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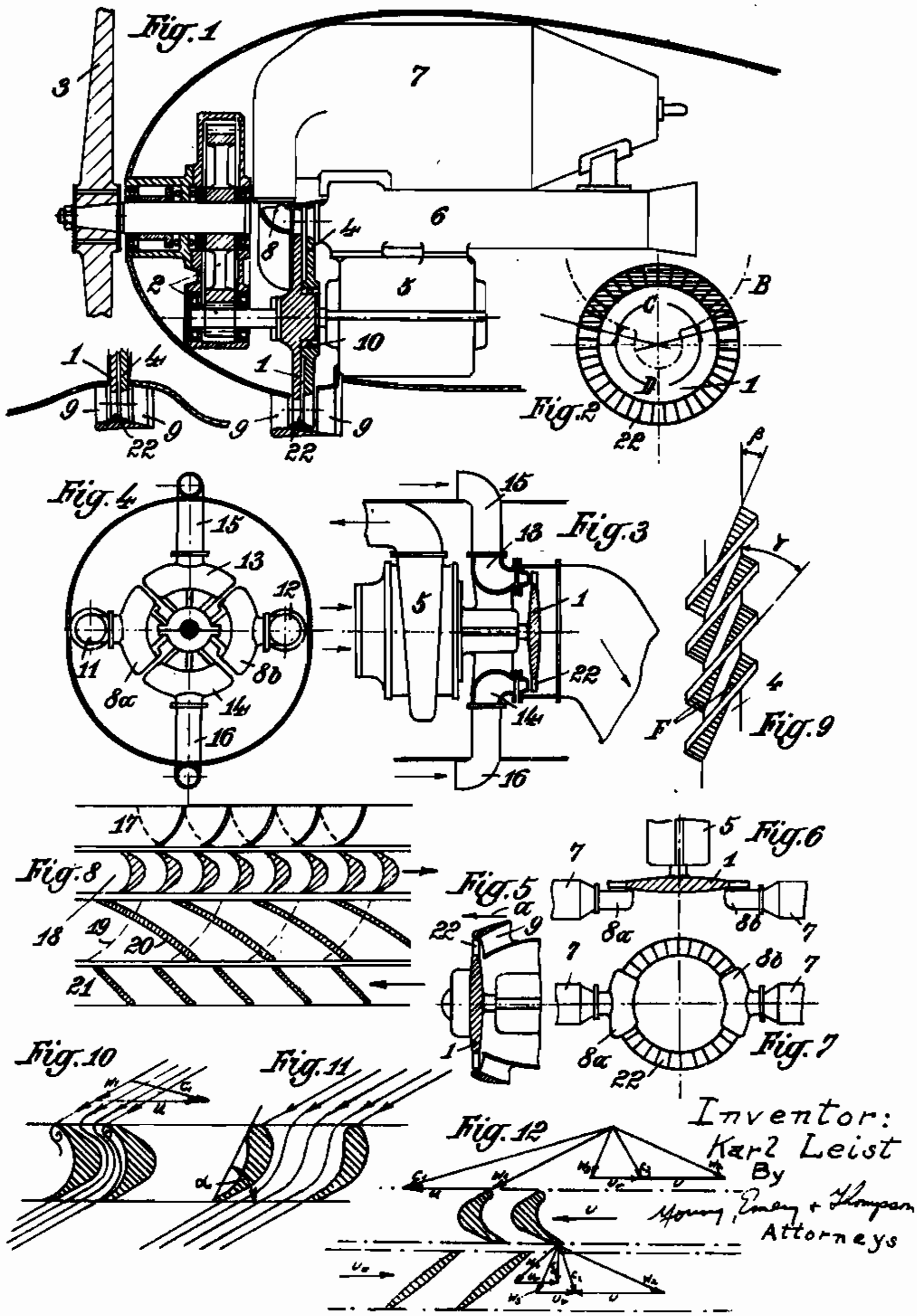

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ALIEN PROPERTY CUSTODIAN

GAS TURBINES

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The invention relates to a gas turbine with partial admission, more particularly axial admission, the turbine being operated by combustion gas or exhaust gas. According to the invention the gas turbine is so constructed that the rotor blades to which driving gas is not admitted are exposed and the surrounding air passes between them for cooling. In other words that section of the rotor blades to which driving gas is not admitted is not separated from the surrounding atmosphere by a closed housing, with the result that there is a considerable cooling, particularly of the inlet edges of the blades, both by thermal conduction as well as by thermal radiation.

In many cases, for example if the conditions under which the machine is incorporated make it appear desirable, an inlet chamber to which the outer air flows through a pipe may be arranged in front of the blades to which air is admitted or in front of the guide blades arranged in front of said rotor blades. To avoid an unbalanced heating and distortion, a number of sectors to which air and gas is admitted or a number of inlet chambers traversed by cooling air and driving gas, which chambers may perhaps not be directly connected together, may be so arranged that cold sectors and warm sectors are each arranged opposite one another in pairs.

In many cases the movement of the air occasioned by the rotating rotor blades will be sufficient for cooling the rotor blades. If the effect of this movement of the air should not be sufficient, it is possible to occasion or augment the air current for cooling the blades in a simple way with small power consumption.

Particularly favourable conditions are obtained when utilising the invention in the propulsion of vehicles. The power required for driving vehicles is usually small in comparison with that needed in power stations and other stationary installations. This makes it possible to have a small heat drop which can be handled in one pressure stage with one or more speed stages and with small quantities of gas, i.e. with a small degree of admission. According to the invention, with 30% admission for example, 70% of the rotor blades are constantly traversed and cooled by the considerable relative wind or by the air stream behind the existing propeller or the propeller incorporated specially for this purpose. This cooling is incidental to the drive either indirectly due to the forward movement of the vehicle or directly due to the driving propeller and it only increases the total power required to a small extent. In the case of an exhaust gas turbine this small increase in the power consumption has moreover to be met not by the turbine but by the motor.

If the cooling air flows in the manner described through a pipe, then the outer end of this pipe may be bent in the direction of travel, i.e. in the opposite direction to the relative wind, in order to increase the pressure in this pipe.

The invention is particularly suitable for turbines with axial admission as here the air current can flow directly through the spaces between blades without deflection. In addition there is the fact that, assuming equal loads, turbines with axial admission can be designed for higher peripheral speeds than turbines with radial admission, so that the former permit a partial admission even with larger output with correspondingly larger heat drop and blade length.

The heat exchange between gas and blade and between blade and air becomes so favourable on the basis of the invention that it is possible to have high final temperatures of the expanded gas without damage to the inlet edge of the rotor blades, which is particularly liable to damage, or without reducing the solidity thereof to an unallowable extent.

In order to improve the cooling, the air current flowing between the blades of the rotor can be occasioned or augmented by a suction towards the outlet end of the turbine. In the case of an open housing, even without the above-mentioned flow due to the relative wind, such a suction can occasion a cooling admission of the outer atmosphere and can be produced in various ways by means of the energy still contained in the exhaust gas when it emerges from the turbine wheel. It can for example readily be occasioned by a ring of blower blades arranged beyond the guide blades. Such a ring of blades may for example be mounted on the hub of the wheel or on the turbine shaft by means of rolling or sliding bearings, more particularly with an overhung wheel arrangement. Over the arc to which gas is admitted, the blower blades may for example be driven by the exhaust gas and the remaining arc can be utilised for producing the cooling current. If the blower is driven in the opposite direction to the turbine wheel, then the centrifugal moment of the turbine shaft is correspondingly reduced. The current of cooling air at the arcuate section where gas is not admitted is drawn by the blower against the turbine blades or through the blade passages, a funnel shaped inflow housing or a pipe as described above being provided if desired. If the peripheral speed of the blower blades is in the opposite direction to that of the turbine wheel, then its blades have an elongated section which, while affording simplicity in manufacture, corresponds approximately to that blade form which is necessary for producing the suction action at the arcuate section to which gas is not admitted.

The blades can be produced in a simple way by making radial incisions in a wheel in such manner that the blade plates left standing between the incisions assume the desired angular position after suitable twisting. If it appears advisable to alter the outlet angle relatively to the inlet angle, then this can readily be done by bending the blades about a radial axis.

In order to obtain a favourable utilisation of the energy of emergence of the gas, guide blades may be provided between turbine and blower blades, in which case for example the guide devices arranged in the arcuate section where gas is admitted may be so constructed that they impart to the gas as large a peripheral component as possible, whereas the guide devices through which air flows may for example reduce the peripheral component to deflect or retard the air current.

At the outside it is advisable to dispose a common stationary cover ring about the turbine and blower blades with the smallest possible radial clearance. In some circumstances guide devices (e. g. guide wheel, guide ring or spiral housing) may be provided at the front of the turbine wheel in such a manner that the cooling current encounters the blades in that direction which is most suitable for good cooling and small losses.

If the guide blades direct the cooling current as far as possible into the direction of rotation of the turbine wheel then the losses become least. It is particularly favourable (above all in the case of exhaust gas turbines) that with high speed of inflow of the cooling air and particularly at small peripheral speeds of the wheel the admission of cooling air not only can produce no losses but can even result in an increase in the output of the turbine. If on the other hand the cooling current is directed against the direction of rotation, then due to the augmented impact there is an increased transfer of heat whereby the cooling action is augmented. More particularly when employed in aircraft and vehicle construction the guide devices may be adjustably arranged in known manner in order to be able to alter the angle of incidence in accordance with different peripheral speeds.

The air which otherwise has to be accelerated by the blades can be set in movement by the inflow and the suction so that in many cases the losses are considerably reduced.

If on the outlet side, stationary guide devices (e. g. guide wheel, guide ring or spiral housing) are arranged at an acute angle to the direction of rotation in place of the blower blades (or in addition thereto behind them as described above, or in front thereof), then in this way the air can be deflected and retarded and thus by a diffuser action a reduction in pressure, i. e. a suction action, can be exercised in front thereof. With increasing magnitude, the suction action can reduce the air resistance of the parts to which the air stream is admitted and finally can assist in the forward drive.

Finally the turbine blades themselves can be so constructed that they exercise a blower action over that arcuate portion to which gas is not admitted.

By suitable construction of the profile of the rotor blades it is possible for example to ensure that the resistance to the flow of air through the blades is reduced to a minimum even if it is not possible to obtain a conveyance of air after the manner of an axial blower due to the fan action. As shown in Fig. 10 and due to the small absolute speed of inflow of the air, the air current encounters the back of the turbine blades at a more or less flat angle varying with the peripheral speed. With a normal substantially symmetrical profile of the turbine blades of a constant pressure turbine there is an abrupt break in the flow beyond the inlet edge as indicated in Fig. 10. By a non-symmetrical construction, i. e. by arranging the chord joining the ends of the profile at an acute angle, it is possible—more particularly if the inlet edge is also rounded off—to obtain a flow free from losses with smaller deflection and smaller interruption in flow beyond the inlet edge as shown in Fig. 11. It is also desirable to round off the inlet edge of the blade because with increasing radius it is better possible to avoid local overheating and fracture. Preferably the radius of the inlet edge is made larger than 0.3 mm. Also, increasing the radii of curvature of the lines of flow in the blade channel has a similar favourable action.

According to the invention, therefore, with air cooling of the blades, it is proposed to employ large radii of rounding off for the inlet edge of the blades amounting for example to more than 0.3 mm. and to make the angle α (Fig. 11) between the chord joining the ends of the profile and the plane of the wheel smaller than 90°.

A further reduction of the losses for the incident flow against the backs of the blades and an increase in the blower action can be obtained by increasing the spacing of the vanes. The danger of an inadequate deflection of the lines of flow at the arcuate portion to which gas is admitted, i. e. a reduction of the peripheral component at the outlet due to excessive spacing with resultant absence of adequate guidance of the flow, can be counteracted by making the outlet angle of the blades corresponding to an efflux angle smaller than corresponds to the desired direction of outlet.

In accordance as to whether it is more important to have a small fuel consumption (e.g. aircraft with large range) or to have a small weight of machine per H.P. (aircraft for sport and for fighting purposes) the exhaust gases together with the kinetic energy still available therein can be directed through a preheater for the combustion air or can be allowed to escape directly into the atmosphere. The high temperatures and speeds of flow of the exhaust gases are very favourable for the transfer of heat in the preheater and reduce its weight.

The above described principle of cooling can be utilised for fresh gas turbines as well as for exhaust gas turbines. The proposed method of cooling can also be employed for steam turbines employing considerable superheating.

Certain embodiments of the invention are shown by way of example in the accompanying drawings, in which Fig. 1 is a side elevation in partial section of a fresh gas turbine for driving the propeller of an aeroplane.

Fig. 2 shows on a smaller scale a front view of the arrangement of Fig. 1 showing more particularly the relative positions of the housing and of the gas turbine rotor as well as by way of example the section of the rotor to which the gas is admitted.

Fig. 3 shows another embodiment in which the compressor lies in front of the turbine, which for example, can be regarded as an exhaust gas turbine.

Fig. 4 is a corresponding end view. The cooling air is introduced through two pipes, the outermost ends of which are bent into the direction of travel.

Figs. 5, 6 and 7, show diagrammatically three views of a further arrangement in which a particularly good cooling is obtained by arranging the turbine rotor at the front of the vehicle, e.g. body or wings of an aeroplane). Here the entire rotor, apart from that part to which gas is admitted, is exposed to the relative wind which has a cooling action. The gas flows from two conduits or burner chambers to the gas nozzles which are arranged opposite one another in two sectors. In Fig. 5 a boundary in the form of a Townend ring is provided in addition to the rotor blades. The guide blades are in addition shown behind the ring. The direction of travel is indicated by the arrow *a*.

Fig. 8 shows the arrangement of various guide devices, namely guide blades arranged in front of the ring of turbine blades, some (shown in full lines) directing the current of cooling air in the opposite direction to the direction of rotation and others (in dotted lines) directing the cooling air into the direction of rotation. Indicated in dotted lines between turbine and blower blades are guide blades which can be arranged on the inlet side so as to increase the tangential component, and shown in full lines are guide blades which are adapted to reduce the flow of the cooling air before reaching the blower blades. Guide blades provided in place of the blower blades or arranged behind them would have a similar appearance. In each case the arrows indicate the direction of movement of the turbine and blower blades.

Fig. 9 is a view in the radial direction of the development of the blower blades showing the acute angle β at which the disc is cut and the larger angle γ obtained by twisting the guide plates left between the cut portions. The shaded surfaces F thus indicate the lateral walls of the channels formed between the blades.

Fig. 10 shows a normal substantially symmetrical constant pressure steam turbine profile in which the air flows in the manner shown in the triangle of velocities towards the back of the blades and breaks off beyond the inlet edge.

Fig. 11 is a corresponding view of blades in accordance with the invention without sharp inlet edges and with a somewhat inclined chord joining the ends of the profile (see angle α), so that with air incident in the same direction the blades are traversed without discontinuity in the movement of the air.

Fig. 12 shows a blade diagram and triangle of velocities for the admission of gas to both rotor rings, from which it is seen that the profile of the blades of the second ring is elongated if the peripheral speed thereof is in the opposite direction to that of the turbine rotor.

In Figs. 1–7, the jet of gas flows from the burner chamber **7** through the nozzles or the nozzle chambers **8**, **8***a* and **8***b* to the blades **22** of the partial admission gas turbine, the rotor of which is indicated at **1**. The useful work of the turbine is transmitted to the propeller **3** by way of a gear train **2**. Arranged on the outlet side of the blades of the gas turbine is a ring **4** of blower blades which is mounted on the hub of the turbine rotor **1** by means of ball or roller bearings **10**. Guide plates **9** are arranged in front of and behind the blades of the gas turbine for improving the flow of cooling air.

The gas turbine also drives in known manner a compressor **5** which serves for compressing the combustion air.

The combustion air is preheated by the exhaust gas of the gas turbine in a preheater **6**.

In Fig. 1 an arrangement with small resistance to flight is shown diagrammatically adjacent the rotor blades, the cooling air being taken up by a channel in the body of the aeroplane and after passing through the blades **22** it flows away through a similar channel.

In the end view (Fig. 2) the ring of blades **22** of the gas turbine **1** is indicated by two concentric circles with radial lines extending between them. The outer periphery of the housing is indicated by B. Gas is admitted to the turbine blades over the arc C within which the turbine blades are cross-hatched, whereas the blades over the arc D do not have gas admitted to them and thus are exposed to the stream of cooling air.

In Figs. 3 and 4 the combustion gas is supplied to the blades by way of the pipes **11**, **12** and the inlet chambers **8***a*, **8***b*, whereas the outer air is directed to the blades by way of the conduits **15**, **16** and the inlet chambers **13**, **14**. The inlet chamber **8***a* is disposed symmetrically opposite to the chamber **8***b* and correspondingly the inlet chamber **13** is arranged symmetrically opposite to the inlet chamber **14** so that an unbalanced heating and distortion is avoided.

In Fig. 8, the guide blades in front of the turbine blades **18** are indicated at **17**, while the guide blades on the gas side are indicated at **19** and the guide blades on the air side between the turbine blades and the blower blades **21** are indicated at **20**. According to the invention further guide blades could be provided beyond the blower blades also.

In the diagram of Fig. 12 the upper curved profiles show the blades of the gas turbine, whereas the lower elongated profiles indicate the blades of the blower arranged at the outlet end of the turbine. In Figs. 10 and 12:

c_1 indicates the absolute speed of emergence of the gas from the nozzle,

w_1 the relative speed of entry to the turbine blades,

u the peripheral speed of the blades of the turbine rotor,

w_2 the relative speed of emergence from the rotor,

c_3 the absolute speed of emergence from the rotor,

w_3 the relative speed of entry of the gas to the blades of the blower,

u_v the peripheral speed of the blower blades,

w_4 the relative speed of emergence from the blower,

c_4 the absolute speed of emergence from the blower blades.

In other respects the representation of the blades differs in no way from the customary representation.

Apart from the embodiments shown in the drawings it is possible to make a large number of modifications within the scope of the present invention. For example the axis of the turbine could be turned through 90°. It would also be possible to use multi-ring equal pressure wheels, in which case the guide devices for directing the current of cooling air could be arranged behind each rotor.

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