Dec. 4, 1962 R. M. BLUCK 3,066,910

COOLED TURBINE BLADE

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FIG. 1

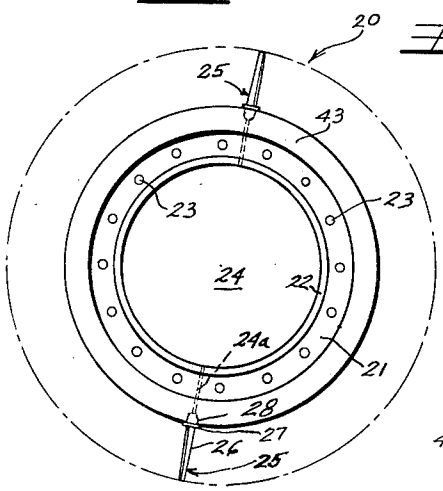


FIG. 2

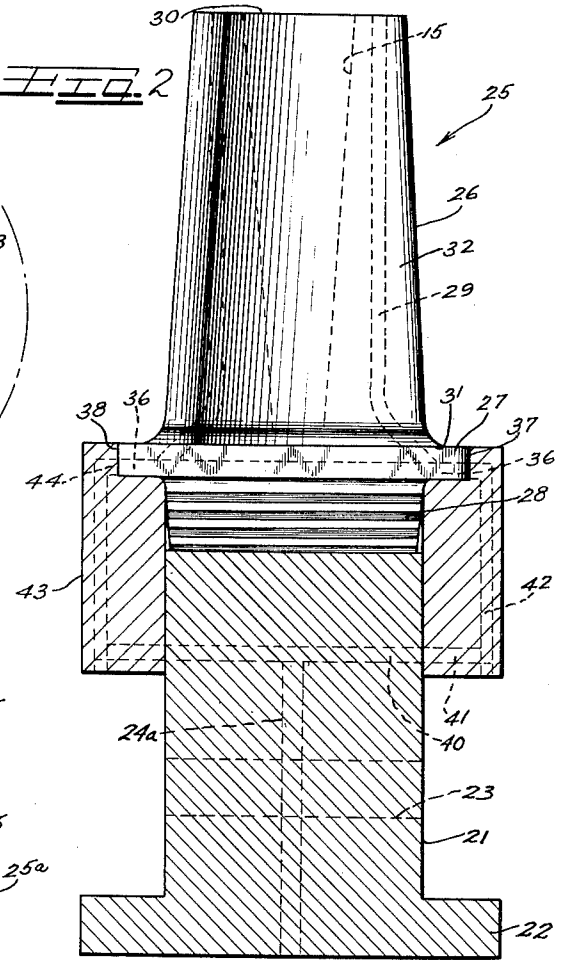


FIG. 3

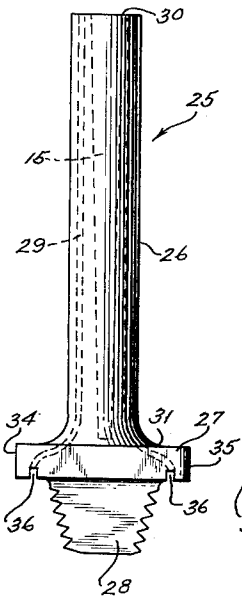


FIG. 5

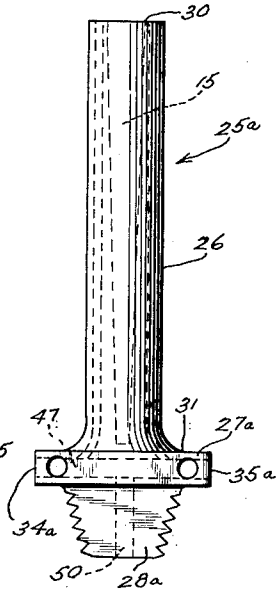
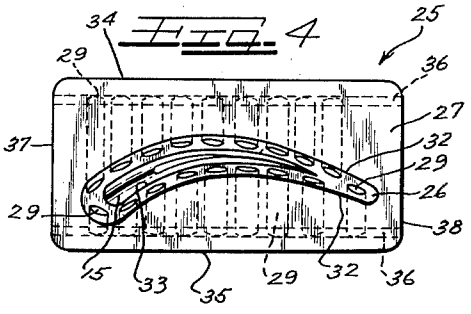


FIG. 4



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COOLED TURBINE BLADE

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FIG. 6

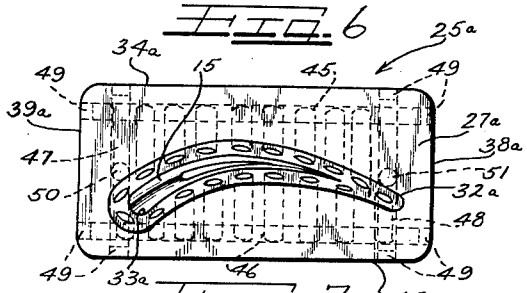


FIG. 8

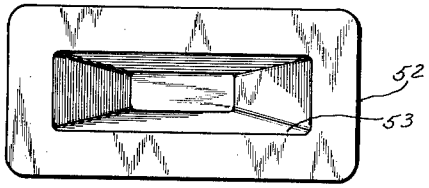


FIG. 7

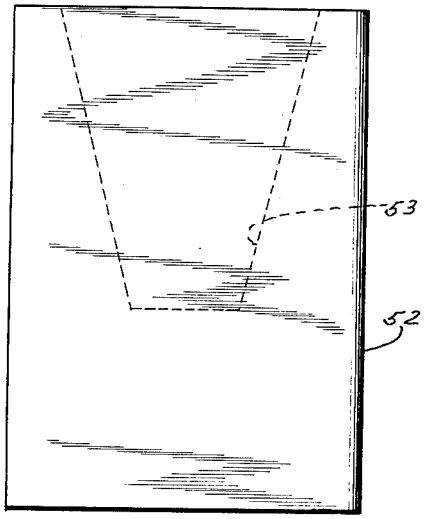


FIG. 9

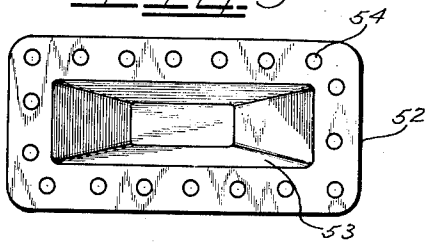


FIG. 11

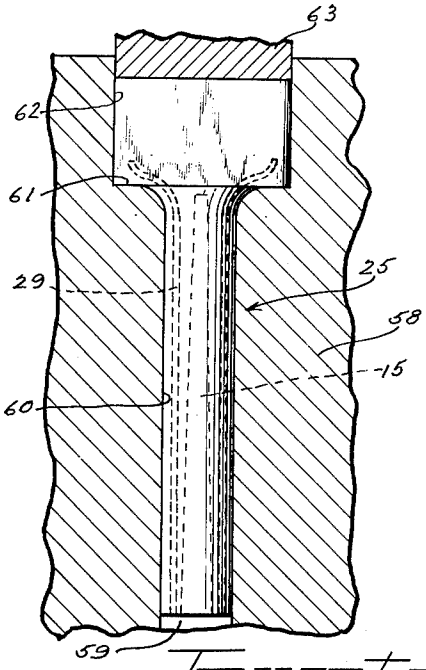
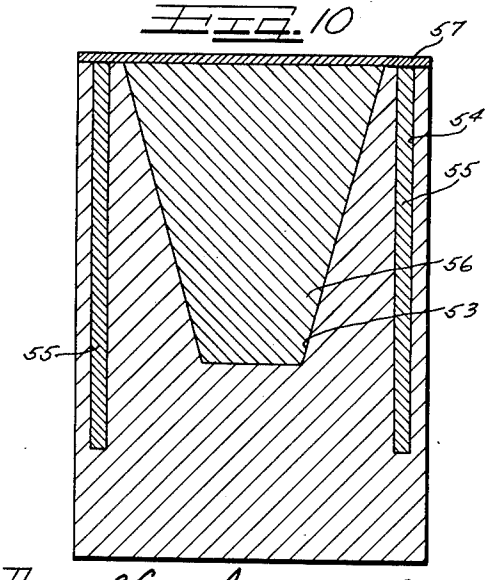


FIG. 10



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COOLED TURBINE BLADE

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Filed July 9, 1958, Ser. No. 747,391
6 Claims. (Cl. 253—39.15)

The present invention relates broadly to the production of passaged metal articles, and is more particularly concerned with compressor blades, turbine blades, turbine stator vanes, and diaphragm vanes or the like provided with coolant passages in the airfoil and base portions thereof.

Due in large measure to the high operating speeds of the modern jet propulsion engines, it is now required that the turbine blades and similar structures be suitably cooled to avoid damage or destruction thereof. Coolant passages have previously been provided in turbine blades by first forming ribs along the inner surfaces of the hollow airfoil portion and securing therein a sheet metal thimble to define the air passages. Further, it has been suggested to form passaged openings within the airfoil portion by casting techniques. The casting method has certain manufacturing advantages over the rib and thimble structure; however, a serious disadvantage in the casting technique is that the internal passages are frequently of irregular shape due to grain size variation and core distortion, and there accordingly results a loss in strength and cooling effectiveness.

It is therefore an important aim of the present invention to provide a turbine blade or similar article having formed therein generally uniformly spaced coolant passages of substantially constant area throughout.

Another object of the invention lies in the provision of a blade construction having passaged openings in the vane or airfoil portion thereof communicating with a fluid inlet through openings in the root or rib portion of the blade.

Another object of this invention is to provide a method of forming spaced openings along the axis of a turbine blade or similar article requiring a minimum number of steps and assuring constant and uniform results throughout the practice thereof.

A further object of the present invention lies in the provision of a turbine blade structure having a generally tapered opening in substantially the central portion of the blade airfoil. This tapered cavity so distributes the weight throughout the airfoil length that centrifugal stresses imposed by the weight of the airfoil are uniform throughout. Surrounding the central taper are air receiving openings closely spaced with respect to one another and to the outer surface of the foil or vane to accomplish cooling during high speed rotation thereof.

A further object of the invention is to provide a fluid cooled turbine blade or vane provided with internal passages in the airfoil portion extending axially thereof and spaced in a generally straight and parallel manner with respect to one another.

A still further object of this invention is to provide a method of forming airfoil shapes having coolant passages extending axially thereof and in which a metal block is formed with a tapered cavity generally centrally thereof and spaced holes provided in surrounding relation to the cavity, the block thereupon being extruded along a portion of its length to form generally uniformly spaced air passages of substantially uniform area throughout.

Other objects and advantages of the invention will become more apparent during the course of the following description, particularly when taken in connection with the accompany drawings.

In the drawings, wherein like numerals are employed to designate like parts throughout the same:

FIGURE 1 is a schematic view, with parts in elevation illustrating the manner in which a series of turbine blades are normally secured to the turbine wheel;

FIGURE 2 is a vertical sectional view through the wheel of FIGURE 1 and showing in elevation one of the blades mounted therein;

FIGURE 3 is an end elevational view of the turbine blade of FIGURES 1 and 2;

FIGURE 4 is a top plan view of the turbine blade of the preceding three views;

FIGURE 5 is an end elevational view of a turbine blade also constructed in accordance with the principles of this invention, and showing a different form of air passageways in the root and shelf portions of the blade;

FIGURE 6 is a top plan view of the turbine blade of FIGURE 5;

FIGURE 7 is a side elevational view of a suitable form of metal block from which the turbine blade may be formed, and showing a central cavity as having been produced therein;

FIGURE 8 is a top plan view of the block of FIGURE 7;

FIGURE 9 is a top plan view showing the block of FIGURE 7 after holes have been located to ultimately provide the air passages in the airfoil portion of the turbine blades;

FIGURE 10 is a sectional view of the block of FIGURE 9 after the holes and central opening therein have been filled with core material and a retaining member attached to the upper surface thereof; and

FIGURE 11 is a fragmentary elevational view, with parts in section, showing an extrusion die configuration within which the turbine blade may be formed.

Referring now to the drawings, there is shown in FIGURE 1 an exemplary turbine wheel 20 having an integral rim portion 21 shaped with a flange 22 and provided with bolt receiving openings 23 by means of which a turbine drum may be formed by securing a hollow flanged shaft (not shown) to the rim portion. An air passage 24 is thus provided centrally of the wheel 20, communicating with passages 24*a* in the rim portion. Received in transversely extending shaped notches formed in the wheel rim portion are a plurality of circumferentially spaced turbine blades 25 each having an airfoil or vane portion 26 integral with a shoulder or shelf portion 27 terminating in a root portion 28 of generally "fir-tree" configuration.

Two forms of turbine blades are herein disclosed, one form being illustrated in FIGURES 1 to 4 and the other in FIGURES 5 and 6. A principal difference between the two embodiments of the invention lies in the particular form of fluid passageways provided in the root and shelf portions. Each, however, is characterized by an essentially identically shaped airfoil or vane portion 26 of constant cross section area proceeding axially outwardly toward the tip end from the shelf or shoulder portion thereof. The airfoil portion metal distribution is tapered for stress reasons by the tapered cavity within the envelope. While the illustrated embodiments are free of twist, changes in profile may readily be effected in the forming operation to be later described, without departing from the novel concepts of this invention. Further, while the shoulder portion 27 is shown as generally rectangular, other shapes may be employed such as a parallelogram, rhombus or the like.

With reference now to the turbine blade 25 of FIGURES 1 to 4, it is to be noted that the airfoil portion 26 is provided axially thereof with a tapered central opening 15 surrounded by a plurality of coolant passages 29. The passage or opening 15 is shaped as required by stress dis-

tribution, and normally is of greater width at the airfoil tip end 30 than at the foil base portion 31. The area of the opening 15 desirably is the maximum for weight saving reasons without sacrifice to the stress values thereof, and said cavity or opening 15 terminates axially outwardly of the shelf portion 27 as appears in FIGURE 3.

The fluid passages 29 are preferably generally elliptical in shape when viewed in plan or cross-section, and are generally of this configuration throughout their lengths, although it may be preferred in certain applications that the area of the openings be relatively greater at their upper or tip ends than at the lower ends thereof. While variations may be practiced, it is preferred that the maximum ratio of the major axis of the passages 29 to the minor axis thereof be 6 to 1, and the minimum ratio 2 to 1. The openings 29 are generally equally spaced with respect to one another, and each extends substantially parallel relative to the other. It is desirable that each passage 29 be spaced relatively closely to the turbine blade outer surfaces 32 for more effective cooling, although to facilitate the formation of the passages 29 in the vane or airfoil portion 26, it may be found preferable that the passages 29 be equally spaced between outer and inner surfaces 32 and 33 of the turbine blade airfoil portion 26. Further with respect to the coolant passages 29, each extends axially throughout the major portion of the length of the vane or airfoil portion 26 and then proceeds radially outwardly into the shoulder portion 27 of the blade toward opposite side surfaces 34 and 35 of said shoulder portion. Each passage 29 thus terminates at one end in the tip portion 30 of the blade airfoil 26 and at its opposite end in passageways 36 provided in the shoulder portion 27.

Each passageway 36 extends generally parallel with the side surfaces 34 and 35 of the shoulder portion 27 and is spaced inwardly from said side surfaces. Each passageway 36 is of grooved or slotted configuration (FIGURE 3) and extends entirely along the length of the shoulder portion between opposite end surfaces 37 and 38 thereof. The passageways may be formed in any desired manner, and machining is a preferred technique for this purpose. The machine cut is of course made of sufficient depth to provide complete communication with the terminus of each of the passages 29.

Referring now particularly to FIGURE 2, shown therein is one arrangement which may be employed to direct a coolant fluid such as air from the turbine wheel hub portion 21 through the passages 24*a* and outwardly through the passages 29 in the airfoil portion 26 of the turbine blade 25. The passages 24*a* communicate with a transversely extending opening 40 in the disc rib portion 21 connecting with a transverse leg 41 of a right angle passage 42 in plate members 43 suitably secured to opposite side surfaces of the rim portion 24. It may be seen that the passages 42 in the members 43 communicate at 44 with each of the slotted passageways 36 in the blade shoulder portion 27, and that bleed air from the turbine compressor is directed through the central hollow portion 24 communicating with the turbine and into the openings 24*a* in disc inner flange. The coolant air is then directed in opposite transverse paths through the opening 40 in the rim portion 21 and through the passages 41, 42 and 44 in the plate members 43. Air is received from the passage 44 by the slotted passageways 36 and axially into the vane or airfoil portion coolant passages 29 to maintain the temperature of said portion 26 at a level sufficiently below gas temperatures to maintain adequate strength within the blade structure to carry centrifugal and gas bending loads.

An alternate arrangement of passageways communicating with the airfoil coolant passages 29 is shown in FIGURES 5 and 6, and reference is now made thereto. Since the airfoil portion 26 and arrangement of the central tapered opening 15 and surrounding coolant passages 29 is essentially identical to the earlier described form of the invention, like numerals have been appended to these features of FIGURES 5 and 6. Further, in the interest of clarity the subscript "*a*" has been applied to the corresponding numerals identifying the inner and outer surfaces of the blade portion and the side and end surfaces of the shoulder portion of the turbine blade 25*a* of FIGURES 5 and 6.

The shelf or shoulder portion 27*a* of the turbine blade 25*a* is provided with a pair of longitudinally extending spaced passages 45 and 46 arranged generally parallel to the side surfaces 34*a* and 35*a* of said shoulder portion. Intersecting the passages 45 and 46 is a pair of spaced transversely extending passages 47 and 48 located inwardly of the shoulder portion opposite ends 37*a* and 38*a* and arranged generally parallel thereto. Opposite ends of the passages 45, 46, 47 and 48 are closed or plugged as at 49 to create a manifold effect.

The root portion 28*a* of the turbine blade 25*a* is provided with a pair of axially arranged openings 50 and 51 parallelly spaced with respect to one another and terminating at their inner ends at generally the center or midpoint of the length of the transverse passages 47 and 48. Generally speaking, each of the openings 45–51 are of the same diameter, and each of said passages may be provided in the shoulder portion 27*a* and root portion 28*a* by drilling techniques in the manner known to the art. As a substitute for a plug 49 in each of the opposite ends of the passages 45–48, the depth of the drilling may of course be controlled so that said passages terminate in an intersecting passage and do not extend outwardly therebeyond as shown.

The axial passages 50 and 51 in the root portion 28*a* of the last described embodiment of the invention communicate outwardly of the shelf portion 27*a* with the rim portion 21 of the turbine disc 20. For this purpose, the rim portion is bored or passaged with suitable openings communicating at one end with the root passages 50 and 51 and at the opposite end with the passage 39 in the disc. Air bled from the turbine compressor is directed through the disc passage 39 into the rim portion openings and through the root passages 50 and 51. The flow of air is then in opposite transverse directions as indicated in FIGURE 6 through the longitudinally extending passages 45 and 46 and axially along the airfoil portion 26 through the spaced coolant passages 29 therein. Effective cooling of the outer surfaces 32*a* of the airfoil portion is thereby accomplished.

The steps in applicant's process of forming a turbine blade of the character disclosed will now be described, and reference is accordingly made to FIGURES 7 through 11 of the drawings. A billet piece 52 of generally rectangular shape, sized to produce the turbine blade shape desired, is first machined to provide a central tapered opening 53 therein. The central cavity may also be formed by drilling a round hole in a tapered cylindrical billet, filling the hole with core rod, upsetting the taper end to a uniform cylindrical shape, flattening to rectangular shape by flat forging, thus forming a billet as shown in FIGURE 7.

As appears in FIGURES 7 and 8, the cavity or opening 53 is of relatively greater area at the open end thereof than at its bottom, and the depth of the opening 53 is approximately two-thirds of the height of the billet piece 52 to provide adequate metal mass for the shoulder and root portions of the turbine blade.

A plurality of holes 54 are then drilled axially of the length of the billet piece 52 generally equally spaced with respect to one another and approximately midway of the thickness of the billet piece at the end adjacent the cavity opening 53 therein. The number of holes 54 may of course vary, and eighteen has been shown for illustrative purposes only. Further, the billet material may vary, and exemplary compositions are Waspalloy, Udimet, Inco 700 and the like. To control the metal movement during the subsequently performed extrusion step, the tapered

opening 53 and drilled holes 54 are filled with a core material which may be manganese steel possessed of the desired characteristics at high temperatures. The drilled openings 54 may be filled by pouring core material therein, or by provision of core rods 55 as shown in FIGURE 10. A wedge-shaped plug or block 56 is preferably employed to fill the central opening 53. To maintain the core material 55 and 56 within the openings 53 and 54 during the extruding step, a plate member 57 may be secured to the billet piece or a welding technique may be employed as a substitute therefor.

The billet piece provided as described is thereupon located in an extrusion die 58 of generally the character shown in FIGURE 11. The die 58 is provided with a cavity 59 corresponding to the shape of the turbine blade 25 and 25*a*, and accordingly is characterized by a relatively slender tapered downstream cavity portion 60 upstream of which is a relatively wider extruding surface 61 against which the shoulder portion of the turbine blade is formed. An upstream cavity portion 62 of generally rectangular configuration is provided within which the root portion of the blade is formed. A punch 63 by downward movement shapes the billet piece 52 into the configuration generally indicated in FIGURE 11. The core material is removed, as by etching with nitric acid, and thereafter the root portion is formed by machining, grooved to provide a "fir-tree" shape, and the collant passages formed in the shoulder portion, and in the root portion in the case of the turbine blade 25*a*.

It is to be noted that the depth of the cavity portion 62 wherein the shoulder and root portions are formed is predetermined, and the length of travel of the punch member 63 also controlled to assure formation of the outwardly turned portions of the coolant passages 29 and sufficient mass of material in the shoulder and root portions. While variations may of course be practiced to provide the turbine blade shape desired, generally speaking the shoulder and root portions formed in the die 58 should comprise between one-fourth and one-half of the total length of the blade, and preferably approximately one-third.

Should it be desired to produce an airfoil or vane portion having a twist therein, this may be accomplished by coining following the extrusion step. As an alternative, employing split extrusion dies, the airfoil shape may be twist guided as it makes its departure from the extrusion orifice. It will further be appreciated the variations in the chord width and section profile can be achieved in coin forging of the extruded shape without changing the passage area and tapered metal distribution. It is important in the latter instance that elongation and flash formation be avoided.

It will be apparent from the foregoing that applicant has provided a novel turbine blade or the like characterized by internal fluid passages in the airfoil and shoulder portion thereof of generally uniform area and substantially equally spaced with respect to one another. Turbine blades thus provided are capable of withstanding operating speeds and temperatures considerably in excess of that heretofore considered possible to attain. By elimination of the earlier proposed casting method there is further avoided the objection of irregular shapes in the internal passages caused in large measure by grain size variation. In addition, the method of this invention is productive of uniform and constant results throughout its practice.

It is to be understood that variations may be practiced in the structures and procedures herein disclosed without departing from the spirit of the invention or the scope of the subjoined claims.

I claim as my invention:

1. A blade structure for turbines and the like, comprising a vane portion having a tapered opening generally centrally thereof defining spaced and integral wall portions, said vane portion having a plurality of open-ended coolant passages formed in said wall portions spaced from said opening and spaced relative to one another, and a base portion integral with said vane portion provided with longitudinally and transversally extending coolant passageways communicating only with the passages in the vane portion and directing coolant thereto in a unidirectional path to control the temperature of said vane portion, said opening being open at a vane end opposite said base portion and decreasing in area towards said base portion, said opening terminating axially outwardly of said base portion and extending therefrom to said vane end of said vane portion opposite said base portion and being free of fluid communication with said passages and passageways.

2. A blade structure for turbines and the like, comprising a vane portion having a tapered opening generally centrally thereof defining spaced and integral wall portions, said vane portion having a plurality of open-ended coolant passages formed in said wall portions spaced from said opening and spaced relative to one another, said coolant passages extending along the vane portion generally axially thereof throughout the major portion of the length of said vane portion and arranged obliquely to said axis at one open end, and a base portion integral with said vane portion provided with coolant passageways communicating only with the passages in the vane portion and directing coolant thereto in a unidirectional path to control the temperature of said vane portion, said opening being open at a vane end opposite said base portion and decreasing in area towards said base portion, said opening terminating axially outwardly of said base portion and extending therefrom to said vane end of said vane portion opposite said base portion and being free of fluid communication with said passages and passageways.

3. A blade structure for turbines and the like, comprising a vane portion having a tapered opening generally centrally thereof defining spaced and integral wall portions, said vane portion having a plurality of open-ended coolant passages formed in said wall portions spaced from said opening and spaced relative to one another, and a base portion integral with said vane portion provided with generally parallel side and end surfaces and a pair of spaced coolant passageways extending longitudinally with respect to said base portion side surfaces and essentially entirely therealong on opposite sides of said vane portion and communicating only with the passages in the vane portion and directing coolant thereto in a unidirectional path to control the temperature of said vane portion, said opening being open at a vane end opposite said base portion and decreasing in area towards said base portion, said opening terminating axially outwardly of said base portion and extending therefrom to said vane end of said vane portion opposite said base portion and being free of fluid communicating with said passages and passageways.

4. A blade structure for turbines and the like, comprising a vane portion having a tapered opening generally centrally thereof defining spaced and integral wall portions, said vane portion having a plurality of open-ended coolant passages formed in said wall portions spaced from said opening and spaced relative to one another, and a base portion integral with said vane portion provided with generally parallel side and end surfaces and intercommunicating coolant passageways extending longitudinally with respect to said base portion side surfaces and essentially entirely therealong on opposite sides of said vane portion and also transversely relative to the base portion end surfaces in a plurality of essentially parallel branches communicating directly with the passages in the vane portion and directing coolant thereto in a unidirectional path to control the temperature of said vane portion, said opening being open at a vane end opposite said base portion and decreasing in area towards said base portion, said opening terminating axially outwardly of said base portion and extending therefrom to said vane end

of said vane portion opposite said base portion and being free of fluid communication with said passages and passageways.

5. A blade structure for turbines and the like, comprising an airfoil portion provided with a generally centrally located tapered cavity and a plurality of essentially identically shaped coolant passages spaced from one another and extending axially along the length of the airfoil portion outwardly of the cavity therein, and a base portion having a plurality of transversely and longitudinally extending intersecting coolant passageways communicating with the airfoil passages and directing coolant thereto to control the temperature of said airfoil, said cavity being open at a vane end opposite said base portion and decreasing in area towards said base portion, said cavity terminating axially outwardly of said base portion and extending therefrom to said vane end of said airfoil opposite said base portion and being free of fluid communication with said passages and said passageways.

6. A blade structure for turbines and the like, comprising an airfoil portion provided with a generally centrally located cavity and a plurality of essentially identically shaped coolant passages spaced from one another and extending axially along the length of the airfoil portion outwardly of the cavity therein, a shoulder portion having a plurality of longitudinally and transversely extending connected coolant passageways communicating with the airfoil passages, and a root portion provided with generally axially extending coolant openings communicating at one end with the shoulder portion passageways and at the opposite end with a source of coolant and directing the same into the passageways and passages to control the temperature of the airfoil surfaces, said cavity being open at a vane end opposite said base portion and decreasing in area towards said base portion, said cavity terminating axially outwardly of said shoulder portion and extending therefrom to said vane end of said airfoil portion opposite said base portion and being free of fluid communication with said passages and said passageways.

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