Dec. 4, 1951 A. BUCHI 2,577,179

COOLING DEVICE FOR RADIAL GAS TURBINES

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Fig.1

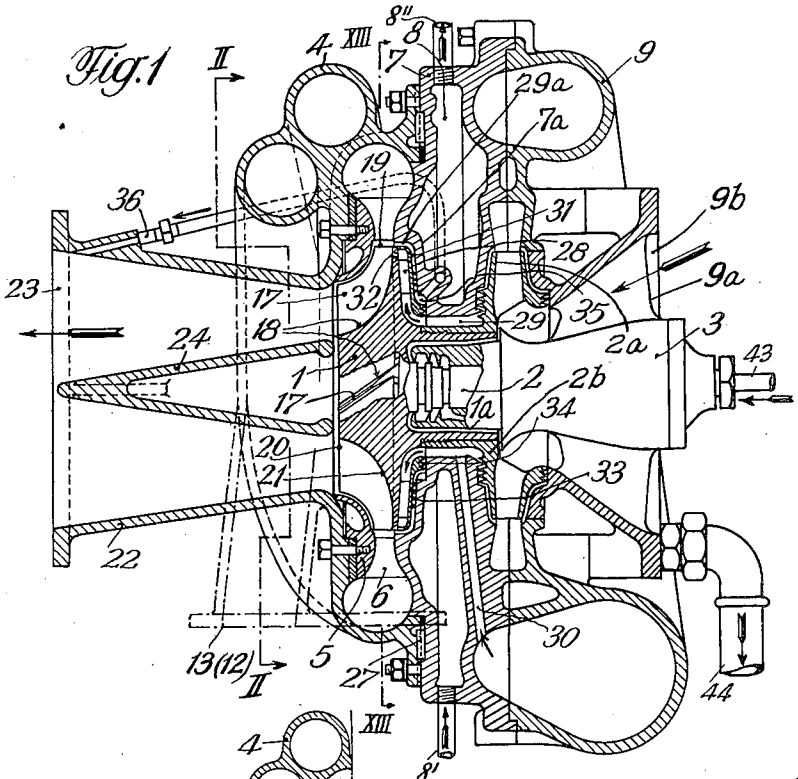


Fig.6

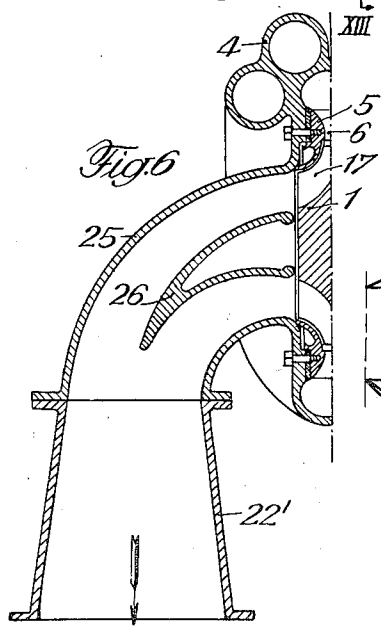


Fig.11

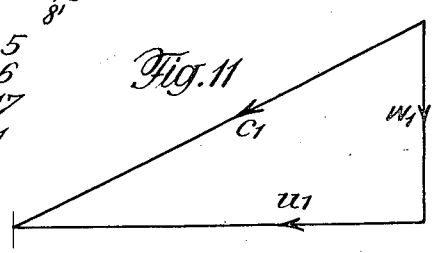
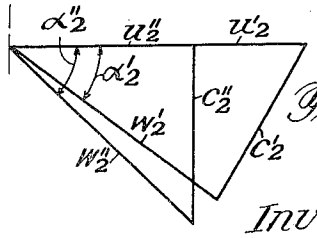


Fig.12



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COOLING DEVICE FOR RADIAL GAS TURBINES

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Fig. 2

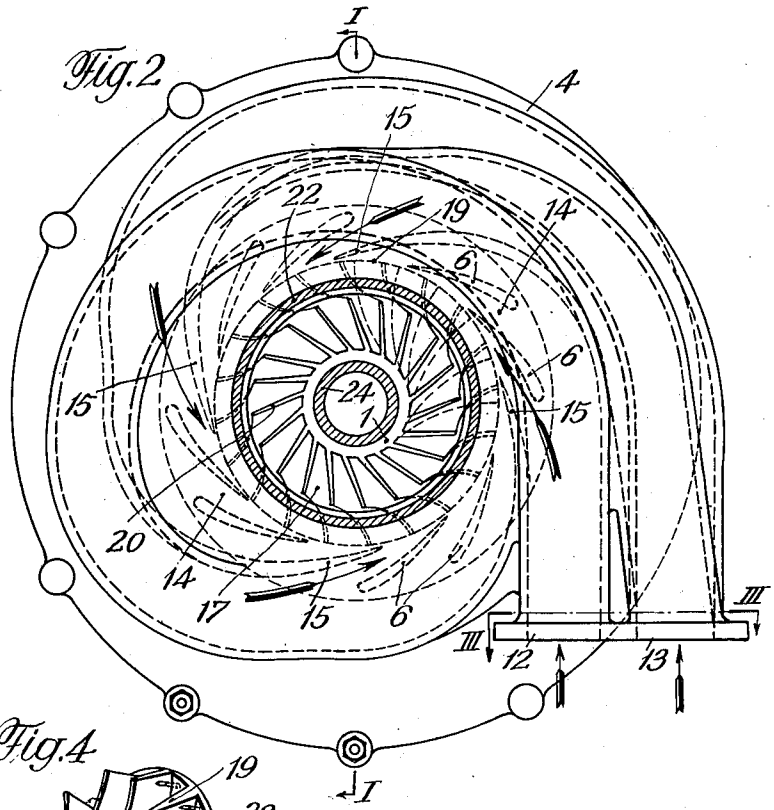


Fig. 4

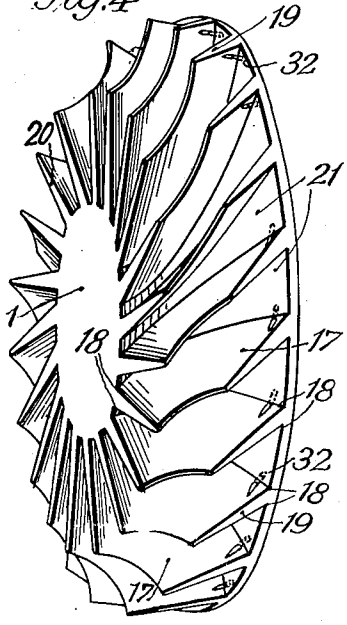


Fig. 5

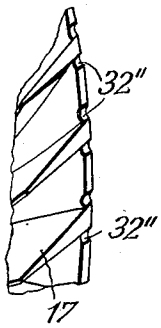
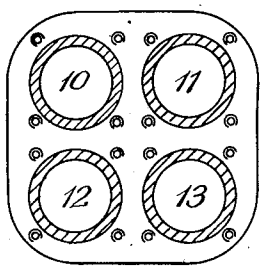


Fig. 3



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Fig. 10

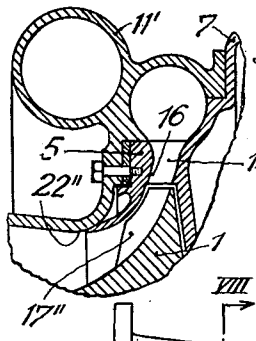


Fig. 7

Fig. 8

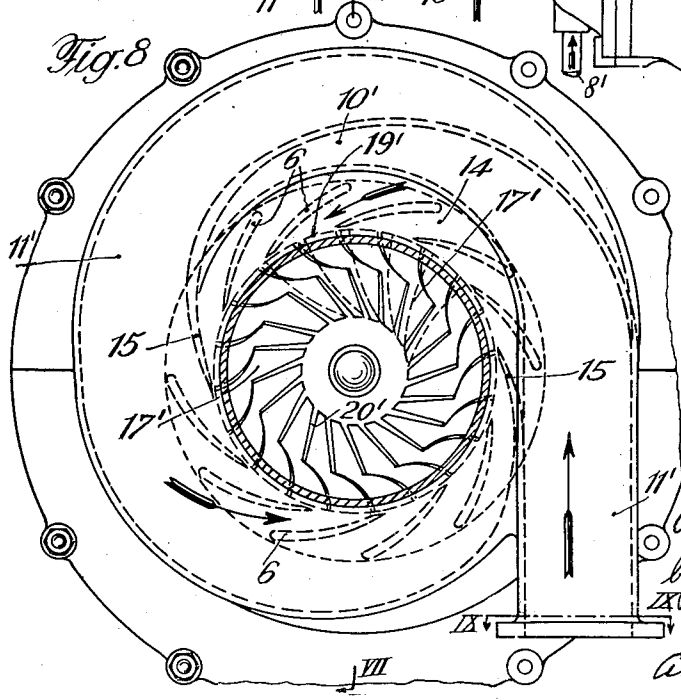
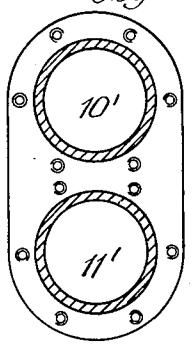


Fig. 9



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COOLING DEVICE FOR RADIAL GAS TURBINES

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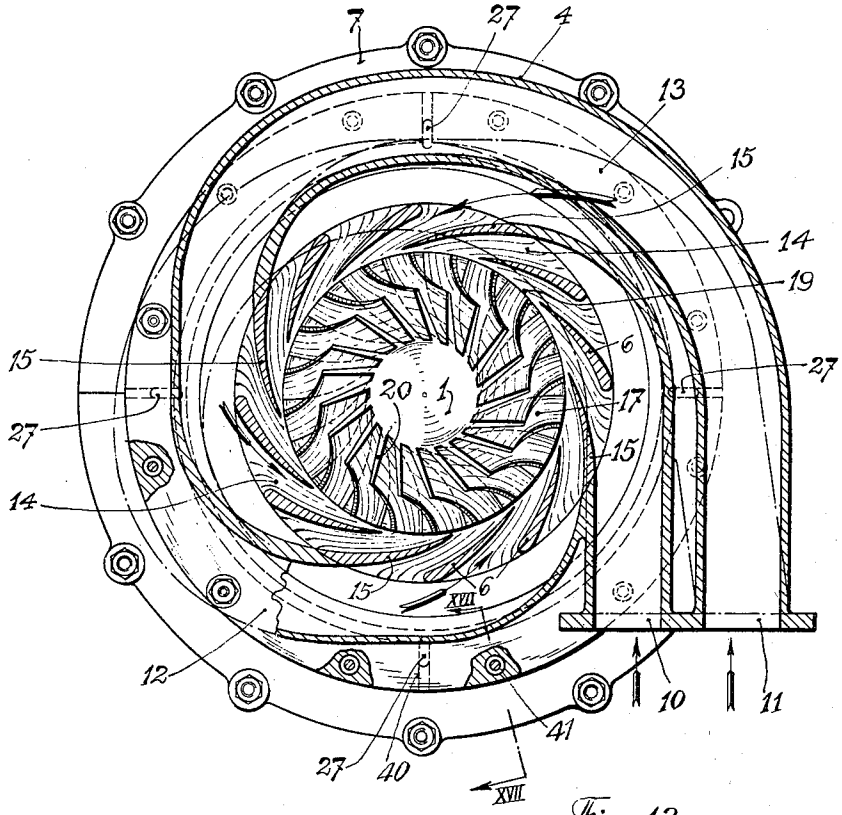


Fig. 13

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COOLING DEVICE FOR RADIAL GAS TURBINES

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Fig. 14

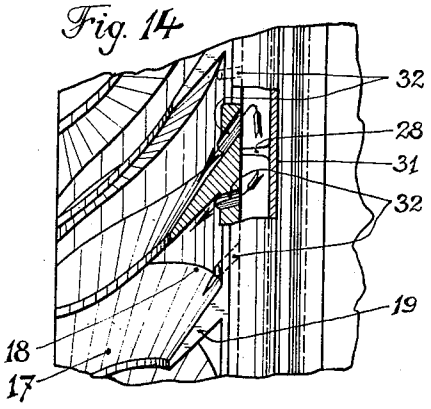
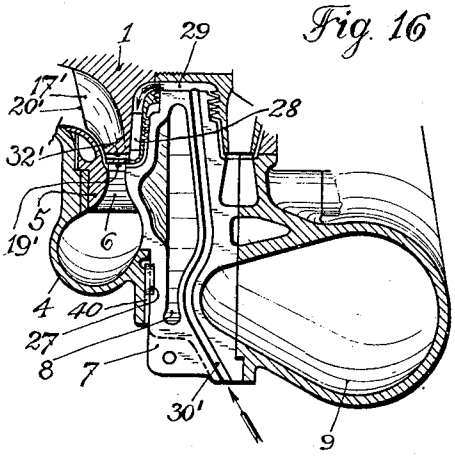


Fig. 16



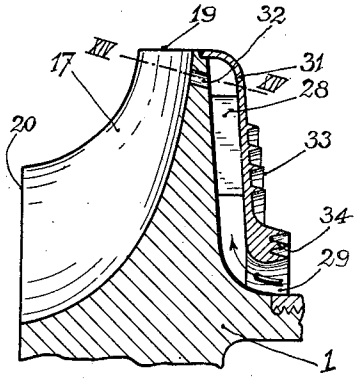
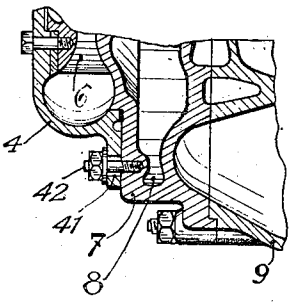


Fig. 15

Fig. 17



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2,577,179

UNITED STATES PATENT OFFICE

2,577,179

COOLING DEVICE FOR RADIAL GAS TURBINES

Alfred Buchi, Winterthur, Switzerland

Application September 14, 1945, Serial No. 616,204
In Canada August 18, 1942

8 Claims. (Cl. 253—39.15)

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This invention relates to arrangements for cooling rotor structures in turbines motivated by hot fluids, such as exhaust gases from internal combustion engines or other combustion chambers. My invention is particularly adapted to cool the blading and other hot parts of a turbine of the type illustrated in my prior Patents 2,390,506 and 2,486,732, the former being issued on my application Ser. No. 462,859 of which this present application is a continuation-in-part.

Thus, I cool the inner end portion of the turbine rotor and of the adjoining filler piece of the diffuser by means of a cooling medium which may be supplied particularly from the end of the driving shaft remote from the turbine rotor.

The face of the rotor disc from which the blading projects and across which the gases are passed through the blading to the diffuser, I shall hereafter refer to as the front face or front side; the opposite face, the rear face or back side. The back side of the turbine rotor disc may be provided, for example, with a cooling fan blading and, if desired, also with an associated covering disc for cooling the turbine rotor by means of cool air. In conjunction with this cooling arrangement cooling air may be forced through the turbine rotor blades through bores thereof or through openings in the rotor disc against the surfaces of the turbine blades, particularly adjacent to the points of entry of the gases and the blade bases. The cooling air may be derived from the surrounding atmosphere or any suitable extraneous place, for example, from any suitable spot on the pressure side of the turbine driven blower. In such an event the arrangement of a cooling fan blading on the back side of the turbine rotor can be dispensed with. However, in order to provide substantial cooling also on that side it is appropriate to employ cooling ribs or the like.

Several embodiments of the invention, inclusive of details thereof, are illustrated by way of example only in the accompanying drawings, in which

Figs. 1 to 6 represent a single stage gas turbine, as a first and preferred embodiment of the invention, the turbine being in driving engagement with a blower rotor and having four different gas supply conduits,

Fig. 1 being a section on the line I—I in Fig. 2;

Fig. 2, a section on the line II—II in Fig. 1;

Fig. 3, a section on the line III—III in Fig. 2;

Fig. 4, a perspective view of the turbine rotor inclusive of the blading thereof;

Fig. 5, a view of a modified detail of Fig. 4, and

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Fig. 6, a sectional view of a modified detail of Fig. 1.

Fig. 7 shows a side elevation partly in section on the line VII—VII in Fig. 8 of a second embodiment of the invention;

Fig. 8 is a sectional view on the line VIII—VIII in Fig. 7;

Fig. 9 is a sectional view on the line IX—IX in Fig. 8;

Fig. 10 shows a modification of a detail of Fig. 7;

Figs. 11 and 12 each represent diagrammatically various velocities;

Fig. 13 is a section on the line XIII—XIII in Fig. 1;

Fig. 14 is a part view of the circumference of the turbine rotor partly in section on the line XIV—XIV in Fig. 15, as seen in the radial direction, showing cooling medium conduction means on a larger scale;

Fig. 15 shows on the same scale a partial section of the turbine rotor inclusive of further details of said cooling medium conduction means, as seen in a plane extending through the rotor axis.

Fig. 16 shows a partial section of the connection between the assembled turbine inlet casing and the closure member inclusive of centering means for said parts on the line XVI—XVI in Fig. 7, and

Fig. 17 is a partial section similar to that shown in Fig. 16 on the line XVII—XVII in Fig. 13 showing further details of said connection.

In Fig. 1, I have shown a turbine rotor 1 coupled with a compressor wheel 2*a* by bearing sleeves 1*a* and 2*b* to form a unit adapted to rotate about the stub shaft 2. The latter is integrated with, or otherwise held firmly by, the support member 3 which is secured to the compressor casing 9 by the vanes 9*a* in the blower inlet 9*b*.

The numeral 5 refers to the nozzle carrier ring fixed in the outer turbine casing part containing the inlet blades 6 and 15 (Fig. 2), which contact with their free ends with the closure member 7. The closure member 7, which is provided with a cooling space 8, is arranged between the gas inlet casing 4 and the compressor collector casing 9. A flow of cooling fluid may be maintained through cooling space 8 by means of an inlet pipe 8' and an exit pipe 8'', as indicated by arrows in Fig. 1.

The turbine rotor is formed as in integral piece having a disc like wheel body 1 the flat blades 17 of which are, for example, worked out of the material of this body. These blades 17, one of

which is shown in elevation centrally of the wheel at 17, 18 (Fig. 1), have the characteristic feature that their surfaces project from the rotor disc 1 in oblique relation to the axis of the rotor and that they extend radially across the full blade width at least at the outer circumference of the rotor disc, when seen in the direction of the rotor axis. At the bases 18 of the blades 17, at the points where the latter are connected to the wheel disc 1, thickened blade portions are provided for reasons of strength. The bases of the blades, when seen transversely to the rotor axis, are curved towards the direction of this axis so to divert the passages between the blades from the radial into the axial direction.

After the gases pass through the blading 17 and leave the edges 20 thereof, the gases enter a diffuser 22 wherein their velocity is converted into pressure for ultimate discharge into the atmosphere. The numeral 24 designates a conically tapering guide piece adjoining the rotor hub which is provided to prevent too abrupt a decrease of the gas velocity in the diffuser.

In order to maintain true alignment between the gas inlet casing 4, expanding due to heat, and the cooled closure casing 7, as well as the turbine rotor 1, and the blower casing 9, both casings 4 and 7 are fixed in relative position to each other, for example, by means of four keys 27, as more particularly shown in Figs. 13 and 16, the axes of the keys intersecting the axis of the turbine.

The flanks of these keys fit snugly with the side walls of corresponding recesses provided for them in the turbine inlet casing 4 and in the closure casing 7 respectively. The recess 40 in the inlet casing is longer than the key 27 and extends beyond both ends of the key, so as to allow for the hot inlet turbine casing to expand freely relative to the cooled closure casing in two directions extending perpendicularly to each other. To this end the holes 41 for the connecting bolts 42 holding the parts 4 and 7 together receive these bolts with clearance (Fig. 17). This connection retains said parts positively in coaxial relation by means of only four points of registry free from the risk of the bolts jamming in their holes.

My present invention is concerned particularly with cooling the turbine rotor disc and accomplishes this effect by supplying cooling air to the back side of the disc in the manner hereafter described. First, it will be observed from Fig. 1 that the wall 7*a* of the closure member 7 which surrounds the sleeves 1*a* and 2*b* and then extends radially outwardly to close off the turbine disc and the gas inlet areas from the cooling fluid chamber 8, is disposed somewhat apart from said sleeves and from the back side of the rotor disc to leave a space 29 around the sleeves, and a further space 29*a* adjacent the back side of the rotor disc. The presence of this latter space permits me to provide fan blading 28 on the back side of the rotor disc. By providing a covering disc 31 over the fan blading, a series of bores 32 about the periphery of the disc 31, and by connecting a source of cooling air to the space 29, as for example by providing a pipe 30 between space 29 and the blower collector casing 9, it will be found that this air will be drawn in by the fan blading 28 through spaces 29 and 29*a* and discharged through the bores 32 onto the turbine blading 17. This cooling air course is illustrated in larger scale in Figs. 14 and 15. In thus passing through bores 32, the air traverses the top surface portions of the blades 17 substantially peripherally of the disc 1. The outer ends 19 and bases 18 of the blades 17 are thus considerably cooled.

Cooling air may also be supplied to the inner end portion of the turbine rotor and that the adjoining filler piece of the diffuser, through the hollow driving shaft of the rotor, by means of a cooling medium supply pipe 43 as shown on the right hand side in Fig. 1, in the direction of the respective arrow. Circulation for this air is provided by the arrangement of inner passages leading to the parts requiring to be cooled (Fig. 1). From said parts the cooling air returns through a return pipe 44 of larger diameter, as shown in Figs. 1 and 7. When the last described cooling system is utilized, it is not necessary also to employ the arrangement of separate fan blading on the back side of the turbine rotor above described.

To prevent the escape of gases from the backside of the turbine rotor, labyrinth sealing means 33 are provided. For the same purpose similar means 34 of smaller diameter may be provided in addition thereto, for example, on the back side of the covering disc 31 (Fig 15). The space 35 extending between the sealing means 33 and 34 and between the back side of the covering disc 31 and the front side of the closure member 7, may be put in communication with the atmosphere or with the discharge conduit 23 of the gas turbine through a conduit 36 (Fig. 1).

In the center of Fig. 2, showing a section on the line II—II in Fig. 1, the construction of the turbine rotor blades 17 is shown in detail. Of the turbine buckets formed by each pair of successive blades 17, the base portions adjacent the peripheral portions 19 on the outer periphery of the rotor extend in the radial direction, while the blades themselves incline to the rotor axis, as mentioned above. The discharge edges 20 of these blades also extend radially or are only slightly inclined to the radial direction. The inlet casing 4 of the turbine is integral with the diffuser arrangement 22. Four supply conduits 10, 11, 12 and 13 (see also Figs. 1 and 3) form an arrangement of crowded convolutions so that the outer diameter of the casing 4 is reduced to a minimum.

Fig. 3, being a section on the line III—III in Fig. 2, exemplifies the manner in which the four separate supply conduits 10, 11, 12 and 13 are relatively arranged.

Fig. 4 being a perspective view of the turbine rotor 1, clearly shows the radially directed entrance ends 19 and the approximately radially directed exit ends 20 of the turbine rotor blading 17. From this illustration it will be plainly seen that the approximately plane flanks of the rotor blades extend transversely to the turbine axis, and that the thickness of these blades increases particularly in the radial direction and toward the blade bases 18 at the turbine wheel disc.

Fig. 4 further shows the bores 32 as arranged in the turbine rotor disc 1 on a single common diameter, for the passage of cooling air, the bores being so directed that this air is projected onto the surfaces of the blades, particularly those surfaces that are situated adjacent to the entrance edges of the turbine buckets, and adjacent to the bases of the blades. Alternatively, bores 32 may be arranged on more than one diameter of the rotor disc for additional bores to be arranged near the blade bases but more remote

from the entrance edges of the buckets. Fig. 4 and more particularly Fig. 14 also illustrates that the cooling air is projected onto both surfaces or flanks of the rotor blades, the front flank as well as the rear flank. It would also be possible to provide other types of passages serving the same purpose in lieu of bores 32, as for example, notches 32'' in the peripheral edge of the rotor disc 1. The cooling air may also flow over on the circumference of the turbine disc from its back side into the turbine blading.

The second embodiment of the invention as shown in Fig. 7 comprises a gas turbine with only two inlet conduits 10' and 11'. The numeral 17' refers to the turbine rotor blades having inlet edges 19' and exit edges 20'. These exit edges 20' are cut off obliquely to the turbine axis (Fig. 7 sectional portion).

This embodiment also provides for arranging a cooling blading 28 on the back side of the turbine rotor 1 for withdrawing cooling air from the space 29. These cooling blades are closed laterally and towards outside by a covering disc 31 also in this case. The individual blades 17 are however provided with bores 32', through which the cooling air delivered by the cooling fan is forced, similarly as in the construction shown in Fig. 1. The cooling fan 28 withdraws air through the space 29 from without by means of a conduit 30' (Fig. 16). The conically tapering interior piece 24' of the diffuser is in this case integral with the turbine rotor 1. Alternatively bores 32 or notches 32'' (see also Fig. 5) for cooling air may be provided in the turbine rotor disc 1 at the same time.

The central portion of the hub of the rotor 1 as well as said interior piece of the diffuser 24 are hollowed and cooled by a cooling medium entering the hollow interior of the piece 24' through a pipe 37 which is fed with said medium by means of a pipe 43. The latter projects this medium into the interior of said piece from which the medium returns through a bore 38 continuing through the rotor and the bearing support therefor. From the end of the bore 38 the medium flows down through a passage 38' and thence out of the machine by means of a discharge pipe 44.

Fig. 8, representing a section on the line VIII—VIII in Fig. 7 as seen from the left hand side of the latter, shows the form of the turbine rotor blades 17' inclusive of their radially directed inlet edges 19' of the turbine buckets and the substantially radially extending exit edges 20' of the blades. The two supply conduits 10' and 11' forming a crowded arrangement of convolutions taper also in this case spirally toward the two blades 15 separating said conduits from each other. Within the interstices between said blades 15 only five nozzle blades 6 are arranged in the nozzle carrier ring 5 for each supply conduit, for leading the gases into the turbine rotor.

The conduits 10' and 11' are collaterally disposed with the joining line of their axes extending in parallelism with the turbine axis.

Fig. 10 represents a modification of the construction of the inlet nozzles 14 and a corresponding form of the turbine rotor blading 17''. The inlet direction of the nozzles 14 is no longer radial, but, when seen transversely to the turbine axis, inclined at an acute angle to the axis of the turbine rotor 1 which corresponds to the direction of flow of gas at point 16 in this figure.

Fig. 11 represents the gas inlet velocity triangle at the blade entrance 19 of the turbine, in which

c_1 designates the absolute gas admission velocity, u_1 the velocity at the circumference of the rotor, and w_1 the relative gas admission velocity which is approximately radially directed in accordance with the present invention.

Fig. 12 represents the gas velocity diagrams at the exit end 20 of the turbine rotor. The character u_2' refers to the circumferential velocity at the extreme outer exit diameter, w_2' to the relative gas velocity thereat, and c_2' to the corresponding absolute gas velocity. The character u_2'' represents the smaller circumferential velocity at the blade bases, w_2'' the relative gas velocity at the last named point, and c_2'' the corresponding absolute gas velocity.

I claim:

1. In a radial gas turbine, the combination of a rotor provided with driving blades on the front side thereof, a casing, in which the rotor is housed, composed of a front closure member and a back closure member secured together, a passage for supplying cooling air between the back side of the rotor and the back closure member, and conduits extending through the rotor from the back side thereof to the front side thereof to conduct cooling air from the supply through the rotor to the blade surfaces to supply a layer of cooling air which cools and protects the blades against the heat of the gases passing through the turbine.

2. In a radial gas turbine, the combination of a rotor provided with driving blades on the front side thereof, a casing, in which the rotor is housed, composed of a front closure member and a back closure member secured together, a passage for supplying cooling air between the back side of the rotor and the back closure member, and conduits extending through the rotor from the back side thereof to the front side thereof adjacent the radially outer portions of the blades to conduct cooling air from the passage through the rotor to the radially outer portions of the blade surfaces to supply a layer of cooling air which cools and protects the blades against the heat of the gases passing through the turbine.

3. In a radial gas turbine, the combination of a rotor provided with driving blades on the front side thereof, a casing, in which the rotor is housed, composed of a front closure member and a back closure member secured together, a passage for supplying cooling air between the back side of the rotor and the back closure member, and conduits arranged substantially circumferentially of the rotor, extending through the rotor from the back side thereof to the front side thereof to conduct cooling air from the passage through the rotor to the surface of the blades, the conduits being directed to conduct air adjacent one side, at least, of each blade toward its radially outer portion.

4. In a radial gas turbine, the combination of a rotor provided with driving blades on the front side thereof, a covering disc secured to but spaced from the back side of the rotor forming therebetween an annular cooling air chamber, a passage leading from the chamber to an air supply, fan blades in the chamber on the back side of the rotor to draw air from the supply through the passage into the chamber, the rotor being provided with cooling air bores disposed adjacent the radially outer portions of the rotor and communicating with the chamber, the said bores being directed to conduct air toward at least one

side surface of each blade and substantially toward the radially outer blade portion.

5. A radial gas turbine as defined in claim 4 in which the said passage leads from the said chamber to atmosphere for said air supply.

6. A radial gas turbine as defined in claim 4 in combination with a blower driven by the turbine and in which the said passage leads from said chamber to the compressed air delivered by said blower for said air supply.

7. In a radial gas turbine, the combination of a rotor disc provided on its front face with axially extending blading for the actuating gas, and means for supplying a coolant fluid to said blading, said means including an annular coolant pressure fluid chamber comprising in part an axially directed space around the hub of the rotor defined by a cylindrical axially extending hub-surface and a housing wall radially spaced therefrom, and in further part by a radially directed space defined on one side by the rear face of said rotor disc and on the opposite and outer side, by a housing wall surface axially spaced from the said rear face of said rotor disc, a source of coolant fluid maintained under pressure, conduits adapted to conduct fluid from said source through the housing wall radially spaced from the said hub surface into the axially directed space, and passages about the periphery of, and through the rotor disc leading from the radially directed space and extending at least partially in axial direction toward the leading edges of the said blading, whereby predetermined quantities of coolant fluid may be projected upon said edges of the turbine blading and swept along with the actuating gas.

8. In a radial gas turbine, the combination of a rotor disc provided on the front face with axially extending blading for the actuating gas, and means for supplying a coolant fluid to said blading, said means including an annular coolant pressure fluid chamber comprising in part a stationary space around the hub of the rotor defined by a cylindrical axially extending hub-surface and a housing wall radially spaced therefrom, and in further part by a rotatable space defined on one side by the rear face of said rotor disc and on the opposite and outer side by a covering disc axially spaced from the rear face of said rotor disc, said covering disc being rigidly connected to the rotor disc-perimeter and rotatable therewith in abutment with said radially spaced housing wall, a source of coolant fluid maintained under pressure, conduits adapted to conduct fluid from said source through the said radially spaced housing wall to the said stationary space, and passages about the periphery of the rotor disc from said rotatable space, extending at least partially in axial direction toward the leading edges of the rotor blading, whereby jets of predetermined quantities of coolant fluid under pressure may be projected in relative stationary condition directly upon the leading edges of the said blading and said coolant fluid is swept along with the actuating gas.

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