

Jan. 31, 1967

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3,301,526

STACKED-WAFER TURBINE VANE OR BLADE

Filed Dec. 22, 1964

2 Sheets-Sheet 1

FIG. 1

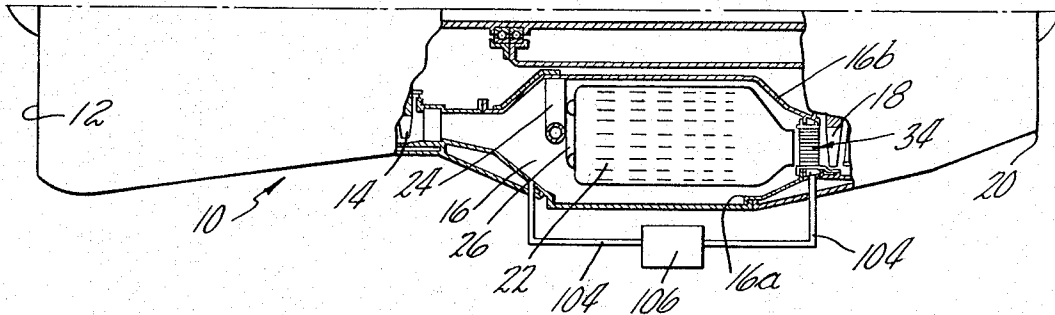


FIG. 2

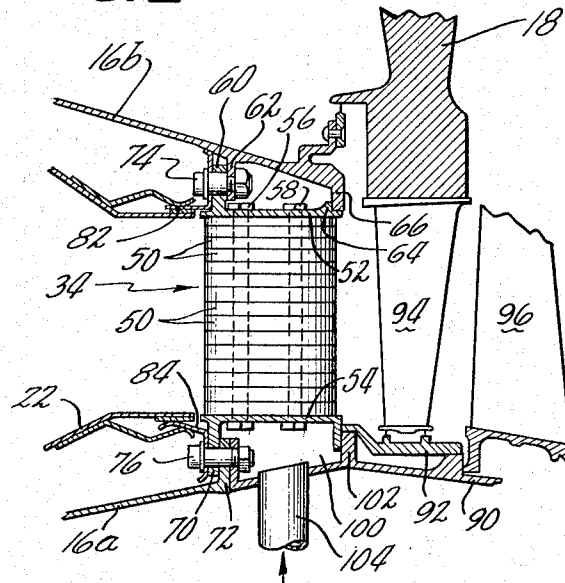
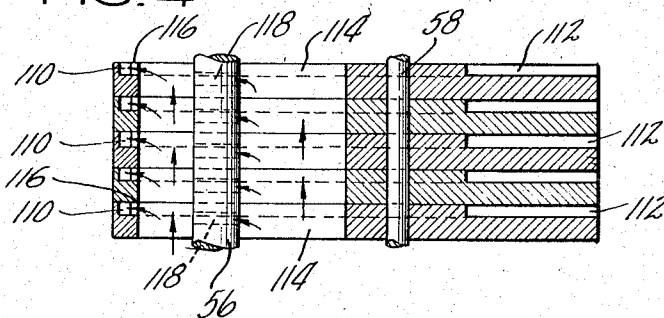


FIG. 4



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FIG. 5

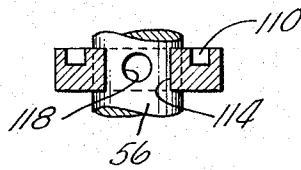


FIG. 3

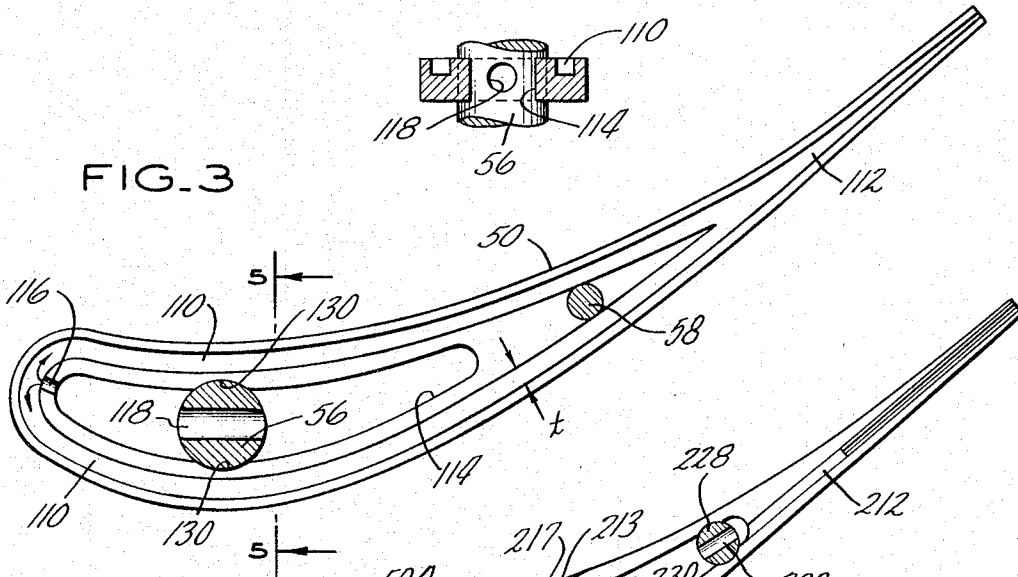


FIG. 6

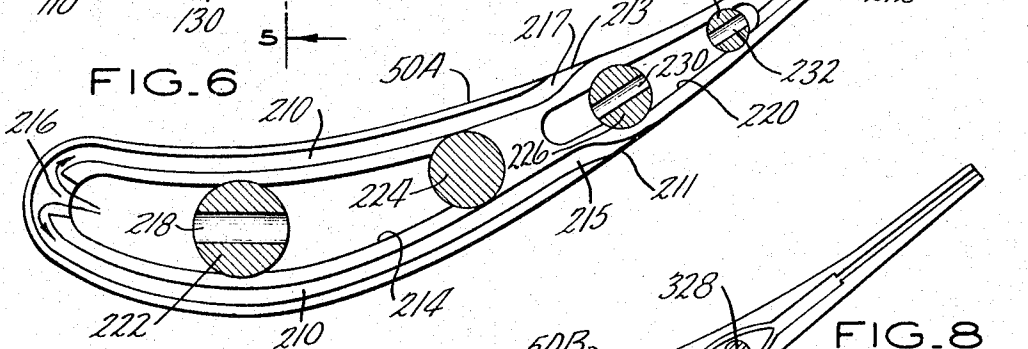


FIG. 7

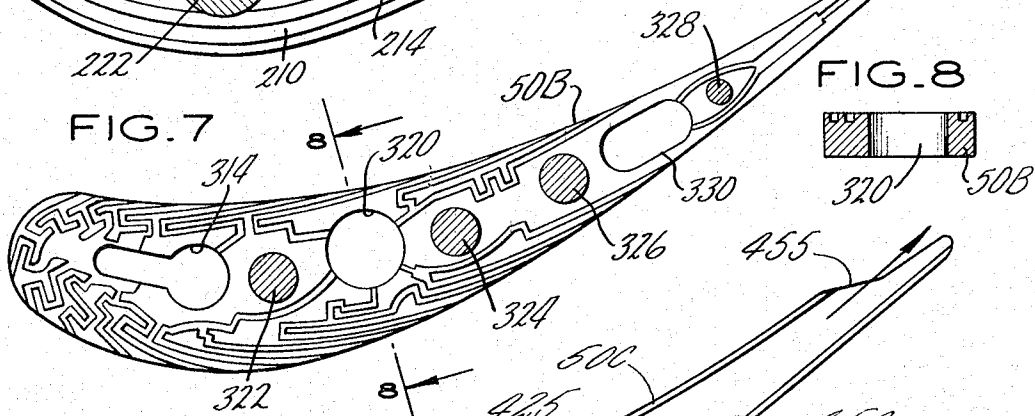


FIG. 8

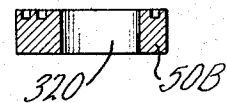
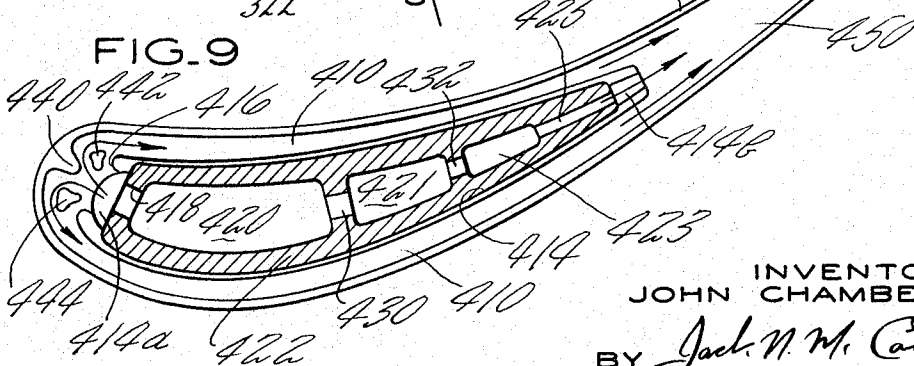


FIG. 9



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STACKED-WAFER TURBINE VANE OR BLADE
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18 Claims. (Cl. 253—39.1)

This invention relates to a stacked wafer construction of elements needing a maximum use of cooling in conjunction with high temperature.

An object of this invention is to provide each wafer with cooling flow passages formed into the walls to provide optimum convective heat transfer characteristics.

Another object of this invention is to provide a means for forming a vane or blade having grooves or channels therein with large length/diameter ratios.

A further object of this invention is to allow control of wafer thickness and cooling passage spacing to provide proper convection cooling of the internal metal.

Another object of this invention is to provide for any flow leaving a blade or turbine vane which enters the main gas stream in the direction of free stream flow.

A further object of this invention is to provide that the wafers may be canted or slanted with respect to the free stream flow in order to increase the barrier effect of the discharged coolant.

Another object of this invention is to provide metering manifolds so that cooling can be efficiently distributed to compensate for varied pressure and temperature patterns across an airfoil section.

Other objects and advantages will be apparent from the specification and claims, and from the accompanying drawings which illustrate embodiments of the invention.

FIGURE 1 is a side view of a turbojet power plant partially in section;

FIGURE 2 is an enlarged view showing a vane formed of wafers, along with its supporting structure, between the exit of the combustion chamber and the turbine;

FIGURE 3 is a view looking at one side of one modification of the wafer used in FIGURE 2;

FIGURE 4 is a view taken along the longitudinal curved center line of FIGURE 3;

FIGURE 5 is a view taken along the line 5—5 of FIGURE 3;

FIGURE 6 is a view looking at one side of another modification of the wafer used in FIGURE 2;

FIGURE 7 is a view looking at one side of a third modification of the wafer used in FIGURE 2;

FIGURE 8 is a view taken along the line 8—8 of FIGURE 7; and

FIGURE 9 is a view looking at one side of a fourth modification of the wafer used in FIGURE 2.

Referring to FIGURE 1, a turbojet aircraft power plant 10 is shown consisting of an air inlet section 12 and a compressor section 14, a combustion chamber cavity 16, a turbine 18 and an exhaust duct 20. A plurality of combustion chambers 22 are located within the combustion cavity 16 located between the compressor 14 and turbine 18. The combustion chambers 22 are fed fuel by fuel manifold 24 and nozzles 26.

Air enters the power plant through inlet section 12, is compressed as it passes through compressor 14, is heated in a power generating function as it passes through combustion chamber cavity 16 and combustion chamber 22, and then passes through turbine 18 in a power extraction function and thence is exhausted in jet exhaust through exhaust duct 20. It is necessary that the combustion chamber 22 be supported within the combustion cavity 16 and it is further necessary that the compressor 14 and turbine 18 be mounted for rotation. Since these arrangements do not form part of this invention, this

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is shown schematically. The patent to Robin et al., U.S. Patent No. 2,852,914, shows a combustion chamber support means and other related structure.

In FIGURE 2 the outer annular wall 16a of the chamber cavity is shown along with the inner annular wall 16b. The rearward ends of these walls fixedly mount a plurality of guide vanes 34. This mounting means will be hereinafter described. Each guide vane 34 is formed of a plurality of wafers 50 stacked to the desired height. The wafers are cut from any suitable high temperature, highly conductive material, such as TD nickel. Because of the high conductivity and the small distance from surface to groove, the temperature gradient in the wafer can be held to a low level. Each stacked wafer guide vane is positioned between an inner end member 52 and an outer end member 54 by two thru-bolts 56 and 58. Members 52 and 54 are formed on their sides to fit with like members to form an annulus. Members 52 each have a flange 60 extending inwardly therefrom and members 54 each have a flange 70 extending outwardly therefrom. When the turbine vane assembly is built up, the annular assembly is then put into position with the flanges 60 of the assembly abutting the flange 62 at the end of the inner annular wall 16b. A small flange 64 on the other end of each member 52 also abuts an end flange 66 of the inner annular wall 16b. The flange 70 of each member 54 of the assembly also abuts a flange 72 formed at the end of the outer annular wall 16a. A plurality of bolts 74 affixes the flanges 60 to the flange 62 and a plurality of bolts 76 affixes the flanges 70 and flange 72 together.

The bolts 74 also retain an annular member 82 which forms a seal with the member connecting the rear ends of the combustion chambers 22. A like sealing member 84 is also held in position by the bolts 76.

While an annular manifold can be formed on either the inner or outer periphery of the members 52 or 54 or both, the manifold 100 of FIGS. 1 and 2 is shown formed adjacent the member 54. The outer wall 16a is formed having a rearwardly extending portion 90 which supports an annular member 92 which forms a seal with the tips of the blades 94 of the turbine 18. This portion 90 is fixed to the end of wall 16a by the bolts 76. A set of stator vanes 96 also has the outer periphery of its supporting annular ring fixed to the portion 90. A flange 102 extends inwardly from the portion 90 and seals with the member 54.

A fluid under pressure is directed to the annular manifold 100 by a conduit 104. Conduit 104 has its forward end connected adjacent the exit of the compressor for a fluid supply. A control mechanism 106 can be placed in the conduit 104. This control mechanism 106 can be a valve controlled by the pilot, thermostatically controlled by a temperature in the area of the turbine vanes or controlled by other means.

In FIGURE 2 the inner annular member 52 can present a solid surface to the meeting end of the guide vane but the outer annular member 54 must have opening means to permit the flow of fluid from the manifold into the interior of the vane.

The stacked wafer 50 as shown in FIGURE 3 has a channel 110 extending around its outer edge adjacent its periphery with the channel at the rear end of the wafer opening to exhaust at 112. The width *t* being varied as necessary to vary the local cooling capacity to match the local cooling requirement. One large opening 114 is located in the forward part of each wafer at its widest portion to provide a manifold for passage of the cooling fluid through the wafers longitudinally when they are stacked. A metering orifice 116 appears in each wafer

to connect the opening 114 with the forward part of the channel 110.

For vane assembly a small opening is provided between the rear part of the opening 114 and the point at which the channel 110 converges with itself at the rear of each wafer to receive a thru-bolt 58 when the wafers are stacked to a desired height. The thru-bolt 56 extends down through the flow passageway 114 formed by the alignment of openings and is held in place by mating grooves 130 on the sides of the opening. Passageways 118 extend through the bolt 56 so that fluid behind the bolt is available for flow to the metering orifices 116. The size of each orifice can be controlled to obtain proper flow through each channel 110 formed between adjacent wafers.

The stacked wafer 50A as shown in FIGURE 6 has a channel 210 extending around its outer edge adjacent its periphery from its foremost point to a point just aft of its center where it opens to the outer surface of the blade at 211 and 213. Restrictions 215 and 217 are formed at these points, respectively, to provide a high exit velocity.

One large opening 214 is located in the forward part of each wafer at its widest portion to provide a manifold for passage of the cooling fluid through the wafers longitudinally when they are stacked. A metering orifice 216 appears in each wafer to connect the opening 214 with the forward part of the channel 210. A second large opening 220 is located in each of these wafers behind the opening 214 and with its forward end adjacent the location of the openings 211 and 213.

A channel 212 extends from the rear end of opening 220 to the rearward trailing edge of the wafer. Thus, channel 212 provides cooling from the opening 220 to the trailing edge of the wafer. The coolant discharged from the openings 211 and 213 cool the walls surrounding the cavity 220.

For vane assembly two thru-bolts extend lengthwise through each of the openings 214 and 220. These thru-bolts are engageable with its cooperating inner annular member 52 and its cooperating outer annular member 54. Thru-bolts 222 and 224 extend through aligned openings 214 and thru-bolts 226 and 228 extend through aligned openings 220. Each of these four thru-bolts is held in place by mating grooves on the sides of the openings. Passageways 218 extend through the bolt 222 so that fluid between the bolts 222 and 224 is available for flow to the metering orifices 216. Passageways 230 and 232, respectively, extend through bolts 226 and 228 so that fluid in front of a bolt 226 is available for flow to the portion of the opening between the bolts and the fluid between the bolts is available for flow to passageways 212.

The stacked wafer 50B as shown in FIGURE 7 has three openings or feed holes 314, 320 and 330 located along its length to provide three manifolds for passage of cooling fluid through the wafers longitudinally when they are stacked. The opening 314 is located adjacent the forward end of the vane, the opening 320 is located adjacent the mid-point of the vane and the opening 330 is located about midway between the opening 320 and the trailing end of the blade. In this modification, a groove pattern is formed on one side of the wafer comprising a plurality of grooves extending from the openings 314, 320 and 330 with each one emerging on the surface of the wafer. These channels are cut with a very large length/diameter ratio so that the coolant efficiently removes heat from the wafer before it emerges.

This coolant is discharged in a downstream direction also providing some film cooling effect in addition to the internal convection cooling. The end of each groove has a portion of its length aligned in a direction at an acute angle to the periphery of the wafer to positively direct the flow therefrom rearwardly of the airfoil section. The number of channels and the amount of coolant flow is varied to provide strong cooling where wafer heat

transfer is greatest and less cooling where the heat transfer is not as necessary. In doing this, a relatively uniform wafer temperature can be achieved and, therefore, a relatively uniform vane temperature. Some of the grooves are provided with sharp turns or other restrictions as needed to create enough pressure drop to limit the flow to the desired amount for each channel, despite large differences in external static pressure at various points on the vane.

A plurality of these wafers are assembled to form a vane by the use of four thru-bolts 322, 324, 326 and 328; these thru-bolts merely extend through openings specifically for that purpose. These thru-bolts like those of the other modifications hold a desired number of wafers at a plurality of locations between a set of inner and outer annular members 52 and 54.

The stacked wafer 50C as shown in FIG. 9 has one large opening 414 extending rearwardly from the forward part of the wafer at its widest portion. A strut 422 extends through these openings 414 of assembled wafers when the parts are assembled. The strut 422 is fixed at each end to an end member 52 and 54 as in the other designs. This strut may be integral with one of the members. Openings 414 are contoured to snugly fit the strut 422. As can be seen, a small portion 414a at the front edge of the wafer and a portion 414b at the rearward end of the wafer is unobstructed.

The strut 422 has three longitudinal holes extending therethrough, 420, 421 and 423. These holes or passages direct the cooling fluid through the assembled vane from its cooperating chamber 100. Passageways 418 are located between the longitudinal hole 420 and opening portion 414a. Passageways 430 connect the longitudinal hole 421 with longitudinal hole 420 and passageways 432 connect longitudinal hole 423 with longitudinal hole 421. Passageways 420, 421 and 423 allow coolant to flow freely to the leading edge. Longitudinal hole 423 is connected to the opening 414b by metering passageways 425.

A channel 410 extends from a point adjacent the leading edge portion of each wafer along each convex and concave side to a point adjacent the rearward end of opening 414. A metering orifice 416 appears in the face of each wafer to connect the portion 414a of the opening 414 with the forward part of each channel 410. A main flow splitter vane 440 extends rearwardly from the leading edge of the wafer towards the orifice 416. This is to divide the flow of fluid from the orifice 416. A small turning vane 442 is placed in the channel 410 at its origin between the vane 440 and the side of orifice 416 as it extends along the concave side of the wafer and a small turning vane 444 is placed in the channel 410 at its origin between the vane 440 and the side of orifice 416 leading to the convex side.

At the point where the channels 410 end, adjacent the rearward end of opening 414, the wafer is formed having a wide passageway 450 from there to the trailing edge of the blade. The end of the wafer is cut away at 455 to improve the aerodynamic flow at the trailing edge of the blade. This cutaway in effect reduces the turbulence caused by a blunt ended airfoil section.

It is to be understood that the invention is not limited to the specific description above or other specific figures, but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, a plurality of said wafers having a groove pattern on a face thereof, each wafer having opening means therein, the opening means of adjacent wafers cooperating with each other, said groove pattern of the wafers having the internal ends of its grooves connected to its opening means, the other ends of said grooves intersecting the periphery of the wafer, each groove having a high L/D ratio, each groove

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forming a passageway with the cooperating side of the adjacent wafer.

2. The combination as claimed in claim 1 including each passageway having a controlled width, depth and length so that a predetermined flow passes through each passageway.

3. The combination as claimed in claim 1 including the end of each groove of said groove pattern of a wafer having a portion of its length aligned in a direction at an acute angle to the periphery of the wafer to direct a flow therefrom rearwardly of the airfoil section.

4. The combination as claimed in claim 1 including some of the grooves having sharp turns to create enough pressure drop to limit the flow to the desired amount for each channel.

5. The combination as claimed in claim 1 wherein the groove pattern is as shown in FIGURE 7.

6. A wafer for use in forming an airfoil-shaped member being comprised of a relatively thin member having an airfoil cross section, said wafer having an opening therethrough in its forward part for directing a coolant through the wafer, one face of said wafer having a first groove extending around the outer edge to a location adjacent the rear part of said airfoil cross section where its two ends terminate, a second groove at this point extends rearwardly and directs flow out the trailing edge of the blade, said two ends of the first groove cooperating with said second groove, and a third groove connecting said opening with said first groove.

7. A wafer for use in forming an airfoil-shaped member being comprised of a relatively thin member having an airfoil cross section, said wafer having an opening therethrough in its forward part for directing a coolant through the wafer, one face of said wafer having a first groove extending around the outer edge to a location adjacent the rear part of said airfoil cross section where its two ends terminate, a second groove at this point extends rearwardly and directs flow out the trailing edge of the blade, said two ends of the first groove cooperating with said second groove, a third groove connecting said opening with said first groove, and a splitter vane extending from the wall of said first groove adjacent the leading edge of the airfoil cross section and being directed towards the center of said third groove.

8. A wafer for use in forming an airfoil-shaped member being comprised of a relatively thin member having an airfoil cross section, said wafer having an opening therethrough in its forward part for directing a coolant through the wafer, one face of said wafer having a first groove extending around the outer edge to a location adjacent the rear part of said airfoil cross section where its two ends terminate, a second groove at this point extends rearwardly and directs flow out the trailing edge of the blade, said two ends of the first groove cooperating with said second groove, a third groove connecting said opening with said first groove, a splitter vane extending from the wall of said first groove adjacent the leading edge of the airfoil cross section and being directed towards the center of said third groove, and a turning vane located between the splitter vane and each end of the third groove.

9. A wafer for use in forming an airfoil-shaped member being comprised of a relatively thin member having an airfoil cross section, said wafer having an opening therethrough in its forward part for directing a coolant through the wafer, one face of said wafer having a first groove extending around the outer edge to a location adjacent the rear part of said airfoil cross section where its two ends terminate, a second groove at this point extends rearwardly and directs flow out the trailing edge of the blade, said two ends of the first groove cooperating with said second groove, a third groove connecting said opening with said first groove, a splitter vane extending from the wall of said first groove adjacent the leading edge of the airfoil cross section and being directed to-

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wards the center of said third groove, and a fourth groove connecting said opening with said second groove between the ends of said first groove.

10. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, each wafer having a groove pattern on a face thereof, each wafer having opening means therein, the opening means of adjacent wafers cooperating with each other, said groove pattern of each wafer having the internal ends of its grooves connected to its opening means, the other ends of said grooves intersecting the periphery of the wafer, each groove having a high length/cross-sectional area, each groove forming a passageway with the cooperating side of the adjacent wafer, said means for maintaining said wafers together including a member extending through said cooperating opening means, said member having openings therein to permit a flow of coolant through said member.

11. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, each wafer having a groove pattern on a face thereof, each wafer having opening means therein, the opening means of adjacent wafers cooperating with each other, said groove pattern of each wafer having the internal ends of its grooves connected to its opening means, the other ends of said grooves intersecting the periphery of the wafer at a plurality of points, said groove pattern comprising a groove connected to said opening means and extending from a point adjacent the forward edge along each side to a point approximately halfway down the length of the airfoil section and a groove connected to said opening means and extending to a point in the trailing edge, each groove having a high length/cross-sectional area, each groove forming a passageway with the cooperating side of the adjacent wafer.

12. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, each wafer having a groove pattern on a face thereof, each wafer having opening means therein, the opening means of adjacent wafers cooperating with each other, said groove pattern of each wafer having the internal ends of its grooves connected to its opening means, the other ends of said grooves intersecting the periphery of the wafer at a plurality of points, said groove pattern comprising a groove connected to said opening means and extending from a point adjacent the forward edge along each side to a point approximately halfway down the length of the airfoil section and a groove connected to said opening means and extending to a point in the trailing edge, each groove having a high length/cross-sectional area, each groove forming a passageway with the cooperating side of the adjacent wafer, said side grooves having a restriction where they intersect the periphery of the wafer.

13. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, each wafer having a groove pattern on a face thereof, each wafer having a plurality of openings therein, the openings of adjacent wafers cooperating with each other to form coolant passages, said groove pattern of each wafer having the internal ends of its grooves connected to one of said openings, the other ends of said grooves intersecting the periphery of the wafer, each groove having a high L/D ratio, each groove forming a passageway with the cooperating side of the adjacent wafer, said grooves having restrictions therein to control the pressure drop there-through.

14. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, each wafer having a groove pattern on a face thereof, each wafer having opening means therein, the opening means of adjacent

wafers cooperating with each other, said groove pattern of each wafer having the internal ends of its grooves connected to its opening means, the other ends of said grooves intersecting the periphery of the wafer, each groove having a high L/D ratio, each groove forming a passageway with the cooperating side of the adjacent wafer, said groove pattern being as shown in FIGURE 7.

15. A turbine vane having a supporting post, a plurality of discs surrounding said post in stacked relation, at least some of said discs having grooves in one surface thereof to define, in conjunction with the adjacent disc, passages for the flow of a coolant, said grooves terminating at their outer ends in the periphery of the disc for the escape of the coolant onto the surface of the vane, said discs also having aligned openings therein to define a passage for the coolant, and the inner ends of said grooves communicating with said passage, the area and length of the several grooves being such that the pressure at the outlet end of each groove may be proportioned to the static pressure on the vane at that point thereby assuring a selected coolant discharge rate for each groove.

16. A blade-shaped member including in combination, a series of stacked wafers of airfoil section, means for maintaining said wafers together, each wafer having a groove pattern on a face thereof, each wafer having an opening therein, the opening of adjacent wafers cooperating with each other, said means for maintaining said wafers together including a hollow stem, said hollow stem being positioned between end plates, said aligned openings having a contour to receive said hollow stem while leaving forward and rearward manifolds formed by the wafers and external part of the hollow stem, means for directing a coolant into said stem through one of said end plates, said stem having openings so that coolant from within can pass into the forward and rearward manifolds, said groove pattern of each wafer having the internal ends of its grooves connected to said forward manifold and rearward mani-

fold, said grooves exhausting at the trailing edge of the wafer, each groove having a high L/D ratio, each groove forming a passageway with the cooperating side of the adjacent wafer.

5 17. A turbine vane having a supporting post, a plurality of discs of airfoil shape surrounding said post in stacked relation, at least some of said discs having grooves in one surface thereof to define, in conjunction with the adjacent disc, passages for the flow of a coolant, said grooves terminating at their outer ends in the periphery of the disc for the escape of coolant, said post having openings for the passage of coolant, said discs forming a manifold with said post at the forward part of the discs, said manifold receiving coolant from the 10 openings in said post, said grooves having their inner ends connected to said manifold.

18. A turbine vane having a supporting post, a plurality of discs surrounding said post in stacked relation, at least some of said discs having grooves in one surface thereof to define, in conjunction with the adjacent disc, passages for the flow of a coolant, said grooves terminating at their outer ends in the periphery of the disc for the escape of the coolant onto the surface of the vane, said discs also having aligned openings therein to 20 define a passage for the coolant, and the inner ends of said grooves communicating with said passages, said grooves having a pattern as shown in FIGURE 7.

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