Aug. 7, 1951

N. C. PRICE

2,563,269

GAS TURBINE

Original Filed May 22, 1943

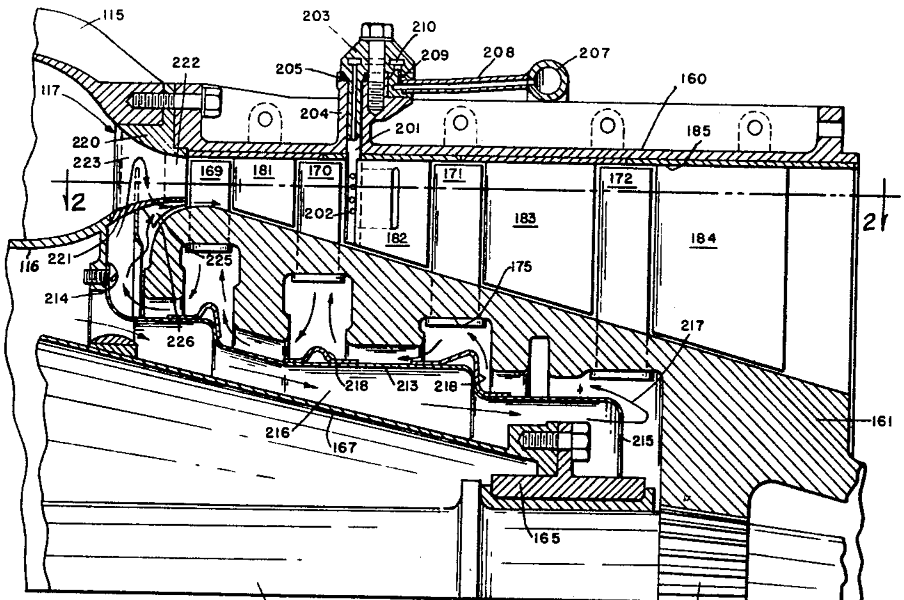

Fig. 1.

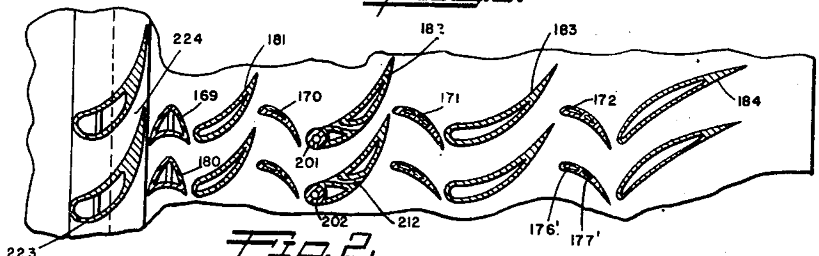

Fig. 2

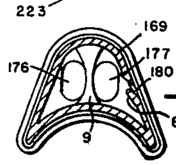

Fig. 4

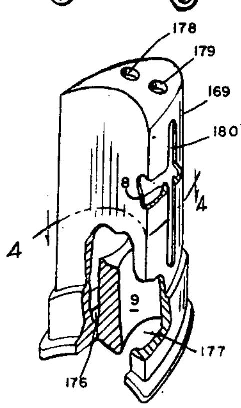

Fig. 3

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Patented Aug. 7, 1951 2,563,269

UNITED STATES PATENT OFFICE

2,563,269

GAS TURBINE

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Original application May 22, 1943, Serial No. 488,029, now Patent No. 2,468,461, dated April 26, 1949. Divided and this application February 7, 1945, Serial No. 576,655

1 Claim. (Cl. 60—41)

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This invention relates to prime movers of the gas reaction type, and relates more particularly to gas turbines useful in internal combustion reaction type engines or power plants. This application is a division of copending application, Serial No. 488,029, filed May 22, 1943, Patent No. 2,468,461, and said application Serial No. 488,029 is a continuation in part of copending application, Serial No. 433,599, filed March 6, 1942, now Patent No. 2,540,991.

My copending applications above identified, disclose gas reaction propulsive apparatus embodying, briefly, multi-stage air compressors, high temperature gas turbine means, and a combustion chamber between the compressor and turbine means whereby the gases of combustion from the combustion zone drive the turbine, which in turn, drives the compressors, there being nozzle and augmenter means for discharging the efflux gases to produce an efficient, high velocity, expansive propulsive reaction jet. The present invention is concerned, primarily, with the cooling of the blading in the high temperature gas turbine and it is a general object of the invention to provide novel and particularly effective cooling means for the turbine blading, whereby the turbine is capable of efficient and sustained operation at higher gas temperature ranges than conventional gas turbine mechanisms.

It is another object of the invention to provide a high temperature gas turbine in which coolant fluid, preferably air, is continuously circulated through the blading, or at least certain blading of the turbine, to maintain the individual blades at low or relatively low, temperatures. In accordance with the invention the blades are hollow and provision is made for flowing or forcing the coolant through the blades from the interior of the turbine wheel, thus preventing overheating of the blades even where exceedingly high temperature gases are utilized for turbine operation.

It is another object of the invention to provide a gas turbine of the character referred to in which the cooling means for the turbine buckets or blades materially increases the efficiency of the turbine. The hollow internally cooled buckets or blades have orifices or slots for discharging streams of the cooling air to flow along the trailing convex surfaces of the buckets, to cool the same, and prevent or inhibit turbulent flow at these areas and thus increase the efficiency of the blading and the turbine as a whole.

A further object of the invention is to provide a turbine blading cooling arrangement in which

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the coolant is continuously bled from the free ends of the buckets or blades into the small clearance space between the blade ends and the internal surface of the turbine housing lining, thus assuring maintained coolant flow through the hollow or passaged blades and assisting in cooling the blade ends.

A still further object of the invention is to provide a gas turbine construction in which the cooling air is caused to flow through the interior of the turbine wheel in heat exchange relation to the inner surface of the wheel shell and the root ends of the blades, and a portion of this air is deflected into the hollow blades for passage therethrough and for return to the interior of the turbine wheel with the exception of that portion of the air which is bled from the slots and blade orifices. Thus a single main airstream is utilized to cool the rotor wheel, blade roots, and bodies of the blades, as well as to reduce turbulence at the blades, and thereby increase blade efficiency as above mentioned.

Other objects and features of the invention will become apparent from the following detailed description throughout which reference is made to the accompanying drawing in which:

Figure 1 is a fragmentary cross sectional detail of a portion of a gas turbine embodying the present invention;

Figure 2 is a fragmentary cross sectional view showing the developed general arrangement of the turbine blades and counter-vanes as viewed from line 2—2 on Figure 1;

Figure 3 is an enlarged, perspective view of an impulse type turbine blade; and

Figure 4 is a cross section taken on line 4—4 of Figure 3.

I have herein disclosed the invention embodied in a turbine means suitable for use in a turbo-compressor type power plant of the class adapted for the propulsion of aircraft and other high speed vehicles. Such power plants include compressor means driven by the turbine and combustion chamber means receiving air under pressure from the compressors and supplying gases of combustion and heated air to the turbine as a propellant or driving medium. Where the power plant is of the reaction type it further includes nozzle means for discharging the gases in the form of a reactive jet. As the present invention is primarily concerned with the turbine, the other units or means just mentioned are omitted from this description as being unessential to a full understanding of the invention.

The gas turbine of the power plant is contained within a cylindrical housing 160 and comprises a hollow rotor 161 having the general shape of a truncated cone which is coaxially positioned within the said power plant with the end of minimum diameter facing rearwardly in the direction of flow of the propellant gases to form an expansion zone of increasing cross sectional area between said rotor and the inside surface of said housing. The turbine rotor 161 is splined at 162 to the rear end of a hollow shaft 164, which is in turn, rotatably supported concentrically within the power unit upon a rear main bearing 165 and a forwardly located auxiliary bearing (not shown). The rotor shaft main bearing 165 is supported by means of a hollow, conically shaped cantilever housing member 167 which extends forwardly toward the compressor portion of the power plant. The shaft 164 extends forwardly to drive the compressor.

The gas turbine rotor is provided with a plurality of rows of hollow impeller blades or buckets as best shown at 169—172 in Figure 1 and which may be constructed of heat resistant, high strength metal such as a nickel-chromium-iron alloy. As clearly illustrated in Figure 3, the walls of the hollow buckets are of outwardly diminishing thickness to reduce the weight, raise the natural frequency of the buckets and lower the stresses in the buckets. The turbine rotor blades are adapted to be inserted from the inside of the rotor cavity to make light press fits through suitably shaped openings broached in the rotor shell, and during rotation they are held firmly in place against shoulders 175 by the resulting centrifugal forces.

The blades 169, comprising the first row of impeller blading, are preferably of the impulse bucket type as illustrated in Figures 2, 3 and 4, while the blades in the other rows are of the reaction type and have cambered airfoil sections as illustrated in Figure 2.

Each of the hollow buckets 169 is provided with a pair of openings 176 and 177. The openings extend through the root shanks of the blades and serve to connect the interiors of the blades with the cavity of the rotor shell. As clearly shown in Figure 3, the adjacent ports 176 and 177 are separated by ribs or webs 9 projecting some distance into the blades to assure air circulation throughout the lengths of the blades, and to extend the cooling surfaces within the blades. The outer end of each bucket has a pair of relatively small transversely spaced apertures 178 and 179 so that cooling air may flow from the interiors of the buckets to bleed into the clearance space between the ends of the buckets and the inner surface of the turbine housing. The apertures 178 and 179 insure the continuous flow of the cooling air throughout the full length of the buckets. The cooling air flowing outwardly through the buckets becomes warmer as it approaches the bucket tips. The wall thickness of the buckets diminishes in proportion to this increase in temperature so that the increase in heat transference through the bucket walls compensates for the rise in temperature of the outwardly moving air. Furthermore, the diminishing wall thickness of the buckets increases the cooling surface areas of the buckets and reduces the thermal differential in the outer portions of the buckets.

The impulse buckets 169 are further provided with apertures or slots 180 in the downstream walls of their convex sides as shown in Figures 3 and 4. There is preferably a single continuous slot 180 extending throughout the major portion of the length of each impulse bucket. Each slot 180 serves to discharge a stream of air from the interior of its respective bucket so that the air flows along or over the trailing surface of the bucket. This air flowing over the trailing portions of the buckets assists in cooling the buckets and reduces turbulence at the rear of the blades or buckets. As illustrated in Figures 3 and 4, lips 8 are provided on the interiors of the buckets and are shaped to give the slots 180 a nozzle shape. The slots 180 are pitched in the same general direction as the gas flow past the buckets to recover the kinetic energy of the ejected cooling air and to increase the efficiency of the buckets by preventing a separation of the gas flow from the buckets. The air is discharged from the pitched slots 180 into low pressure regions at the downstream sides of the buckets, which augments the airflow, and the discharged air forms boundary layers along the surfaces of the buckets.

In accordance with the invention, means are also provided for circulating coolant through the impeller blades 170, 171 and 172. Each of these blades has a pair of ducts 176′ and 177′ similar to the ducts 176 and 177 of Figures 3 and 4. The ducts 176′ and 177′ provide for the circulation of coolant or air from the interior of the rotor wheel through the hollow or ported blades.

A plurality of rows of intermediate or stator blades 181, 182, 183 and 184 is provided intermediate the above described rows of turbine impeller blades. The stator blades are supported from the inner surface or lining 185 of the turbine housing.

An intermediate row of specifically constructed stationary vanes is shown at 182 through which intermediate fuel injection into the turbine expansion zone may be effected. Each of such vanes is formed with a cambered airfoil shaped trailing body portion and a detachable tubular leading edge element 201. The tubular element 201 is provided with a row of a plurality of apertures 202 opening out onto the convex side of the vane adjacent its closed inner end and makes connection at its outer end with a compression union 203 located on the outside of the housing. The tubes 201 are adapted to be inserted and withdrawn from the turbine through special fittings 204 attached to or forming a part of the turbine housing.

Liquid fuel or a mixture of liquid fuel and air under suitable pressure is supplied from a ring manifold 207 to the intermediate injection tubes 201 by way of a plurality of lateral tubes 208, nipples 209, and ducts 210 in the compression union 203. The intermediate fuel injection means is more fully described and claimed in my copending application, Serial No. 578,302, filed February 16, 1945, Patent No. 2,479,777.

A tubular baffle 213 of stepwise diminishing diameter and spaced from but conforming generally with the inside surface contour of the turbine rotor shell is attached at 214 to the rearward inner wall of the combustion chamber Z and extends rearwardly to a point 215 adjacent the rear end of the rotor cavity. The diverging annular space 216 thus defined, between the conical bearing support 167 and the said inner wall 116 of the combustion chamber and the baffle 213, serves to conduct cooling air under pressure from the compressor means (not shown), rearwardly to the inner apex of the turbine rotor cavity adjacent the main bearing 165 and thence forwardly, as shown by arrows 217. The air flows along the inner surface of the turbine rotor cavity in contact with the inner ends of the impeller blade roots and finally reaches the openings in the annular nozzle ring 117 in the outlet from the combustion chamber Z.

A number of convex circular barriers 218 attached to the baffle 213 serves to deflect cooling air into contact with the inner root ends of the turbine impeller blades and into the hollow blades.

A small portion of the cooling air thus conducted to the inside surface of the turbine rotor flows into the impulse buckets 139 through the ducts 176 and 177 in the bucket shanks and from there is discharged through the slots 180 into the turbine expansion zone. The resultant jets of air from the slots 180 pass along the trailing portions of the convex surfaces of the buckets concurrent with the combustion gases and serve to increase the efficiency of said impellers by preventing or inhibiting the occurrence of turbulent flow. Another portion of the air entering the turbine buckets bleeds out of the apertures 178 and 179 in the bucket ends, and passes into the expansion zone through the small clearance space between the bucket ends and the inner surface of the turbine housing lining. The air thus flowing through the interiors of the impulse buckets and discharged through the slots 180 and the apertures 178 and 179 serves also to cool the buckets which are subjected to the highest temperature gases.

The nozzle ring 117, is constructed of a pair of concentric rings 220 and 221 with adjacent convex surfaces so shaped and positioned as to form a smoothly curved diverging nozzle passageway 222. Circumferentially spaced vanes each set at an angle with respect to the longitudinal axis of the unit extend radially between the inner curved surfaces of the nozzle rings 220 and 221 to impart a spiral flow or swirl to the combustion gases entering the first row of turbine buckets.

The passage formed between the inner surface of the nozzle ring 221 and the adjacent rounded surface 226 of the rotor 161 forms in effect a second nozzle entrance to the turbine expansion zone for the introduction of heated cooling air from the rotor cavity.

In the operation of the turbine a portion of the compressed air from the compressor means flow through the tapering, substantially annular passage 216 formed between the conical shaped main bearing support 167 and the inner shroud 116 of the combustion chamber and its baffle extension 213 to the inner apex of the gas turbine rotor cavity adjacent the main rotor bearing 165. From there a portion of the cooling air turns, as indicated by arrow 217 in Figure 1, and flows forwardly along the inner surface of the turbine rotor shell in heat exchange contact with the inner ends of the impeller blade roots, and finally is exhausted to the gas turbine expansion zone inlet through the annular cooling air nozzle ring passageway 226 where it joins the combustion gases issuing from the combustion zone 131 in chamber Z in laminar flow. The cooling air prior to being exhausted through the vaned cooling air nozzle passageway 226, is deflected by the annular baffles 218 to flow through the internal grooves of the rotor 161 as indicated by the arrows in Figure 1. The air is thereby caused to circulate through the hollow buckets 169 to 172 to cool the same and to discharge from the slots 180 and apertures 178 and 179 as described above.

From the foregoing it will be evident that the invention may have a number of equivalent embodiments and arrangements of associated components. It is to be understood, therefore, that the foregoing is not to be limiting but may include any and all forms of apparatus which are included within the scope of the claim.

I claim:

In a gas turbine, a hollow turbine blade having a tip portion and a root portion, the internal surfaces of the hollow blade being sloped so that the walls of the blade diminish in thickness from the root portion toward the tip portion, a tip wall extending across the tip end of the blade, an axial web in the root portion of the blade for increasing the cooling surface area thereof and extending only a limited distance in the blade, the root end of the hollow blade being open for the reception of coolant, said tip wall having at least one restricted port for the discharge of coolant from the tip of the blade and to maintain coolant flow axially through the blade, the rear wall of the blade relative to the direction of the gas flow having a longitudinally extending slot spaced substantially mid-way between its leading and trailing extremities for discharging a layer of the coolant over the rearward portion of said surface, and inwardly projecting lips on the internal surface of said rear wall extending along the margins of said slot and shaped to give the slot a nozzle-like configuration and increasing the depth of the slot.

NATHAN C. PRICE.

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