbine of branch A gases at a temperature as high as may be safely accommodated by the rotor materials in order to obtain a high operating efficiency. Obviously a gas temperature destructive to the rotor material may not be continuously applied, but by employing with the heated gas of branch A the cooling air of branch B a weighted averaged temperature at the rotor blades is obtained which can be below the critical value for the rotor blade material although the branch A gases themselves might be higher.

It is pointed out that the branch gases are applied to the rotor at spaced intervals of the nozzle sector so that the mixture of the heated gas with the cooling gas does not occur until they have left the nozzles proper. (See Fig. 4.)

Thus to combine the two temperature branches is a useful operation. In addition, however, two important conditions affecting the gas streams are introduced. In the one condition a heat exchange is obtained between the two branches through the heat exchanger 21. By this means a proportion of the heat developed in the branch B air by the added compressor action is removed so that, on expansion at the turbine nozzle, the cooling effect is increased. In addition, heat is absorbed by the branch A air thus increasing the internal energy of this gas stream. The heat exchanger therefore serves to increase the effectiveness of both heating and cooling.

A second desirable condition arises from the utilization of the cooling air as a power agent for driving the turbine rotor. This results from stepping up the pressure of the air and applying it by nozzles directly to the rotating blades in parallel with the branch A gas nozzles. Preferably the cooling air velocity at the nozzles should be the same as that secured at the nozzles of branch A so that proper introduction of the working fluid into the blade entrance channels may be accomplished without undue shock or spill over. This velocity equivalence is secured by proper selection of compression values in branch B and nozzle design.

Referring to Figure 2 there is shown a heating cycle with enthalpy-entropy coordinates and designating letters corresponding with letters on Figure 1. Following the first compression *ab* with resultant temperature rise, heat is absorbed at constant pressure due to the heat exchanger, as indicated by *bc*, and the combustor increases gas temperature to peak *d* along *cd*, a temperature normally in excess of rotor material resistance. Adiabatic gas expansion does work along *de*. Point *m* on curve *bd* represents usual maximum temperature which will result in a temperature after expansion below the highest safe temperature at the rotor, as employed in prior systems.

Figure 3 indicates the cooling cycle, with heat addition *ab* and *bf* in branch B due to compressors 12 and 13. Expansion through the heat exchanger reduces air temperature along *fg* so that on expansion through the turbine nozzle a drop of temperature *gh* is obtained.

Stated in terms of equation the net work theoretically developed by the system per pound, for example, would be

$$W = (A(d-e) + B(g-h)) - ((A+B)(b-a) + B(f-b))$$

and the efficiency is $W/A(d-c)$. The average temperature leaving the turbine nozzles is

$$A(T_e) + B(T_h)$$

which since A and B are fractions less than unity results in an average T substantially less than T_e , the peak temperature value.

Thus it appears that heated gases at supercritical peak temperatures and supercooled coolant may be applied to the turbine rotor at equal velocities to develop an increased overall efficiency for the system.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A gas turbine unit comprising a first air compressor, a combustion unit for receiving air from said first compressor, a fuel supply for said combustion unit, a turbine having a set of velocity nozzles and a rotor provided with blades, a shaft forming a common driving element between the turbine rotor and first compressor, a second compressor mounted on and rotatable with said rotor shaft, a heat exchanger, a first conduit connecting the first rotor through the heat exchanger and the combustion unit to one sector of the turbine nozzles, and a second conduit connecting said first compressor through the second compressor and heat exchanger to another sector of said turbine nozzles whereby the turbine rotor is subjected to the rotative effect of both gas and air streams and to the cooling effect of said air stream.

2. A gas turbine unit comprising a turbine having a rotor provided with edge blades, a set of stationary nozzles and an enclosing casing; a combustion unit; conduit connections between the combustion unit and one sector of said nozzles; a source of fuel for said combustion unit; means for supplying air under reduced compression to said combustion unit; means for supplying air under increased compression directly to another sector of said nozzles; and a heat exchanger operatively connected to both compression means for removing heat from said increased compression means, whereby the cooling effect thereof on said turbine rotor is increased.

3. A gas turbine unit comprising a turbine having a rotor provided with edge blades; a set of stationary nozzles and an enclosing casing; a combustion unit; a source of fuel for said combustion unit; first and second compressors; shaft means connecting said compressors and turbine for simultaneous operation; a heat exchanger including a casing and a heat transfer medium therein; first conduit connections from the first compressor to one nozzle sector of the turbine nozzles and through said heat exchanger and combustion unit; second conduit connections from the first compressor to another nozzle sector of the turbine nozzles and through the second compressor and the heat exchanger, said compressors acting cumulatively on air passing through said second conduit connections to increase the pressure over the air in said first conduit connections.

4. A gas turbine unit comprising a turbine having a rotor provided with edge blades, a set of stationary nozzles and an enclosing casing; a combustion unit; conduit connections between the

combustion unit and one sector of said nozzles; a source of fuel for said combustion unit; means for supplying air under reduced compression to said combustion unit; means for supplying air under increased compression directly to another sector of said nozzles; and a heat exchanger operatively connected to both compression means for removing heat from said increased compression means, whereby the cooling effect thereof on said turbine rotor is increased, said heat exchanger including a casing, a heat transferring medium, and two heat transfer elements each connected in series with one of said conduit connections.

5. In a gas turbine system, a gas turbine including a rotor with radial peripheral blades and adjacent circumferential stationary nozzles, means for supplying heated gases to a sector of said stationary nozzles, and added means for supplying coolant under pressure to another sector of said stationary nozzles, said added means including compressor apparatus and a cooling device whereby the effective drop of temperature of the coolant at the rotor is increased.

6. In a gas turbine system, a gas turbine including a rotor, radial peripheral blades and adjacent circumferential stationary nozzles, a combustor for supplying heated gases to a sector of said stationary nozzles, a first compressor for supplying compressed air to said combustor, and means including a second compressor for supplying coolant under pressure to another sector of said stationary nozzles.

7. In a gas turbine system, a gas turbine including a rotor having radial peripheral blades,

and adjacent circumferential stationary nozzles; a combustor; a first compressor for supplying compressed air to said combustor; a conduit connection between the combustor and a sector of said stationary nozzles for supplying to said sector compressed heated gases; and means including a second compressor for supplying a coolant, at a pressure in excess of said compressed air, to another sector of said stationary nozzles.

8. In a gas turbine system, a gas turbine including a rotor having radial peripheral blades, and adjacent circumferential stationary nozzles; a combustor; a first compressor for supplying compressed air to said combustor; a conduit connection between the combustor and a sector of said stationary nozzles for supplying to said sector compressed heated gases; and means including a second compressor for supplying a coolant, at a pressure in excess of said compressed air, to another sector of said stationary nozzles, said pressure and nozzle capacities being such as to secure equal velocities at the nozzles of both nozzle sectors.

SAUL ALLAN KANE.

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