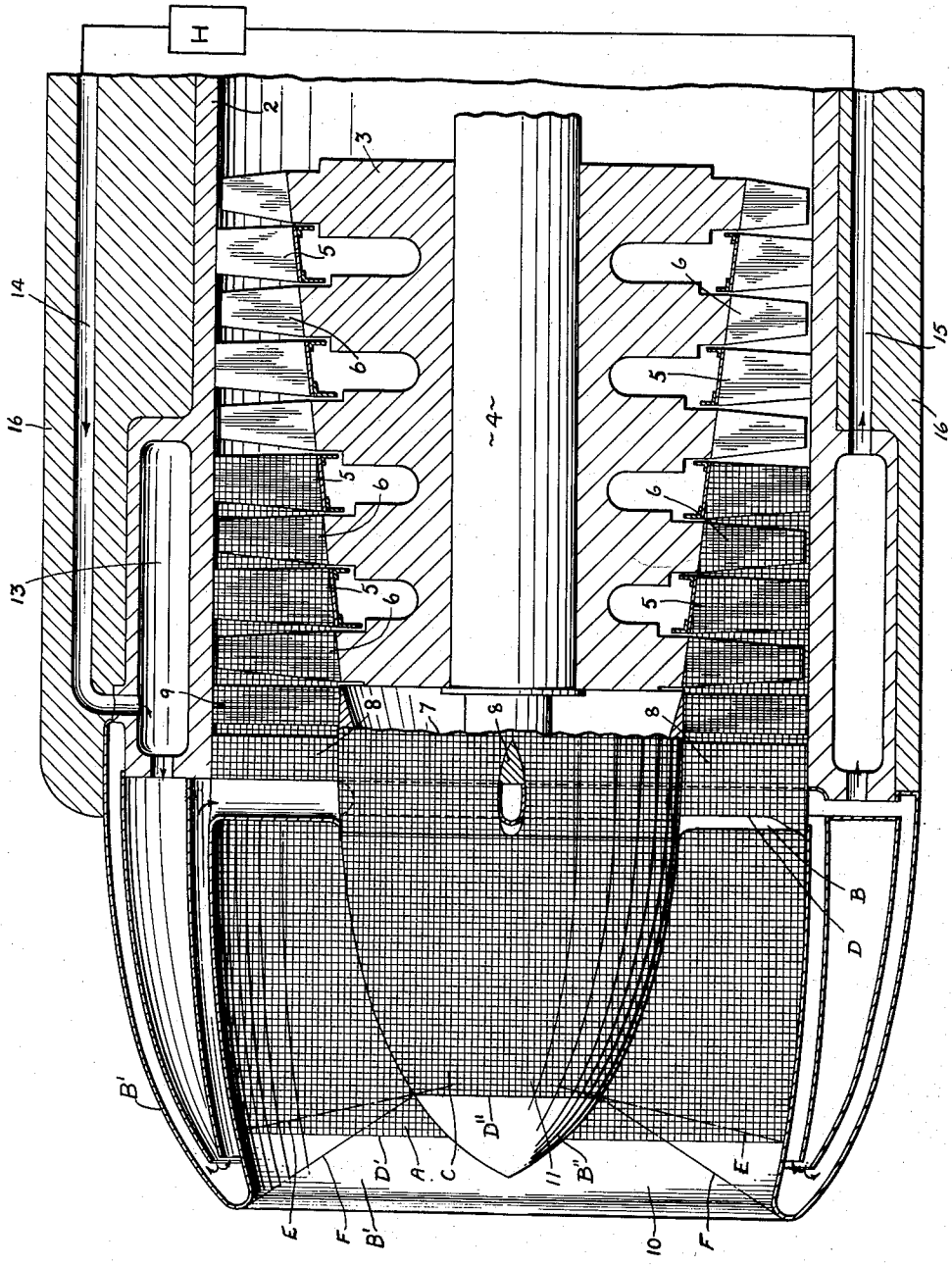
Oct. 13, 1953

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2,655,308

ANTIICING OF COMPRESSORS OF AIRCRAFT
GAS TURBINE ENGINES
Filed Nov. 12, 1949



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Patented Oct. 13, 1953

2,655,308

UNITED STATES PATENT OFFICE

2,655,308

ANTIICING OF COMPRESSORS OF AIRCRAFT GAS TURBINE ENGINES

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Application November 12, 1949, Serial No. 126,762
In Great Britain November 18, 1948

3 Claims. (Cl. 230—132)

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This invention relates to means of preventing the formation of ice on the intake components and the blades of air compressors, and particularly those of the axial type, used in aircraft gas turbine engines.

The formation of ice on the intake components of air compressors, such as the intake fairing, the nose bullet, struts, inlet guide vanes and the like, causes serious obstruction to the flow of air passing through them and considerable damage may result from pieces of ice breaking loose and being carried by the air stream into the rotating parts. Furthermore, in the first few stages of compressors of the axial flow type, ice may form on the blades themselves, thereby materially reducing the compressor efficiency. The formation of ice can be prevented either by the introduction of fluid, such as alcohol, to lower the freezing point of the moisture coming into contact with the components or by the application of heat to raise the temperature locally above the freezing point of water. The chief objections to the former method lie in the complications involved in the fluid supply system and the fact that, for reasons of weight, only sufficient fluid can be carried to enable the system to function intermittently, when icing conditions have been detected, by which time some ice will have already formed. The application of heat can be effected in a number of ways but each presents special difficulties: the obvious solution of the problem by the heating of the air stream as a whole cannot be adopted because such charge heating lowers the performance of the compressor and in any event it demands an excessive supply of heat: the direct heating of small moving parts, such as rotor blades, presents major mechanical problems which add weight and complications to the compressor: and the indirect heating of such parts by electrical induction is liable to impose fatigue stresses in the parts concerned.

A main object of the invention is to provide a simplified construction for heating such items as rotor blades and other parts, to which the conduction of heat introduces mechanical difficulties, and to eliminate such features as slip-rings, rotating glands, seals subject to disturbance for maintenance purposes, and other complications associated with the heating of moving and removable parts by electrical and mechanical methods: a construction achieving these objects will materially improve reliability, facilitate manufacture, and reduce both weight and cost.

Another object of the invention is to provide

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a construction whereby surfaces susceptible to ice formation may be heated with a minimum rise of temperature of the air entering the compressor. A further object of the invention is to achieve the aforesaid heating of surfaces susceptible to ice formation, without introducing any stresses liable to cause fatigue or other failure in the static or moving parts.

According to the present invention the foregoing objects are achieved by the application of a dark coloured finish to the surfaces of the compressor which are exposed to the air stream and are susceptible to the formation of ice thereupon, and by providing heat-producing means to project radiant heat on the said surfaces having a dark coloured finish.

Other objects and advantages of the invention will be apparent in the course of the following description of an application of the invention to a typical axial flow compressor of a gas turbine engine. Before proceeding with a description of the invention it is considered advisable for the sake of greater clarity to describe a compressor with which the invention may conveniently be used.

The accompanying drawing forming a part of this application is a part-sectional view of an axial compressor as used on a gas turbine engine.

The outer or stator casing of a compressor is indicated by the numeral 2 and the numeral 3 indicates the compressor rotor which is rotatably carried on a shaft 4 journalled in the stator, in the conventional manner. Stator blades 5 are mounted in circumferential rows around the inside of the stator casing 2 and the rotor 3 carries blades 6 similarly mounted in rows and coacting aerodynamically with the stator blades 5. The compressor shown in the drawing has five stages of stator and rotor blades but this has no direct bearing on the application of the invention. Any number of stages may be employed according to the performance requirements of the compressor.

The front bearing for the shaft 4, together with associated gearing for the auxiliary drives, is housed in a casing 7 which is supported in the outer casing 2 of the compressor by long-chord streamlined struts 8.

Immediately forward of the first row of rotor blades is a circumferential row of inlet guide vanes 9 which are supported at their inner ends on the casing 7 and at their outer ends on the stator casing 2 of the compressor.

Around the compressor intake which is shown at the left hand side of the drawing is an outer

peripheral wall or circular intake fairing 10, and the air enters through the annular space formed by this fairing 10 and an inner body confined by a nose bullet 11. It is common practice to mount various engine auxiliaries, such as a starter, on the forward end of the compressor, and the nose bullet 11 serves as a fairing for these auxiliaries and must be mounted in such a manner that it can be readily removed for maintenance of the auxiliaries in service. The method of mounting is irrelevant to this description but it is relevant to the invention that the nose bullet 11 must be readily removable and should be of as simple and robust construction as it is practicable to make it. The base of the nose bullet 11 is seated upon the forward face of the casing 7, so that the surfaces of the two components blend in fair lines.

In the neighbourhood of the outer mounting of the inlet guide vanes 9 and of the first two or three rows of stator blades 5, the stator casing 2 is jacketed so that a heating medium, such as tetracresyl silicate or oil, can be circulated through the space 13 provided by the jacket. The heating medium is ducted to the jacket through a conduit 14 and, after passing around the jacket, it is ducted back to a heat source indicated diagrammatically at H, by a conduit 15. The heat source, which is situated in the tail pipe of the engine, derives its heat through a suitable heat exchanger from the exhaust gases from the turbine. The heater jacket and the conduits 14 and 15 of the heating system are heavily lagged as indicated at 16 to prevent the loss of heat externally to the compressor.

In a similar manner heat is applied to the intake fairing 10 by a jacket deriving its heat through the conduit 14 from the turbine exhaust through the heat source H. This jacket must extend down into the leading edge of each of the struts 8 and by an arrangement of baffles in the double skin of the intake fairing 10 and by the location of the return to the heat exchanger, adequate circulation through the leading edges of these struts may be assured.

According to this invention, within the range of the jacket or other source of conducted heat, the stator blades 5, the inlet guide vanes 9 and the inner surface of the stator casing 2, upon which the said blades are mounted, are finished in a matt black in order to furnish an efficient radiating surface.

Similarly, the inner surface A of the intake fairing 10 is finished in a matt black. The struts 8 are finished in a matt black over the trailing portions of their surfaces but for reasons which are explained later the greater portions B of their leading edges are left bright and preferably polished. The outer and a portion of the inner surfaces B' of the intake fairing 10 are also left bright. The line of demarkation D' on the inner surface between the black area A and the bright area B' is a circumferential line so located along the surface that hypothetical lines E passing through the said circumferential line and extending normal to the said surface will pass through the hereinafter defined line of demarkation D'' between the black area C and the bright area B'' of the nose bullet 11.

The black finish may be applied by any of the well known methods appropriate to the material of which the components are made, but such finish must be of the kind produced by a dye or by a chemical treatment such as oxidization, to insure that it will adhere in all conditions of temperature, flexure and abrasion.

The surfaces of the rotor blades 6 and of the nose bullet 11 are also finished in a matt black by any suitable chemical or dyeing process appropriate to the materials of which they are made. However, the extreme forward portion B'' of the nose bullet 11 is not so treated but is left bright and preferably polished. The line of demarkation between the black area C and the bright area B'' of the nose bullet is a circumferential line D'' so located along the surface that hypothetical lines F passing through the said circumferential line D'' and extending normal to the surface will be tangential to the curved surface at the leading edge of the intake fairing 10. Similarly the lines of demarkation D between the bright areas B of the struts and their black areas are curves so located along the surfaces of the struts that hypothetical lines passing through the said curved lines and extending normal to the surfaces will be tangential to the curved surface at the leading edge of the intake fairing 10. Thus, hypothetical lines extending normal to any point on the bright areas B of the struts will pass directly through the annular space or entry through which air is admitted.

Apart from their surface finish, the rotor blades 6 and the nose bullet 11 are in no way different from normal components and embody no other provisions for the application of heat for anti-icing purposes.

In operation, the heat carried by the heating medium to the heating jackets is conducted to the inner surfaces of the stator casing 2 and the intake fairing 10. The stator blades 5 and the inlet guide vanes 9 are heated by conduction through their mountings in the stator casing. The struts 8 also derive heat from the heating medium circulated through their leading edges. A portion of this heat is utilized to keep these fixed components free from ice and the greater part of the remainder is radiated from the surfaces which are finished in a matt black, and is readily absorbed by the black surfaces of the rotor blades 6 and the nose bullet 11, to keep these parts also free from the formation of ice. The heat thus radiated and absorbed will not appreciably raise the temperature of the air between the radiating and absorbing surfaces, so avoiding the undesirable effects of charge heating.

It will be observed that the radiating surfaces are of considerably greater area than the absorbing surfaces of the rotor blades and of the nose bullet, and that furthermore, the absorbing surfaces are well situated in relation to the radiating surfaces so that they are subjected to a concentration of radiation from all sides.

The bright areas B, B' and B'' of the struts 8, of the intake fairing 10 and of the nose bullet 11 are so situated that they cannot take part in this interchange of heat between the fixed and moving or removable components; they are finished bright and are polished in order to reduce the amount of heat which they themselves may radiate outwardly, either directly or by reflection. The most serious accumulation of ice tends to occur at the forward end of the nose bullet, that is on the area B'' in the compressor described. By this invention, heat is supplied to this area in the following sequence: firstly by radiation from the area A of the intake fairing 10, secondly by absorption by the area C of the nose bullet 11 and thirdly by conduction

of the said absorbed heat through the metal of the nose bullet from the area C to the area B''. The heat is then available at the area B'' for anti-icing purposes and by virtue of the polished finish its wasteful radiation into the sky is reduced to a minimum.

Some heat will inevitably be transferred between a metal surface and a stream of air passing over it at a different temperature, so that a portion of the heat supplied to the radiating surfaces of the construction described will be carried away by the air stream entering the compressor: this loss will increase as the temperature difference between the radiating surfaces and the air stream increases. It is fortunate, therefore, that icing conditions very rarely occur at atmospheric temperatures below 20° F. since at temperatures appreciably below this value the said convection losses become prohibitive. However under normal icing conditions, the temperature of the radiating surfaces need not exceed the limitations imposed by the materials now available or by practical consideration of the power required to heat the said radiating surfaces, in order to maintain the temperature of the absorbing surfaces at a value not lower than the freezing point of water.

As stated hereinbefore, the method by which heat may be applied to the stationary components namely the stator blades, the struts, and the intake fairing is not relevant to this invention. It will be realized, in addition, that the invention can be applied in whole or in part. The greatest benefits from this invention are to be derived by small parts rotating at high speed which present considerable mechanical difficulties to all other methods of heating. It is, therefore, to be understood that the form of the invention herewith shown and described, is to be regarded as an illustrative application of the same and that various changes in the arrangement of the parts and minor departures from the use of the ideal matt black finish may be resorted to without departing from the spirit of the invention or the scope of the claims.

What I claim as my invention is:

1. In a rotary air compressor provided with a heat generating device and having an annular intake through which air is admitted, the said annular intake being defined by an outer peripheral wall and an inner body centrally located relative to the peripheral wall and spaced therefrom, the surface of the inner body being susceptible to the formation of ice thereupon, means transmitting heat from the heat generating device to the outer peripheral wall, a dark finish applied to the portions of the surface of the said inner body which are so located and formed that hypothetical lines extending normal to any point on the said portions will intersect the outer peripheral wall, a bright finish applied to the other portions of the surface of the inner body, a dark finish applied to the portions of the outer peripheral wall which are so located and formed that hypothetical lines extending normal to any point on the said portions will intersect the aforesaid portions of the surface of the inner body which have a dark finish applied thereto, and a bright finish applied to tthe other portions of the outer peripheral wall.

2. In a rotary air compressor provided with a heat generating device and having an annular intake through which air is admitted, the said annular intake being defined by an outer peripheral wall having a leading edge and an inner body centrally located relative to the peripheral wall and spaced therefrom, the surface of the inner body being susceptible to the formation of ice thereupon, means transmitting heat from the heat generating device to the outer peripheral wall, a dark finish applied to one portion of the surface of the inner body, and a bright finish applied to the other portion of the surface of the inner body, the line of demarcation between the two portions being a line so located on the surfaces of the inner body that hypothetical lines passing through the said line of demarcation and extending normal to the said surfaces will be tangential to the leading edge of the aforesaid outer peripheral wall, the portion to which a dark finish is applied being that portion from which normals intersect the outer peripheral wall.

3. A rotary compressor as claimed in claim 1, having struts which are susceptible to the formation of ice thereupon and which extend from the inner body to the outer peripheral wall, in which a dark finish is applied to portions of the surfaces of the struts and a bright finish is applied to other portions of the surfaces of the struts, namely, to portions of the surfaces of the struts which are so located and formed that hypothetical lines extending normal to any point on the said portions will pass directly through the annular entry through which air is admitted.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,268,320	Brandt	Dec. 30, 1941
2,317,019	Altemus	Apr. 20, 1943
2,408,867	McCollum	Oct. 8, 1946
2,435,990	Weiler	Feb. 17, 1948
2,446,663	Palmatier	Aug. 10, 1948
2,469,375	Flagle	May 10, 1949