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3,220,697

HOLLOW TURBINE OR COMPRESSOR VANE

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2 Sheets-Sheet 1

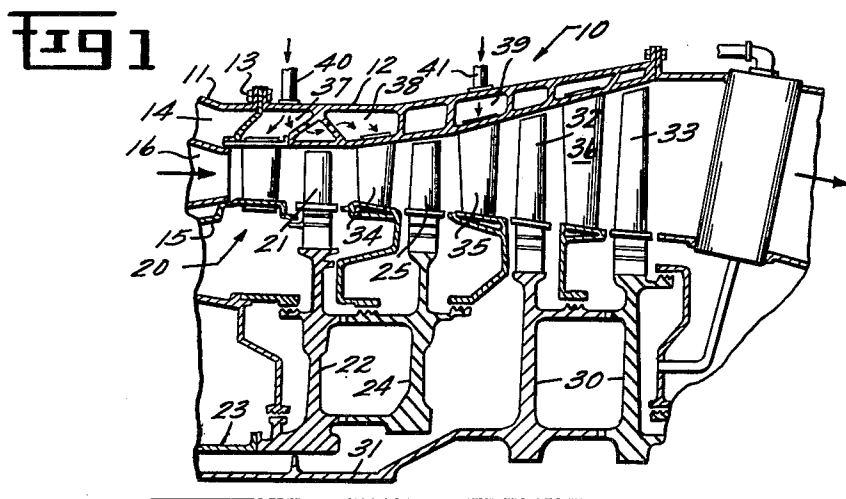
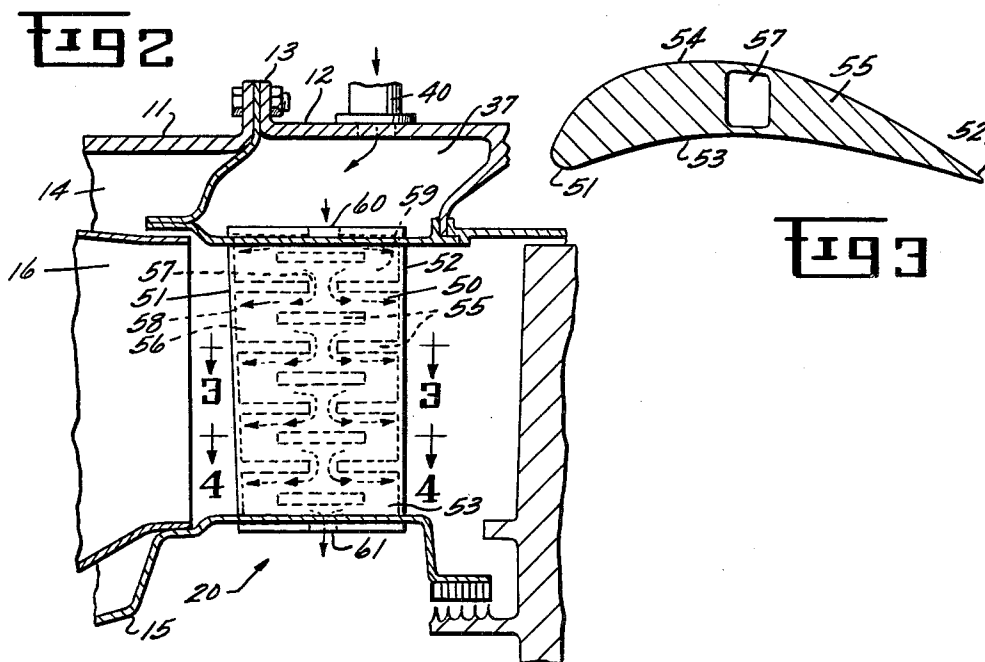
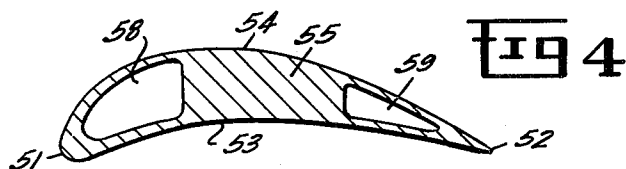


Fig 3



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Fig 5

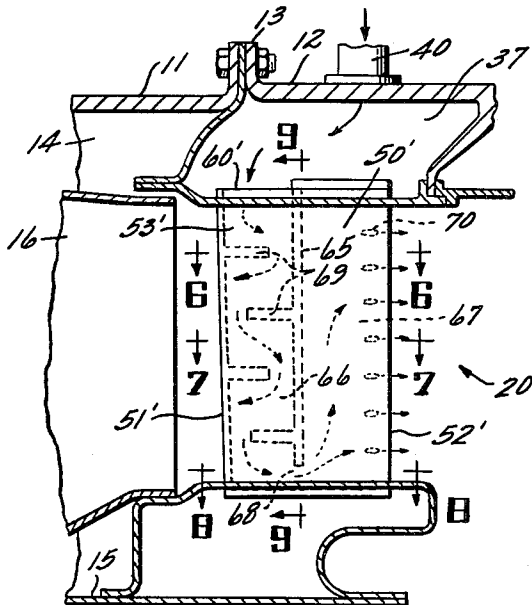


Fig 10

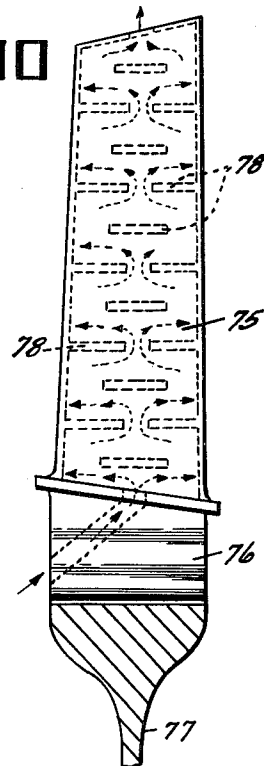


Fig 6

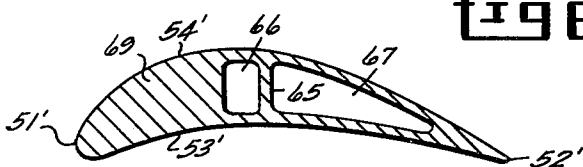


Fig 7

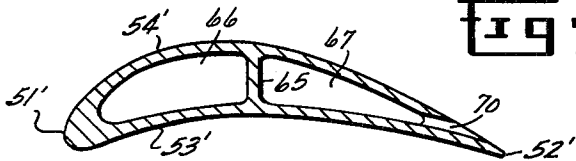


Fig 8

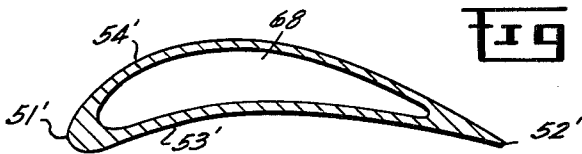
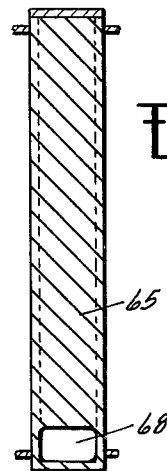


Fig 9



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HOLLOW TURBINE OR COMPRESSOR VANE

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2 Claims. (Cl. 253—39.15)

This invention relates to blading for fluid flow machines such as turbines and compressors and, more particularly, to a vane construction having improved means for controlling and directing the flow of a heat transfer fluid through the interior of the vane.

The efficiency of a gas turbine engine may be increased by increasing the operating temperature of the turbine. As a practical matter, however, the turbine operating temperature, and hence the efficiency, is limited by the high temperature capabilities of the various turbine elements. As a result, turbine designers have expended considerable effort toward increasing the high temperature capabilities of turbine elements, particularly the airfoil shaped vanes upon which the high temperature combustion products impinge. Some increase in the efficiency has been obtained by the development and use of new materials capable of withstanding higher temperatures. These new materials are not, however, generally capable of withstanding the extremely high temperatures desired in modern gas turbines. Consequently, various cooling arrangements for the vanes have been utilized for extending the upper operating temperature limit while preventing pitting and burn out of the vanes by keeping the vane material at temperatures it is capable of withstanding.

This cooling is generally accomplished by providing internal flow passages within the vanes to accommodate the flow of a cooling fluid, the fluid typically being compressed air bled from the compressor. It will be obvious to those skilled in the art that the engine efficiency theoretically possible is reduced by the bleeding off of cooling air. It is therefore imperative that cooling air be utilized effectively, lest the decrease in efficiency caused by extraction of the air be greater than the increase resulting from the higher turbine operating temperature. In other words, the cooling system must be efficient from the standpoint of minimizing the quantity of cooling air required. It is also a requirement that all portions of the vane must be cooled adequately. In particular, adequate cooling must be provided for the leading edge, the portion of the vane which is most adversely affected by the high temperature combustion gases.

It has been found that the typical cooling configurations available in the prior art tend to have deficiencies with respect to the foregoing requirements. Cooling systems which use minimum quantities of cooling air usually fail to cool adequately all portions of the vane. As a result, a critical portion such as the leading edge may burn out or pit after a relatively short operating period. On the other hand, those systems which adequately cool all portions of the vane, including the leading edge, generally require too much air for efficient overall engine performance, the reason being that the cooling air is not used effectively. For example, the system may direct the cooling air through the interior of the vane in a manner which results in the creation of a substantial boundary layer between the vanes and the stream of cooling air. The boundary layer, an essentially stagnant film which adheres to the wall surface, results in relatively low coefficients, or rates, of heat transfer. Other characteristics of the system, such as inadequate heat transfer area, can also prevent effective use of the cooling air.

A very similar situation exists with respect to compressor inlet guide vanes where adverse atmospheric conditions encountered during flight may cause ice to form

and accumulate. This icing condition may be counteracted by directing a heating fluid through internal passages within the vanes, the fluid again typically being compressed air bled from the compressor. For reasons much the same as those discussed above, the heating fluid must be utilized effectively and all portions, particularly the leading edges, of the vanes must be heated adequately.

It is therefore a primary object of this invention to provide an improved vane structure capable of accommodating the flow of a cooling or heating fluid in a highly efficient manner.

It is another object of this invention to provide an improved vane structure capable of accommodating the flow of a cooling or heating fluid such that all portions of the vane are heated or cooled adequately without requiring an excessive amount of fluid.

Briefly stated, in accordance with the illustrated embodiments of the invention, a radially extending hollow vane has a plurality of axially extending baffles forming a plurality of transverse channels in the interior of the vane. The channels are connected in fluid flow relation such that at least one serpentine passage is formed within the vane. An inlet for heat transfer fluid is provided at one end end of the serpentine passage and an outlet is provided at the other end of the passage. In operation, a cooling or heating fluid flowing through the channels is repeatedly directed against selected inner wall surfaces of the vane as high velocity jets in directions substantially normal to the wall surfaces. The baffle arrangement of this invention promotes mixing of the heat transfer fluid, prevents formation of a boundary layer, and increases the total heat transfer area. In order to promote rapid conduction of heat, the baffles are preferably formed integrally with the rest of the vane. In one form of the invention, the serpentine passage described above is provided along the leading edge only of the vane, the trailing edge being film cooled or heated by fluid being exhausted directly into the primary gas stream. As used in this description, the term "vane" is used in a generic sense to refer to airfoil-shaped elements used in fluid flow machines. As such, the term applies not only to those members popularly known as vanes, but also to other airfoil shaped members commonly known as blades, buckets, etc.

While the novel features of this invention are set forth with particularity in the appended claims, the invention, both as to organization and content, will be better understood and appreciated, along with other objects and features thereof, from the following detailed description taken in conjunction with the drawing, in which:

FIG. 1 is a sectional view of a portion of a gas turbine engine;

FIG. 2 is a sectional view of a portion of the assembly of FIG. 1 showing a nozzle guide vane utilizing the invention;

FIG. 3 is a sectional view of the nozzle guide vane of FIG. 2 along the line 3—3;

FIG. 4 is a sectional view of the nozzle guide vane of FIG. 2 along the line 4—4;

FIG. 5 is a sectional view similar to FIG. 2 of a nozzle guide vane utilizing an alternative embodiment of the invention;

FIG. 6 is a sectional view of the nozzle guide vane of FIG. 5 along the line 6—6;

FIG. 7 is a sectional view of the nozzle guide vane of FIG. 5 along the line 7—7;

FIG. 8 is a sectional view of the nozzle guide vane of FIG. 5 along the line 8—8;

FIG. 9 is a sectional view of the nozzle guide vane of FIG. 5 along the line 9—9; and

FIG. 10 is a sectional view of a turbine bucket utilizing one form of the invention.

Referring to the drawing, and particularly to FIGS. 1 and 2, a portion of a gas turbine engine 10 is illustrated, the engine having an outer cylindrical casing comprised of annular sections 11 and 12 secured together by suitable fastening means at an annular flange connection 13. An annular combustion space indicated generally at 14 is defined between the casing section 11 and an inner wall 15, and an annular combustion liner 16 within which the actual combustion occurs is located within the combustion space 14.

An annular nozzle diaphragm indicated generally by 20 in FIG. 1 is located at the downstream end of the combustion liner 16 for supplying the hot products of combustion to a row of turbine buckets 21 at the proper velocity and at the proper angle. The turbine buckets 21 are peripherally mounted on a turbine wheel 22 which, along with its associated shaft 23 and a second turbine wheel 24 having buckets 25 mounted thereon, is rotatably mounted within the engine 10 by suitable mounting means not illustrated. The turbine unit comprising the wheels 22 and 24 and the shaft 23 drives the compressor (not shown) of the engine 10.

The particular engine illustrated by FIG. 1 has a power turbine unit downstream of the turbine wheel 24, the power turbine unit comprising a second set of turbine wheels 30 secured to a second shaft 31 which is connected to a load (not shown). Peripheral rows of buckets 32 and 33 are mounted on the wheels 30. Stationary stator vanes 34, 35, and 36 supply the combustion products to the buckets 25, 32, and 33, respectively, at the proper velocity and at the proper angle.

The casing section 12 has annular manifolds 37, 38 and 39 therein which surround the nozzle diaphragm 20 and the first two rows of stator vanes 34 and 35, respectively. The manifolds 37, 38, and 39 are supplied with compressor bleed air through conduits 40 and 41. The compressed air received by the manifolds is directed through the interiors of the vanes comprising the nozzle diaphragm 20 and the rows of stator vanes 34 and 35 in accordance with the teaching of this invention.

Turning now to FIG. 2 in particular, the nozzle diaphragm 20 is comprised of a plurality of radially extending guide vanes 50 having axially spaced leading and trailing edges 51 and 52, respectively. The vanes 50 have an aerodynamic airfoil shape as best shown by FIGS. 3 and 4, the leading edge 51 being rather blunt and the trailing edge being tapered. A concave side wall 53 and a convex side wall 54 join the leading edge 51 and the trailing edge 52 to develop the aerodynamic airfoil shape.

Each of guide vanes 50 has a substantially hollow interior; in accordance with this invention, a plurality of baffles 55 are provided in the hollow vane interior. The baffles 55, which are preferably formed integrally with the vane side walls 53 and 54 so as to promote rapid heat conduction with the side walls, extend transversely of the vane interior to define therein a plurality of axially extending channels 56. Openings are provided in the baffles 55 to connect sequentially adjacent ones of the channels in fluid flow relation. As illustrated by FIGS. 2, 3, and 4, the openings in adjacent baffles are staggered such that at least one serpentine flow passage is provided along the length of the vane 50. In particular, as shown by FIG. 3, an opening 57 is provided in one of the baffles at approximately the midchord position. The adjacent baffle as illustrated by FIG. 4, has openings 58 and 59 adjacent the leading and trailing edges, respectively. Other arrangements of the openings will occur to those skilled in the art; the important factor is that the openings be staggered such that the desired serpentine flow path is provided.

During high temperature operation, compressed air is bled from the engine compressor and supplied to the annular manifold 37 within the casing section 12 through the conduit 40. From the manifold 37, the air flows through an inlet aperture 60 at the outer end of the guide

vane 50 into the interior of the vane. The baffles 55 cause the cooling air to follow the tortuous path indicated by the arrows in FIG. 2. It is a feature of this invention that the baffles 55 are positioned such that the cooling air is repeatedly directed against the interior walls of the leading edge 51 and the trailing edge 52 in directions normal to the wall surfaces. This flow directing arrangement prevents the formation of a boundary layer along with the low heat transfer coefficients which accompany a boundary layer and promotes complete mixing of the cooling air. In other words, the air is repeatedly directed against the inner wall surfaces as high velocity jets and thereby provides a scrubbing action of the interior wall surfaces, the resulting heat transfer coefficients being extremely high. In addition, the total amount of heat transferred is enhanced by the extended heat transfer area provided by the baffles 55. After providing extremely effective cooling, the cooling air is discharged through an outlet aperture 61 at the other end of the vane 50.

As indicated previously, the leading edge of the vane is most adversely affected by the high temperature combustion gases. Therefore, in order to adequately cool the leading edge, it may be desirable to space the baffles 55 such that a relatively large flow of coolant fluid is directed along the leading edge 51. This can be done by positioning the baffles 55 to decrease the cross-sectional area of the axially extending channels 56 toward the trailing edge 52 of the vane. Alternatively, the embodiment of the invention illustrated by FIG. 5 may be utilized to provide extremely effective cooling along the leading edge.

In the embodiment illustrated by FIG. 5, the nozzle diaphragm 20 is comprised of a plurality of radially extending guide vanes 50' having axially spaced leading and trailing edges 51' and 52', respectively. The vanes 50' have an aerodynamic airfoil shape as best shown by FIGS. 6, 7, and 8.

A radial partition 65 divides the interior of each vane into a first region 66 adjacent the leading edge 51' and a second region 67 adjacent the trailing edge 52'. A fluid passageway 68, best shown by FIGS. 8 and 9, is provided at one end of the radial partition 65 to connect the regions 66 and 67. As shown by FIGS. 6, 7, and 9, the partition 65 is preferably formed integrally with the side walls 53' and 54' so that the rapid conduction of heat between the interior and exterior of the vane 50' is facilitated.

Returning now to FIG. 5, an aperture 60' is provided in the end of the guide vane opposite the passageway 68, the aperture 60' communicating with the manifold 37 in the engine casing. A plurality of axially extending baffles 69 are provided in the first region 66 to define a serpentine flow passage between the inlet aperture 60' and the passageway 68. As best shown by FIG. 6, the baffles 69, like the radial partition 65, are preferably formed integrally with the vane side walls 53' and 54' so as to provide rapid heat conduction. A plurality of radially spaced bleed apertures 70 are provided adjacent the trailing edge 52', one of the apertures being illustrated more clearly by FIG. 7. Cooling or heating fluid within the second or trailing edge region 67 can be exhausted through the apertures 70 to provide film cooling or heating of the tapered trailing edge 52'.

As in the case of the embodiment of FIG. 2, the baffles 69 are positioned such that the cooling air is repeatedly directed as high velocity jets against the inner wall surface of the leading edge 51' in a direction normal to the wall surface. In other words, the air provides a scrubbing action on the inner wall surface, thereby increasing substantially the heat transfer capability at the leading edge. The baffles 69 and the radial partition 65 provide extended heat transfer surfaces. After providing extremely effective cooling along the leading edge, the cooling air flows through the passageway 68 to cool the trailing edge 52'. As illustrated by the arrows of FIG. 5, the cooling air flows through the second or trailing edge

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region 67, from which it flows outwardly through the bleed apertures 70 to film cool the trailing edge.

It will be obvious to those skilled in the art that the stationary stator vanes 34 and 35, as well as the nozzle diaphragm 20, can be cooled effectively in the manner just described. The invention is not, however, limited to use in stationary vanes. FIG. 10 illustrates the invention applied to a high temperature turbine bucket 75 peripherally mounted by a dovetail type base connection 76 to a turbine wheel 77. The turbine bucket 75 is hollow, and axially extending baffles 78 are provided in the hollow interior as shown. Cooling air, as illustrated by the arrows, is directed through the interior of the bucket 75 in the manner described in detail with respect to the nozzle guide vane 50.

While the invention has been described in connection with turbine vanes exposed to high temperature environments, it is also applicable to compressor inlet guide vanes. To counteract an icing condition on an inlet guide vane, a heating fluid such as compressor bleed air may be passed through a serpentine passageway formed in accordance with the present invention.

It is thus seen that a fluid van constructed in accordance with this invention has fluid guiding structure therein which directs a cooling or heating fluid to provide extremely effective heat transfer at the leading edge region of the vane. As a result of the efficient operation, vanes constructed in accordance with this invention require a minimum amount of heat transfer fluid.

It will be understood that the invention is not limited to the specific details of the construction and arrangement of the particular embodiments illustrated and described herein. For example, while the vane structure as described is best formed as an integral casting, the vane may be of fabricated construction with the radial partition and the baffles being individually formed and inserted into the interior of the vane. It is therefore intended to cover in the appended claims all such changes and modifications which may occur to those skilled in the art without departing from the true spirit and scope of the invention.

What is claimed as new and desired to secure by Letters Patent of the United States is:

1. A vane for use in an axial flow turbine or compressor comprising:

- a thin walled radially extending vane body having axially spaced leading and trailing edges,
- the walls of said vane body defining an interior cavity therein,
- a radial partition within said vane body dividing said cavity into a first region adjacent said leading and a second region adjacent said trailing edge,
- first and second pluralities of axial baffles in said first region alternating in radially spaced interdigitated relationship,

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each of said first plurality of baffles contacting said leading edge and extending axially therefrom into proximity to said radial partition to form therebetween a radial opening, and each of said second plurality of baffles contacting said radial partition and extending axially therefrom into proximity to said leading edge to form therebetween a radial opening,

said first and second pluralities of baffles thereby being overlapped axially to form a plurality of radially spaced, axially extending channels interconnected by said radial openings to form a single serpentine passageway between radially opposite ends of said vane body,

inlet means at one end of said vane body to admit a fluid into said serpentine passageway,

and outlet means at the other end of said vane body to discharge a fluid from said serpentine passageway to said second region,

the axial overlap between said baffles being such that a fluid flowing through said serpentine passageway is directed repeatedly against the inner wall surface of said leading edge in a direction substantially normal to said wall surface.

2. A vane as defined by claim 1 in which a plurality of apertures are provided adjacent said trailing edge of said vane for exhausting the fluid from said second region.

References Cited by the Applicant

UNITED STATES PATENTS

2,699,598	1/1955	Daugherty	253—39.15
2,801,073	7/1957	Savage	253—39.15
2,847,185	8/1958	Petrie	253—39.15
2,879,028	3/1959	Stalker	253—39.15
2,920,866	1/1960	Spurrier	253—39.15
2,956,773	10/1960	French	253—39.15
2,973,937	3/1961	Wolf	253—39.15
3,017,159	1/1962	Foster	253—39.15
3,045,965	7/1962	Bowmer	253—39.1
3,051,438	8/1962	Roberts	253—39.15
3,051,439	8/1962	Hilton	253—39.15
3,094,310	6/1963	Bowmer	253—39.15
3,123,283	3/1964	Leis	253—39.1 X

FOREIGN PATENTS

981,599	1/1951	France.
651,830	4/1951	Great Britain.
288,547	9/1953	Switzerland.
292,537	11/1953	Switzerland.

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