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COOLING COMBUSTION TURBINE

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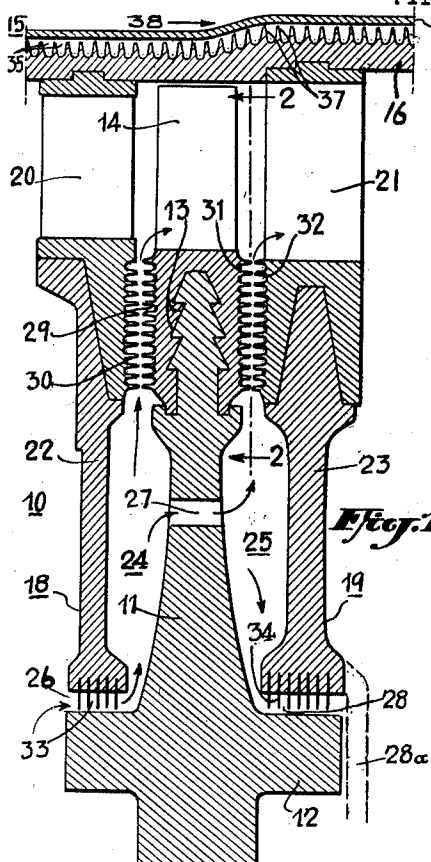


Fig. 1.

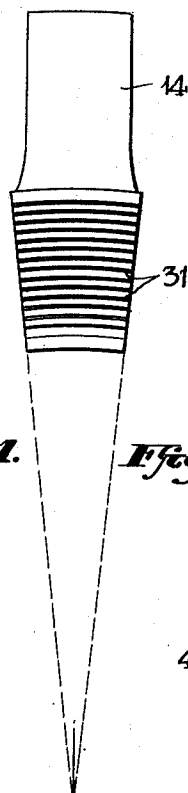
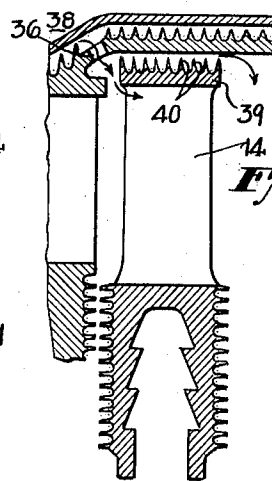


Fig. 2.



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COOLING COMBUSTION TURBINES

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3 Claims. (Cl. 253—39.15)

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This invention relates to improvements in cooling means for gas or internal combustion turbines, particularly of the type employed for jet propulsion of planes and the like, and comprising an air compressor, fuel burning means in the compressor output for providing a jet propulsion reaction, and a gas turbine driven by the combustion products for driving the compressor.

Objects of the invention are to provide highly efficient and effective means for cooling the fixed and rotating parts of gas turbines which are exposed to the heated gases, such as the rotor and stator elements, as well as to provide means for cooling the turbine housing or casing.

Arrangements have heretofore been proposed for cooling the rotor and contiguous stator components, in gas turbines of the character aforesaid, but such prior proposals entail certain limitations upon the metals employed in the turbine construction, in order that the desired temperatures can be achieved, in consequence of which they do not permit the construction of gas turbines of high thermal efficiency. Thus, a serious limitation has been placed upon the power of prior gas turbines per pound of compressed air. The present invention permits the construction of a gas turbine of the type aforesaid, having a thermal efficiency which is equal to or greater than that of the conventional internal combustion engine of the reciprocating piston type. Moreover, the present invention permits the attainment of a power output which is more than double the power output of comparable gas turbines proposed in the past.

In accordance with one modification of the invention, the gas turbine may take the form of a disc-like rotor provided with peripherally disposed vanes or buckets for driving the same, the rotor being rotatably mounted within a turbine housing or jacket, which mounts and supports a stator ring provided with guide vanes or nozzles for directing the hot gaseous combustion products against the rotor vanes or buckets for driving the same. The stator ring is thus mounted in both radially and axially spaced relation to the rotor, in conjunction with which the basal portions of the rotor and stator elements are so concavely shaped, viewed in axial section, as to provide a passage for the injection and flow of cooling air therebetween, this cooling air being supplied from the compressor, and being injected therefrom axially between the stator ring and rotor shaft in the annular passageway provided between them, as above explained, and flowing

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thence radially outward between the opposed, spaced rotor and stator elements against the rotor and stator vanes, at which point it meets the hot gases from the combustion chamber, from whence the combined combustion gases and cooling air are swept past the rotor vanes and discharged through the discharge or jet nozzle of the turbine. In order to prevent the hot combustion gases derived from the combustion chamber of the turbine, from flowing into the cooling air passageway between the rotor and stator elements, the pressure of the cooling air supplied to this passageway from the compressor must exceed the pressure of the hot combustion gases against the turbine blades.

For enhancing the cooling action of the rotor and stator elements due to the flow of cooling air therebetween, as above described, the opposed surface portions of the rotor disc and stator ring, which are situated just below the vanes, are provided with a series of heat-dissipating ribs or fins. These fins may be angularly spaced and extend radially outward in rectilinear or suitably curved manner for centrifugally throwing the cooling air against the rotor vanes, but, in accordance with an important feature of the invention, preferably take the form of a series of radially spaced rings, concentric with the axis of the rotor element. It is found that this latter arrangement greatly increases the cooling action of the rotor and stator elements as compared to the radially extending fin arrangement. It will be understood, of course, that it is within the contemplation of the present invention to provide these cooling fins on either the rotor element alone, or on the stator element alone, but preferably they are provided on both of these elements in the ways above described, since this imparts the greatest cooling action to both the rotor and stator elements.

In accordance with a further modification of the invention, stator rings, constructed as aforesaid, are mounted on opposite sides of the stator disc, in axially spaced relation thereto, to provide radially extending cooling air passageways aforesaid, and at least one of these stator rings is also radially spaced from the rotor shaft to provide therebetween, an annular passageway for the injection of cooling air from the compressor, in addition to which the rotor disc is transversely perforated or slotted at angularly spaced intervals to interconnect the radially extending cooling air passageways aforesaid on the opposite sides thereof. Thus, the cooling air introduced

from the compressor will flow in part radially outward in the cooling air passageway on one side of the rotor disc, and will flow in part through the perforations or slots therein into the cooling air passageway on the opposite side thereof and thence radially outward between the opposed rotor and stator ring surfaces.

In accordance with still another modification of the invention, which is applicable to any of the constructions above described, the turbine housing or casing takes the form of an inner jacket and an outer jacket which are so mounted as to provide an air space therebetween, into which cooling air may be injected from the compressor for cooling the turbine casing, the inner casing being suitably perforated or slotted adjacent the rotor vanes or buckets to provide exits through which the cooling air flowing between these turbine jackets is expelled against the vanes or buckets of the rotor element.

The slotted rotor construction above described is applicable to single-stage as well as to multi-stage turbines.

As a further refinement of the invention, additional heat-dissipating fins may be provided on the outer peripheries of the vanes or buckets of the rotor elements, these fins preferably being axially spaced along these vanes and extending peripherally thereabout, in the form of a peripherally grooved outer ring. In conjunction with this construction, the exit slots provided in the inner turbine jacket are so formed and positioned as to direct the cooling air expelled therefrom, against the heat-dissipating fins thus provided at the outer peripheries of the rotor vanes.

With reference to the turbine casing construction aforesaid, comprising inner and outer, spaced jackets, there are provided, in accordance with a further feature of the invention, on a surface or surfaces of either or both of these jackets, a series of heat-dissipating fins, which preferably take the form of axially spaced ribs extending peripherally about the jacket or jackets, the preferred arrangement being that wherein such fins are provided on the inner surface or surfaces of the jackets, and such that the cooling air from the compressor is caused to flow along these beforesaid fins.

In order to prevent overheating of the combustion chambers aforesaid, I provide, in accordance with still another feature of the invention, a series of heat-dissipating fins on the outer surfaces of such chambers, these fins being preferably angularly spaced and extending axially along the outer surfaces thereof.

In accordance with still another feature of the invention, the cooling air from the compressor is circulated through a water-cooled, or other liquid-cooled, cooling means prior to entering the cooling passages of the turbine above described.

Having thus generally described my invention, reference will now be had, for a more detailed description thereof, to the accompanying drawings, wherein:

Fig. 1 is a view in axial, sectional elevation of a portion of a gas turbine embodying cooling means in accordance with one modification of the invention, this view showing a rotor wheel and contiguous stator rings, together with the associated portion of the turbine housing. Fig. 2 is a view in front elevation of a portion of the turbine wheel of Fig. 1, as taken as 2—2 of Fig. 1.

Fig. 3 is a view in axial, sectional elevation of a fragmentary portion of a turbine wheel and contiguous stator and turbine housing compon-

ents, illustrating another modification of the invention.

Fig. 4 is a view in axial, sectional elevation of a fragmentary portion of a turbine rotor wheel, illustrating a further modification of the invention.

Fig. 5 is a view in axial, sectional elevation of a portion of a multi-stage turbine embodying cooling means in accordance with a further modification of the invention, this view showing a rotor and contiguous stator elements, and also a portion of the turbine housing.

Fig. 6 is a view in axial, sectional elevation through a multi-stage gas turbine and associated combustion chamber and air compressor units, illustrative of still a further modification of the invention.

Referring to Figs. 1 and 2, there is shown generally at 10, a portion of a gas turbine in accordance with one modification of the invention, as above described, and comprising a rotor disc 11, rotatably mounted on a shaft 12, the outer periphery of the rotor disc having keyed thereto, in the manner illustrated at 13, a series of angularly spaced airfoil vanes or buckets 14 for impelling the same. The rotor is enclosed within a turbine housing shown generally at 15, and comprising an inner jacket 16 and an outer jacket 17, mounted in spaced-apart relation, as shown, and for purposes above described and as explained more in detail hereinafter. Secured to and carried by the inner jacket 16, are a pair of stator rings 18 and 19, which are mounted respectively on opposite sides of the rotor disc 11, as shown, these stator rings being provided with guide vanes, as at 20 and 21, for directing hot combustion gases from the combustion chamber, against and respectively away from the rotor vanes 14. The basal portions of the stator rings 18, 19 are of solid construction, as shown at 22, 23. Also, the stator rings are mounted in axially spaced relation to the rotor, as shown at 24, 25. In addition, the basal portions of the stator rings and the rotor disc are concavely shaped, viewed in axial section, as illustrated in Fig. 1, whereby the spacings 24 and 25 provide radially extending air passages on both sides of the rotor, for the flow of cooling air therethrough as above explained. The stator ring 22 on the inlet side is radially spaced from the rotor shaft, as shown at 26, to provide an annular passageway, as shown, between the base of the stator ring 22 and the rotor shaft, for injection of cooling air from the compressor into the radially extending cooling passageway 24. Moreover, the rotor disc 11 is transversely slotted or apertured, at angularly spaced intervals, in the manner shown at 27, for interconnecting the radially extending passageways 24 and 25, on the opposite sides of the rotor disc respectively. In this way, cooling air injected from the compressor into the annular passageway 26, will flow, in part, radially outward through passageway 24 on one side of the rotor against the vanes 20, 14; and will also flow, in part, through the rotor disc slots 27 into the passageway 25 on the opposite side of the rotor disc, and thence radially outward against the vanes 14, 21, thereby cooling both surfaces of the rotor disc, and also the thereto-opposed surfaces of the stator rings. In turbines of the multi-stage type, the base of the stator ring 23 will likewise be radially spaced from the rotor shaft 12 to provide an annular passageway therebetween, as at 28, connecting

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the radial air cooling passageway 25 with passageways corresponding to 24, 27 and 25 of the next succeeding stage, as explained more in detail below. On the other hand, and in turbines of the single-stage type, the annular passage 28 is preferably closed or blocked off, by means of a closure member, as indicated, for example, by the closure plate 28a, thereby to prevent the escape of the cooling air through the passageway 28.

For enhancing the cooling effect of the cooling air flowing through passageways 24 and 25 onto the stator and rotor vanes, as described, either or both of the opposed surface portions of the rotor and stator elements, which are situated immediately below the vanes, are provided with heat-dissipating fins, which, in the preferred embodiment, take the form illustrated in Figs. 1 and 2, comprising a series of radially spaced ribs or fins, extending concentrically about the rotor axis, as illustrated at 29 to 32 inc. Fins 29, 33 preferably are spaced closely together but not in contact in order that jointly they may restrict or "meter" the outward flow of cooling air, such restriction or metering being to a preselected extent depending, of course, upon the distance between such fins 29, 30. Additional heat-dissipating fins may also be provided in the annular passageways 26, 23, formed between the stator rings and the rotor shaft. These fins may be mounted or formed on the stator rings or on the rotor shaft or on both. In the embodiment illustrated in Fig. 1, they are mounted or formed on the inner peripheries of the stator rings in the form of axially spaced, peripheral ribs, as shown at 33, 34.

As above stated, the turbine casing 15, preferably takes the form of the inner and outer spaced-apart jackets 16 and 17, into the space 35 between which, cooling air is injected from the compressor, the inner or the outer jacket being provided with suitable exit passageways like 36, Fig. 3, for expelling the cooling compressed air. Either or both of the jackets 16, 17, may be provided with heat-dissipating fins, the preferred arrangement being that illustrated in Figs. 1 and 3, wherein the inner surface of the inner jacket 16 is provided with a series of axially spaced, up-standing ribs, as at 37, along which the cooling air is caused to flow. Such ribs may wind about the inner casing 16 in the manner of screw threads whereby air flowing therealong, as mentioned above, is caused to move about such inner casing in a similar manner.

Referring to Fig. 3, additional heat-dissipating means may be provided on the vanes 14 of the rotor element, by connecting the same with an outer peripheral ring 38, the exterior surface of which has formed thereon a series of axially spaced peripheral fins or ribs as at 40. In this construction the cooling air exit passages 36 from the turbine housing are so positioned and directed, as shown in Fig. 3, as to direct the cooling air expelled from passages 36 onto the heat-dissipating fins 40 of the rotor vanes.

Fig. 4 illustrates, generally at 41, a rotor disc mounting two sets of axially spaced airfoil vanes or buckets 42, 43. The opposite surface portions of the rotor disc, which are disposed below the vanes 42, 43, are provided with radially spaced, concentric circular grooves or ribs, as at 44, 45, for heat-dissipating purposes as aforesaid. In the rotor construction of Fig. 4, the rotor disc 41 is of course transversely apertured or slotted in

the manner shown at 27 in Fig. 1, causing the cooling air to flow over the opposite surfaces of the rotor disc, including the heat-dissipating fins 44, 45, in the manner generally described and explained in connection with Fig. 1.

Fig. 5 illustrates a gas turbine construction in accordance with the invention, which constitutes a modification of that illustrated in Fig. 1, in that no stator rings are interposed between a pair of adjacent rotor elements. Thus, referring to Fig. 5, a pair of rotor discs 50 and 51, rotating in opposite direction, and provided with peripherally disposed airfoil vanes or buckets 52, 53 respectively, are mounted adjacent one another in axially spaced relation, between journal members 54, 55, thereby to provide between the rotor discs 50, 51, a radially extending air cooling passage 56. The rotor assembly thus formed is journaled to a turbine housing 57, through anti-friction roller or ball bearings, as indicated at 58. The housing 57 encloses the rotor assembly, as shown, and is provided with an annular inlet nozzle 59 extending from the combustion chambers, this inlet nozzle being provided with angularly spaced guide vanes as at 60, for appropriately directing the hot gases from the combustion chambers onto the impeller blades 52, 53 of the rotor assembly.

For purposes of air cooling the rotor and stator elements, the turbine housing 57 is provided, near its base, with one or more transversely extending passageways or slots, as at 61, for the injection of cooling air from the compressor into an inner chamber 62 of the turbine housing. Chamber 62 is partitioned off from the rotor assembly by means of a wall portion 63, the base of which is radially spaced from the rotor assembly to provide an annular passageway therebetween, as shown at 64. The wall portion 63 of the turbine housing is axially spaced from the adjacent rotor disc 50 to provide therebetween a radially extending cooling air passageway 65, which connects with the annular passageway 64. The rotor disc 50 is transversely apertured or slotted as at 66, for inter-connecting the radial passages 65 and 66, disposed on opposite sides, respectively, of the rotor disc 50. The rotor disc 51 is similarly apertured or slotted, as at 67, for inter-connecting the radial passageway 56 with the radial passageway 66a, formed between the rotor disc 51 and the opposite side of the turbine housing 57. Beneath the vanes 60, 52 and 53, the opposed rotor disc and stator surfaces are provided with radially spaced, concentric, heat-dissipating fins or grooves, as at 68, 69, of a character and for purposes as described and illustrated in connection with Figures 1 and 2.

In the construction of Fig. 5, cooling air forced from the compressor through the inlet passage 61, will flow into the chamber 62, thence through the annular passage 64, and thence radially outward through the successive passages 65, 66 and 66a, between the opposed rotor and stator surfaces provided with the heat-dissipating fins 68, 69, the rotor apertures or slots 66, 67 serving to distribute the cooling air between the successive radial passages aforesaid.

Fig. 6 illustrates a multi-stage gas turbine, embodying a turbine construction generally similar to that of Fig. 1, in association with the combustion system and a compressor unit. The rotor assembly of the turbine comprises the turbine wheels 70, 71, 72, mounted on a rotor shaft 73, these turbine wheels being provided with peripherally disposed airfoil vanes or buckets, as

at 74. The rotor assembly is enclosed within a turbine housing, shown generally at 75, within which are mounted, on opposite sides of each of the turbine wheels, stator rings as at 76, 77, these rings being provided with guide vanes as at 78, for appropriately directing the hot combustion gases against and respectively away from the turbine wheel vanes interposed therebetween. The constructions and relative dispositions of the turbine wheels and stator rings, are similar to those of Fig. 1, and the air-cooling arrangement of the Fig. 6 construction is generally similar to that of Fig. 1. That is to say, in the Fig. 6 construction, radially extending cooling air passages are provided between opposed rotor and stator surfaces, as at 78a, the rotor discs are transversely slotted, as at 79, and the inner peripheries of the stator rings are radially spaced from the turbine wheel hubs, as at 80, for interconnecting adjacent radial passages such as 78. Likewise, heat-dissipating ribs or fins are provided beneath the vanes on opposed surface portions of rotor and stator elements, as at 81, these fins being preferably formed in accordance with the Figs. 1 and 2 embodiment above described. The turbine casing 75 is of the hollow construction shown in Fig. 1, and consists of inner and outer, spaced-apart jackets 82, 83, the outer surface of the inner jacket being provided with cooling fins 84 similar to those of the Fig. 1 construction.

Air-cooling of the turbine is effected by the introduction of cooling air from the compressor through a passage 85 in the base of the turbine casing, from whence the air flows into a chamber 86 of the turbine casing, at which point it divides, a portion flowing radially outward through passages such as 87, interconnecting chamber 86 with the air space 88, within the interior of the turbine casing, from whence this portion of the cooling air flows within the turbine casing transversely and circumferentially across the heat-dissipating fins 84 therein, disposed in helicoidal shape to outlet passages such as 89, provided at the opposite end of the turbine casing. The remainder of the cooling air injected into chamber 86 is forced into the interconnected passageways such as 78a, 79, and 80, between the various rotor and stator elements, and flows thence, in part, radially outward past the heat-dissipating fins 81, within each passage, such as 78a, provided between opposed rotor and stator surfaces. In this way a highly efficient and effective air-cooling of the entire turbine, including rotor and stator elements as well as the turbine housing, is effected.

The turbine is driven by hot combustion gases supplied from the combustion system illustrated generally at 90, and comprising an annular housing 91, 92, within which are mounted a series of angularly spaced combustion chambers, or an annular combustion chamber, as at 92a, supplied with fuel from fuel nozzles or burners, as at 93. Mounted on the opposite end of shaft 73 from that of the turbine rotor, is a rotor 94 of a centrifugal air compressor, the stator 95 of which is provided with air passages, as at 96, opening into the combustion housing 91, 92, from whence the air flows into the combustion chambers 92a at least partially through the perforations, therein, as at 97. The resulting combustion products or hot gases pass thence into the turbine through the inlet nozzle 98.

The lower portion 92 of the combustion chamber housing is transversely perforated or slotted, as at 99, to provide passageways through which

cooling air under pressure is fed from the compressor into an annular air chamber 100, disposed between the combustion housing 92 and the rotor shaft 73. In addition, the portion 101 of the compressor stator 95 is radially spaced from shaft 73 to provide therebetween an annular passageway 102, through which additional cooling air from the compressor is forced into the air chamber 100, from whence the cooling air is forced into the turbine, in the manner above described, through the opening 85, interconnecting the air chambers 100 and 86.

The cooling air fed from the compressor may be further cooled before passing into the turbine chamber 86, by circulating the same through a water-cooled, or other liquid-cooled, cooling means such as that illustrated at 103, mounted in the air chamber 100. This cooling means may comprise a flat, tubular member, wound spirally about a form 105, to provide between successive convolutions thereof, air spaces such as 106, through which the air from the compressor is fed in the direction indicated by the arrows. Cooled water or other cooled liquid is circulated through the tubular member 104 in a circulatory system including pump and an air-cooled radiator, through which the liquid is continuously pumped.

Reverting to the combustion chambers 92a, these are preferably provided on the exterior surfaces thereof, with spaced, heat-dissipating fins, as at 107, which preferably take the form of spaced, longitudinally-extending ribs, as shown.

What is claimed is:

1. In a gas turbine, a disc-like rotor having peripherally disposed bucket means, a housing enclosing said rotor and comprising an inner jacket and an outer jacket, said inner jacket mounting a pair of stator rings disposed on opposite sides respectively of said rotor, said stator rings having guide vanes positioned to direct a hot gaseous stream against and away from said bucket means respectively, said stator rings being spaced axially, and at least one of said rings being also spaced radially, from said rotor to provide passages for the flow of cooling air therebetween, said rotor being perforated to connect said passages, said inner jacket being spaced from said outer jacket for the flow of cooling air therebetween, and said inner jacket being slotted adjacent said rotor bucket means for directing said cooling air thereagainst.

2. In a gas turbine, a disc-like rotor having peripherally disposed bucket means, a housing enclosing said rotor and comprising an inner jacket and an outer jacket, said inner jacket mounting a pair of stator rings disposed on opposite sides respectively of said rotor, said stator rings having guide vanes positioned to direct a hot gaseous stream against and away from said bucket means respectively, said stator rings being spaced axially, and at least one of said rings being also spaced radially, from said rotor to provide passages for the flow of cooling air therebetween, said rotor being perforated to connect said passages, said inner jacket being spaced from said outer jacket for the flow of cooling air therebetween, and said inner jacket being slotted adjacent said rotor bucket means for directing said cooling air thereagainst, said rotor disc and stator rings being provided with heat dissipating fins on opposed surface portions thereof, disposed beneath said bucket means and

vanes respectively, and at least one of said jackets being provided with heat dissipating fins.

3. In a gas turbine, a disc-like rotor having peripherally disposed bucket means, a housing enclosing said rotor and comprising an inner and an outer jacket, said inner jacket mounting a pair of stator rings disposed on opposite sides respectively of said rotor, said stator rings being provided with vanes for directing a hot gaseous stream against and away from said rotor bucket means respectively, said stator rings being spaced radially, and at least one of said rings being also spaced axially, from said rotor to provide passages for the injection, under pressure, of cooling air therebetween, said rotor being perforated for connecting said passages, said inner jacket being spaced from said outer jacket, for the injection, under pressure, of cooling air therebetween, and said inner jacket being slotted adjacent said bucket means for exit of said cooling air thereagainst, opposed surface portions of said rotor disc and stator rings, disposed beneath said bucket means and vanes respectively, being provided with radially spaced heat dissipating fins, concentric with said rotor axis, said bucket means being provided about the outer periphery thereof with axially spaced, outwardly

projecting heat dissipating fins, and at least one of said jackets being provided with spaced, heat dissipating fins.

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