United States Patent [19]

Aspinwall

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[54] **COOLED TURBINE BLADE**

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[52] **U.S. Cl.** **416/97,** 415/115

[51] **Int. Cl.** **F01d 5/18**

[58] **Field of Search** 416/96, 97, 92, 95; 415/115, 116

[56] **References Cited**

UNITED STATES PATENTS

2,787,441	4/1957	Bartlett	416/92
2,873,944	2/1959	Wiese et al.	416/92
2,894,719	7/1959	Foster	416/92
3,032,314	5/1962	David	416/96 X
3,314,650	4/1967	McCormick	416/96

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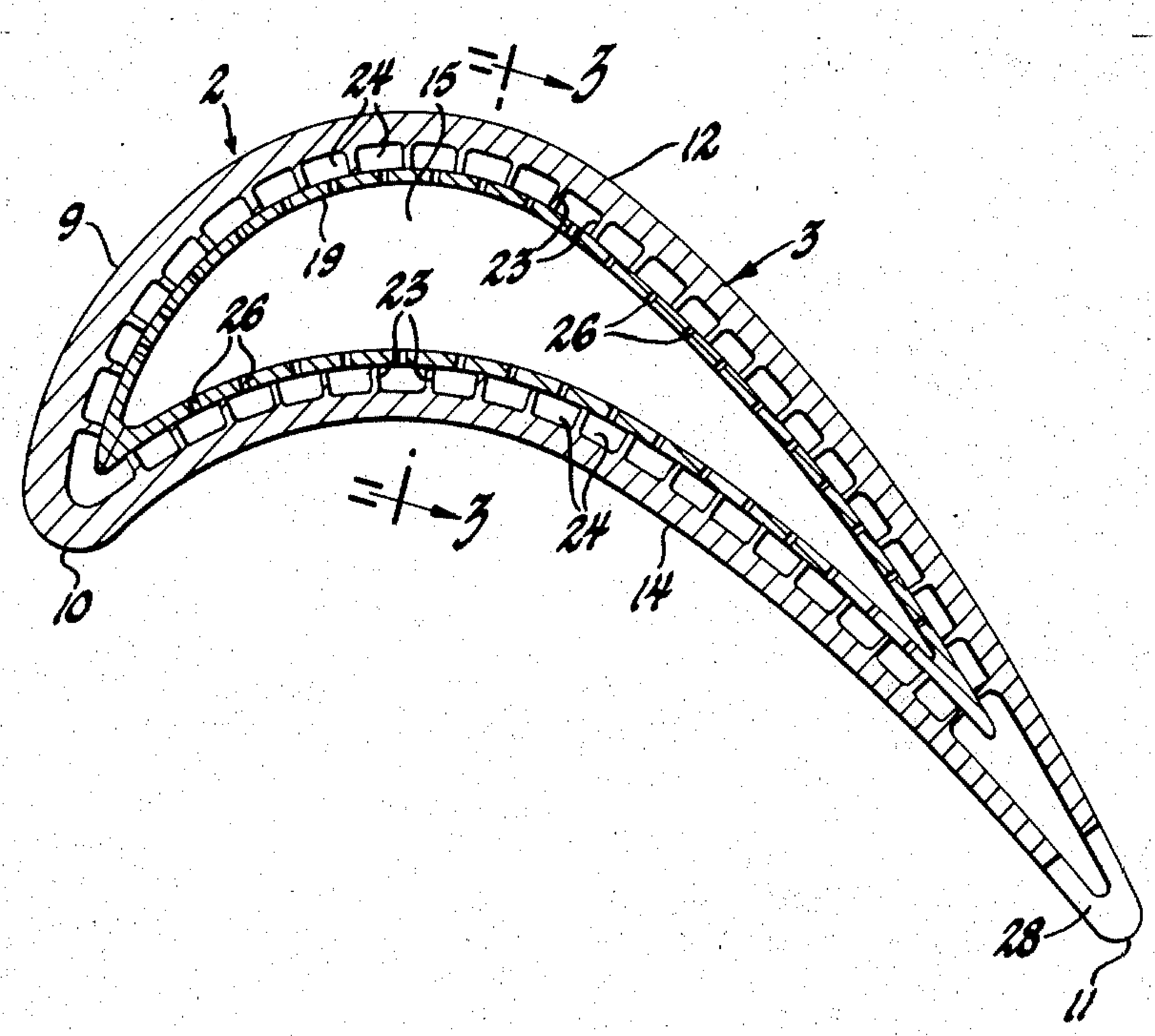
Attorney, Agent, or Firm—Paul Fitzpatrick

[57] **ABSTRACT**

A turbine blade is cooled internally by air discharged through perforations in a liner toward the interior of the blade wall. The liner is spaced from the blade wall by ribs on the wall extending spanwise of the blade. The ribs increase in height toward the blade tip so that spanwise-extending diverging passages for discharge of the cooling gas at the tip of the blade are provided. The liner is of a relatively high conductivity material such as a cuprous nickel alloy. The exterior of the liner is artificially roughened to increase the absorptivity of the liner to radiated heat. The blade has a base into which the liner extends so as to conduct some of the heat through the liner into the base, which is relatively isolated from the hot motive fluid to which the blade is subjected.

4 Claims, 6 Drawing Figures



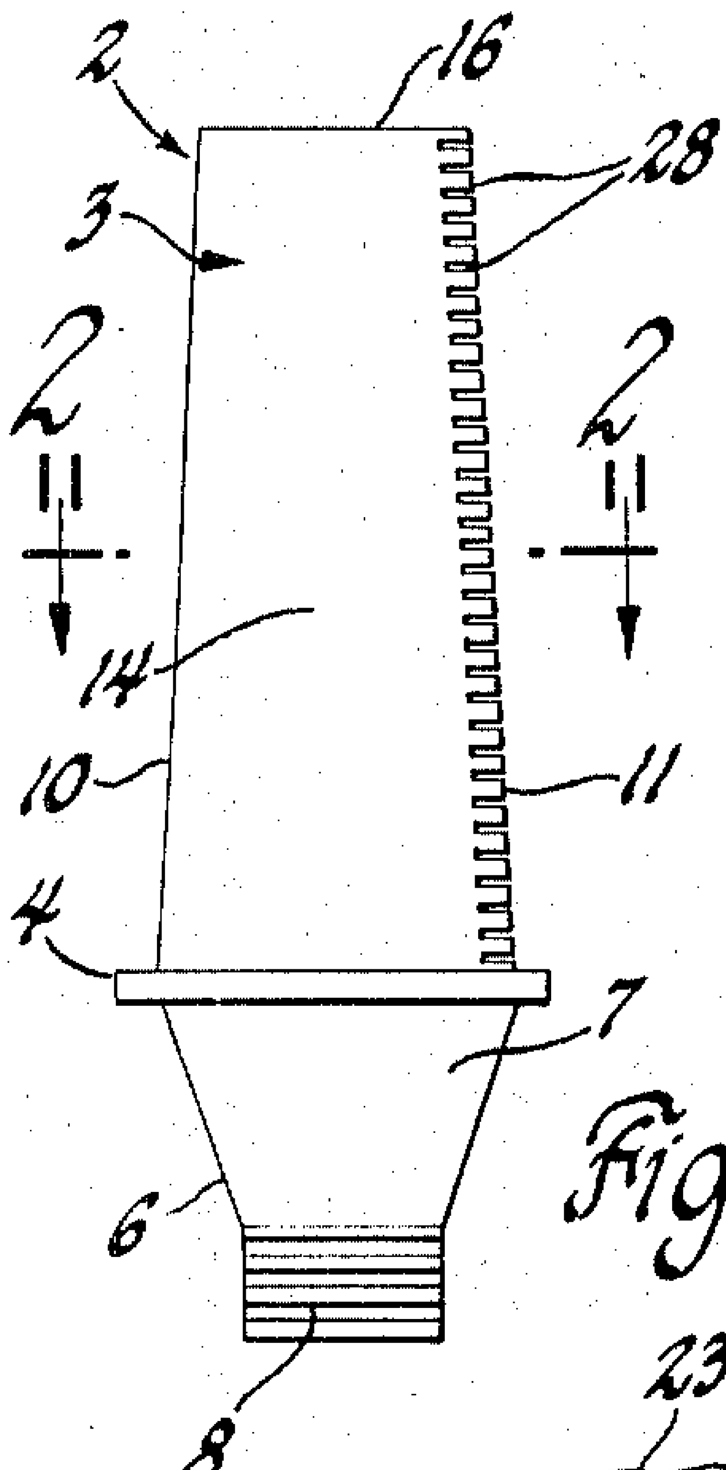


Fig.1

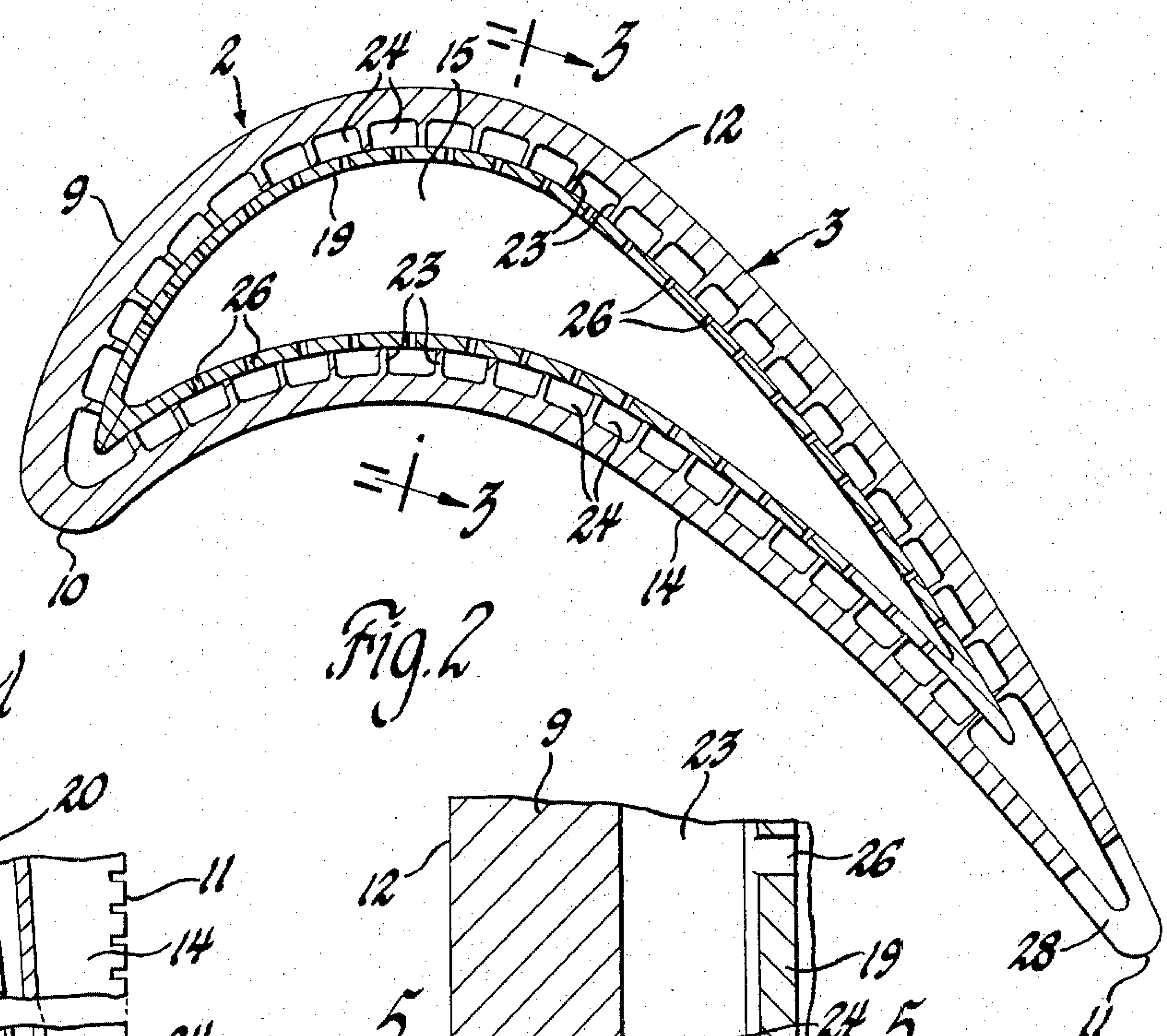


Fig.2

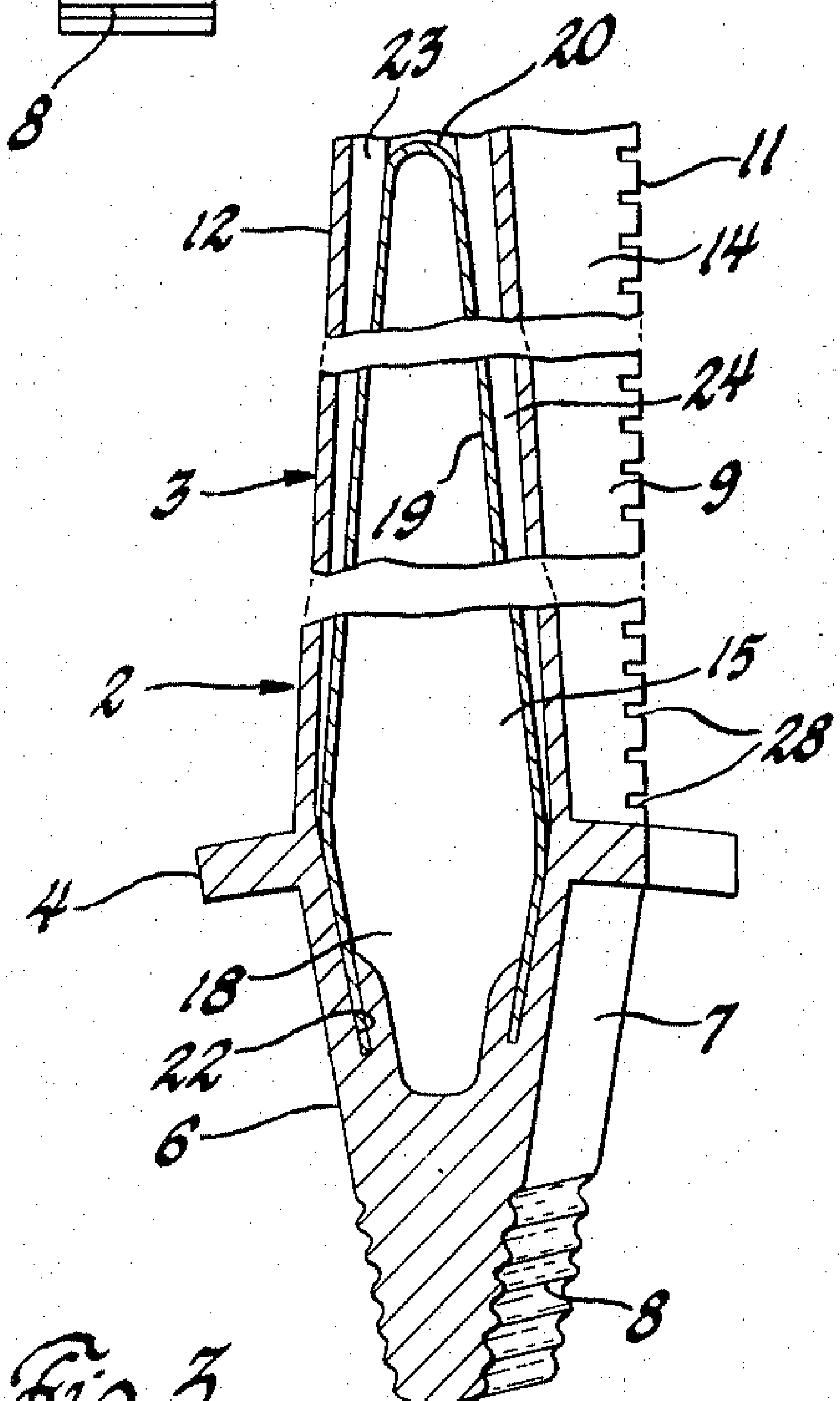


Fig.3

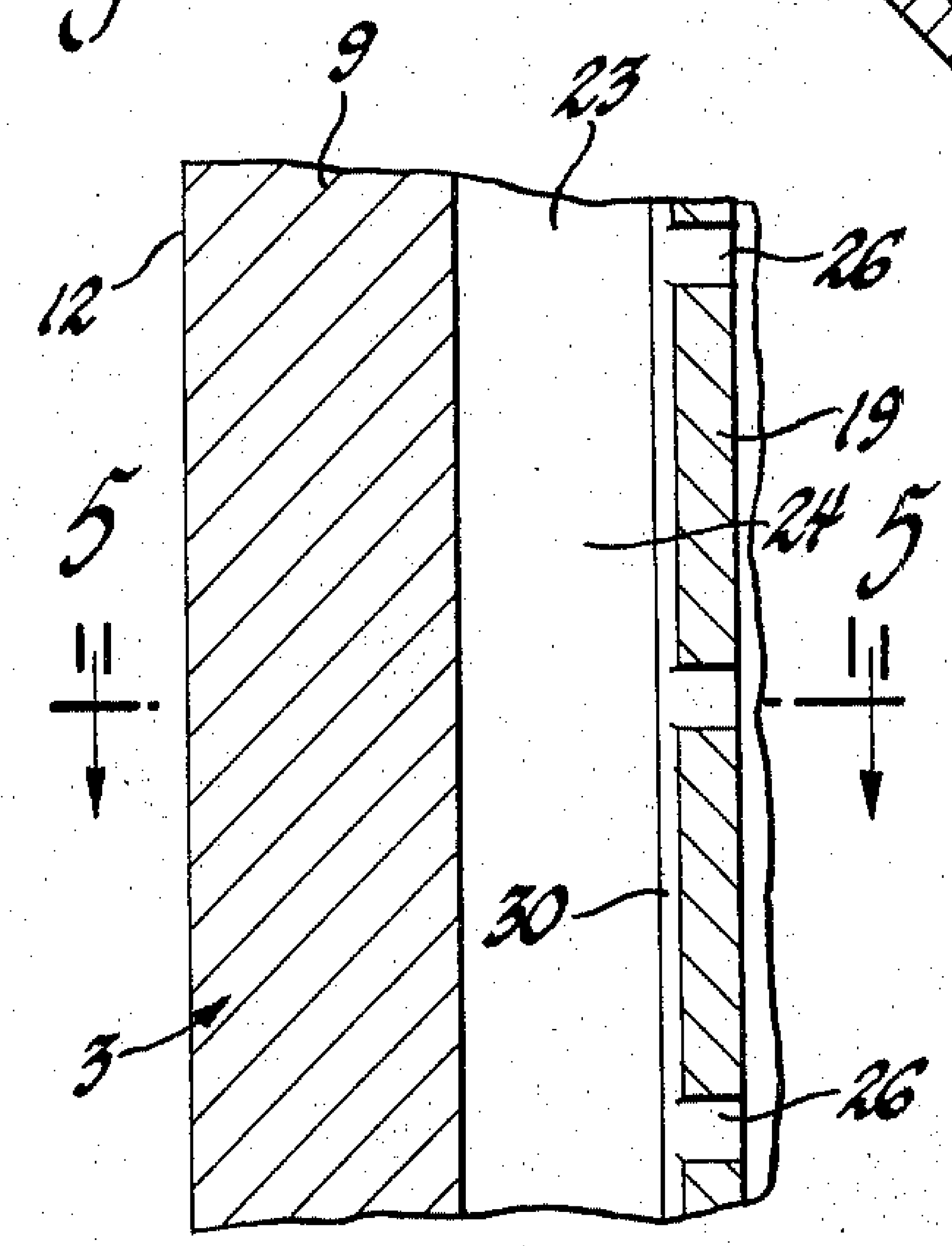


Fig.4

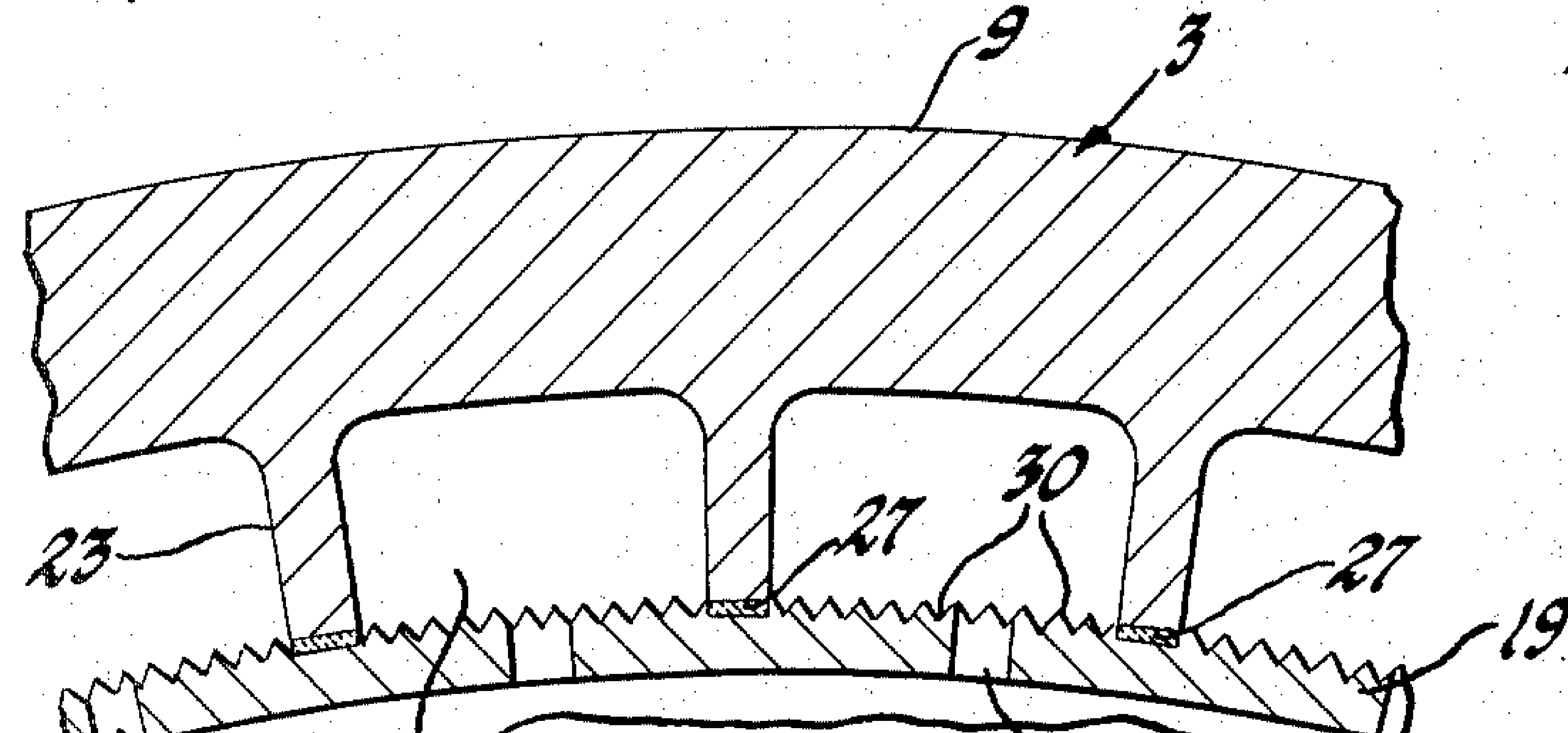


Fig. 5

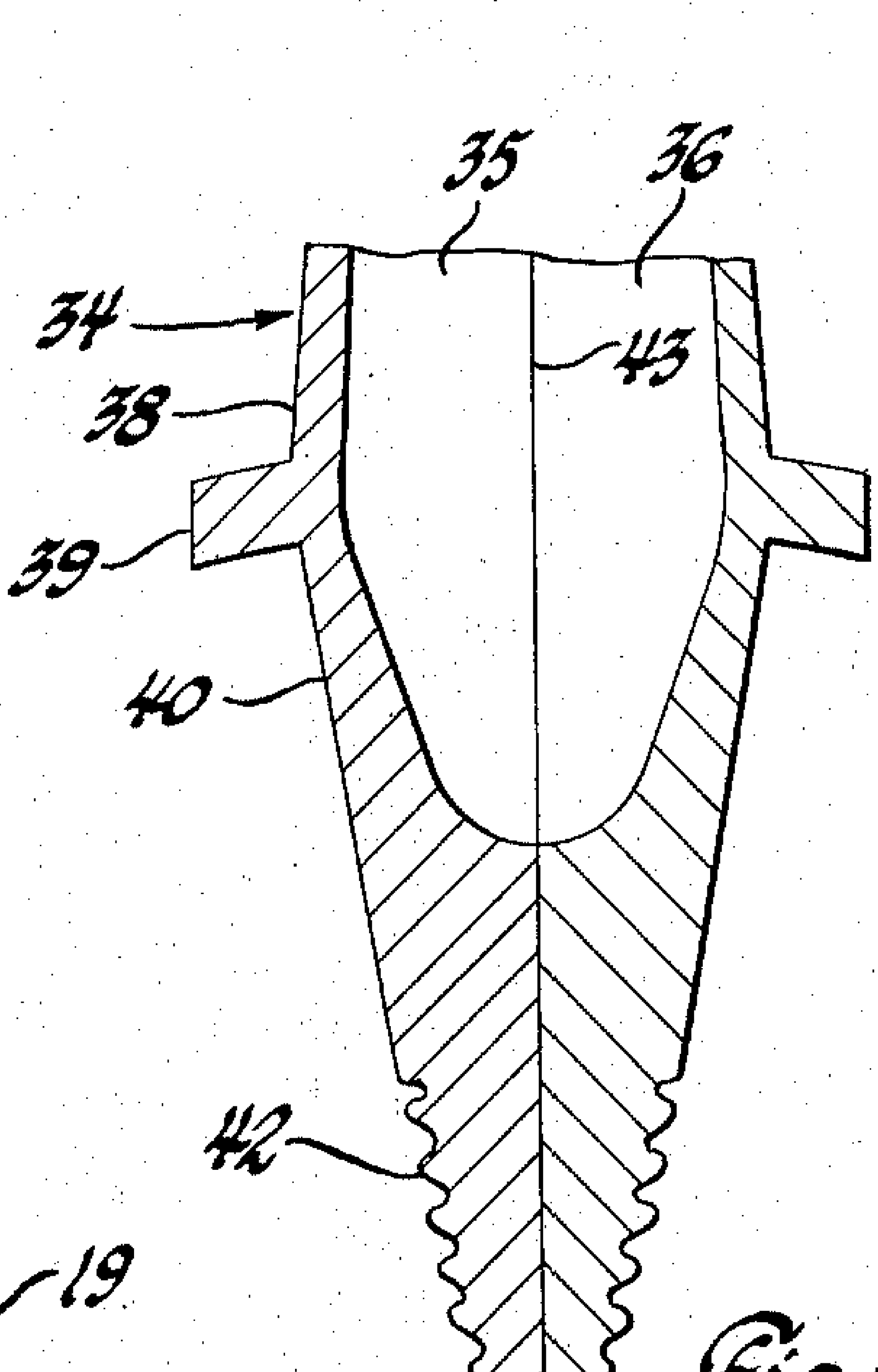


Fig.6

COOLED TURBINE BLADE

My invention is directed toward improvements in the structure of cooled flow-directing members for turbomachines working with hot motive fluids. Such fluid-directing members commonly are the rotor blades and nozzle vanes of turbines such as gas turbines. Hereinafter they will be referred to as blades for conciseness.

Regardless of the advances in metallurgy which have provided increasingly high temperature resistance in alloys used for turbine blades, there remains a need for improved means for cooling such blades, to increase the maximum temperature level of the engine in which they are employed. The reason for high temperature levels is greater efficiency and a lighter weight and more compact power plant.

It is important that cooling be as effective as possible so as to minimize loss of power or efficiency due to the provision of cooling air or other medium for cooling the blades.

My invention is directed to improved structure for internally cooling a turbine blade or vane of a non-porous wall type. The preferred structure of my invention involves a liner from which cooling air is spouted through small perforations toward the wall of the blade, the liner being spaced from the blade wall by ribs extending inward from the wall. Such structures are known. According to my invention, however, the liner is made of a material of relatively high conductivity such as cuprous nickel material and thus has greater than usual ability to conduct some heat out of the airfoil into the blade base. Also, transfer of heat by radiation from the blade wall to the liner is improved by providing a rough surface on the liner to increase the thermal absorptivity of the liner.

The principal objects of my invention are to provide improved means for cooling flow-directing members for high temperature machines, to provide a cooled blade which is of simple and readily fabricated structure, and to provide a system having maximum effectiveness for cooling a blade by internal convection and radiation, as distinguished from transpiration cooling.

The nature of my invention and its advantages will be clear to those skilled in the art from the succeeding detailed description of preferred embodiments of the invention and the accompanying drawings thereof.

FIG. 1 is an elevation view of a turbine blade.

FIG. 2 is a much enlarged transverse section of the blade taken on the plane indicated by the line 2—2 in FIG. 1.

FIG. 3 is a somewhat enlarged longitudinal section of the blade taken in the plane indicated by the line 3—3 in FIG. 2.

FIG. 4 is a greatly enlarged fragmentary view of a portion of the blade wall and liner taken in a plane extending spanwise of the blade.

FIG. 5 is a fragmentary cross section taken on the plane indicated by the line 5—5 in FIG. 4.

FIG. 6 is a fragmentary view illustrating a modified blade structure.

Referring first to FIGS. 1 and 2, FIG. 1 illustrates a blade, the general outline of which may be conventional. The flow-directing member or blade 2 comprises an airfoil or blade portion 3, a platform 4, and a base 6. The platforms of adjacent blades define one boundary of the hot motive fluid path through a cascade of blades. The platform isolates the base 6 from direct contact with the motive fluid. The base 6 comprises a hollow stalk 7 and a dovetail or serrated root 8 adapted for mounting in a turbine rotor structure. Referring particularly to FIG. 2, the hollow blade 3 is defined by a wall 9 and is illustrated as having a suitable cambered airfoil configuration, having a leading edge 10, a trailing edge 11, a convex face 12, and a concave face 14. The blade wall defines an internal chamber 15 of generally airfoil shape, and the tip of the blade at 16 is open. The blade stalk 7 defines an entrance 18 for cooling gas, ordinarily compressor discharge air in a gas turbine engine. A hollow sheet metal liner 19, the surface of which may be considered to be parallel in a rough way to the wall 9, is disposed within the chamber 15.

As illustrated in FIG. 3, the upper end of the liner is closed by a junction between the two side walls of the liner at 20. The base end of the liner may be disposed in slots 22 in the wall of the stalk and suitably fixed there. This is beneficial to conduction of heat from the liner into the blade stalk. Since the stalk first receives the cooling gas and is not in direct contact with the hot motive fluid, it is normally much cooler than the blade wall 9.

The interior of the blade wall 9 bears generally parallel ribs 23 which extend into contact with the blade liner and which, as will be apparent from FIG. 3, increase in height toward the tip of the blade. As a result, spanwise-extending passages 24 defined between the blade wall 9 and the liner 19 and bounded by the ribs 23 increase in depth and area towards the tip of the blade to maintain a more or less constant velocity of flow along the passages as the volume of flow increases. Cooling air which enters the opening 18 in the open blade base end of the liner is discharged through a multiplicity of small perforations or spouting holes 26 distributed along each passage 24. The liner 19 is bonded to the ribs 23 by brazing, diffusion bonding, or other suitable process, as indicated at the points 27 in FIG. 5. In addition to the outlet at the tip of the blade, the trailing edge of the blade may be formed with slots 28 to discharge some cooling air at this point to improve the cooling at the narrow trailing edge.

The airfoil tube apart from the liner may be formed by casting or forging and normally will be of a high nickel alloy such as ordinarily are used in hot situations and may be what are commonly called superalloys. These alloys have relatively low thermal conductivity. The liner 19, on the other hand, is preferably made of a cuprous nickel alloy having relatively high thermal conductivity.

The interior of the blade wall and the ribs 23 ordinarily are left with a relatively smooth finish such as results from the manufacture. The liner, on the other hand, is artificially roughened to provide higher heat absorptivity as shown more clearly in FIGS. 4 and 6. Preferably, this roughening is in the form of contiguous parallel V-grooves 30 preferably of about 90° included angles. This roughness may be produced by etching or by machining or by a process of rolling the sheet as desired. The relatively smooth surface of the blade wall gives it a gray body characteristic, whereas the rough surface of the liner gives it more of a black body characteristic. The relatively higher absorptivity of the liner and the relatively higher emissivity of the wall improve the transmission of heat by radiation from the wall to the liner. This is not the major means for removal of heat from the wall 9, the principal removal being by transfer of heat to the cooling gas. Nevertheless, any improvement in cooling is important.

Thus, we have a very hot wall, the outer surface of which may be 1,000° F. hotter than the cooling air in the interior of the liner. The inner surface of the blade wall is substantially cooler than its outer surface, the ribs cooler yet, and the liner **19** still cooler. Because of the high heat transmitting characteristics of the liner, it is more effective in transmitting heat from the ribs to the cooling air, providing additional effective surface for convection cooling. In the bonded joint there is good transfer of heat from the ribs to the liner. Since the liner is a good heat conductor, it also is instrumental in conducting heat toward the base of the blade into the area which is remote from the motive fluid stream above the platform **4.** Also, because of the greater absorptivity of the ridged or roughened surface of the liner, the transfer of heat from the wall by radiation to the liner is improved. The liner, of course, is cooled by the cooling air flowing within the liner and through the holes **26** through the liner as well as by the air flowing through the passages **24** which air, of course, receives most of its heat from the wall **9.**

It may be helpful to give an example of preferred dimensional values in a blade as described above. The blade may be considered to have a chord of about 1 ½ inches, with a rib every 50 mils (a mil being a thousandth of an inch), the ribs being 10 mils wide, and the air holes **26** about 6 mils in diameter. The distance from the liner to the blade wall increases from about 12 mils to about 40 mils from base to tip of the blade, the blade wall is about 40 mils thick, and the liner is about 10 mils thick. The ridges or grooves **30** on the liner are about 3 mils deep. Such dimensions are subject to change, of course, depending upon the nature of the particular installation and exercise of engineering analysis.

The blade **2** may be cast integrally in one piece, following, for example, the techniques described in McCormick U.S. Pat. No. 3,192,578, July 6, 1965, or the airfoil and base may be cast separately and joined by a welding or diffusion bonding operation. Or, if desired, the structure may be cast in two parts which are then bonded together as illustrated generally in FIG. **6.** The blade **34** of FIG. **6** is made of two parts **35** and **36,** each defining one side of the blade or airfoil **38,** of the platform **39,** of the stalk **40,** and of the root **42.** These are united along a joining surface **43** which ordinarily, in practice, might approximately follow the mean camber line of the blade. The ribbed interior of the blade and other details are not indicated in FIG. **6.**

It should be apparent to those skilled in the art that I have conceived a significant improvement in the principles of internal cooling of blades, giving greater efficiency in the use of cooling air and greater uniformity of temperature throughout the blade.

The description of preferred embodiments of the invention for the purpose of explaining the principles thereof is not to be considered as limiting or restricting the invention, since many modifications may be made by the exercise of skill in the art.

I claim:

1. An internally-cooled flow-directing member for a turbomachine comprising, in combination, a hollow airfoil having an external wall defining an internal chamber, a liner disposed in the airfoil and spaced from the wall, the member having an inlet for a cooling gas at one end of the airfoil and an outlet for the cooling gas at the other end of the airfoil, the wall bearing internal ribs extending spanwise of the airfoil and engaging the liner, the ribs increasing in height toward the cooling gas outlet so that cooling gas passages diverging toward the airfoil outlet are defined by the wall and liner between the ribs, the inner surface of the wall having a relatively smooth finish for high heat emissivity and the outer surface of the liner having a relatively rough finish for high heat absorptivity, and the liner being made of a material of relatively high coefficient of thermal conductivity as compared to the airfoil.

2. An internally-cooled flow-directing member for a turbomachine comprising, in combination, a hollow airfoil having an external wall defining an internal chamber, a liner disposed in the airfoil and spaced from the wall, the liner having an inlet for a cooling gas and defining distributed perforations for discharge of the gas toward the wall, the airfoil defining an outlet for the cooling gas, the wall bearing internal ribs extending spanwise of the airfoil and bonded to the liner, the inner surface of the wall having a relatively smooth finish for high heat emissivity and the outer surface of the liner having a relatively rough finish for high heat absorptivity, the liner being made of a material of relatively high coefficient of thermal conductivity as compared to the airfoil.

3. An internally-cooled flow-directing member for a turbomachine comprising, in combination, a hollow airfoil having an external wall defining an internal chamber, a liner disposed in the airfoil and spaced from the wall, the liner having an inlet for a cooling gas and defining distributed perforations for discharge of the gas toward the wall, the airfoil defining an outlet for the cooling gas, the inner surface of the wall having a relatively smooth finish for high heat emissivity and the outer surface of the liner having a relatively rough finish for high heat absorptivity, the liner being made of a material of relatively high coefficient of thermal conductivity as compared to the airfoil; the airfoil having a base isolated from the flow passing by the airfoil and including an inlet for the cooling gas, the liner extending into the base.

4. An internally-cooled flow-directing member for a turbomachine comprising, in combination, a hollow airfoil having an external wall defining an internal chamber, a liner disposed in the airfoil and spaced from the wall, the liner having an inlet for a cooling gas and defining distributed perforations for discharge of the gas toward the wall, the airfoil defining an outlet for the cooling gas at the tip of the airfoil, the wall bearing internal ribs extending spanwise of the airfoil and engaging the liner, the ribs increasing in height toward the airfoil tip so that cooling gas passages diverging toward the airfoil tip are defined by the wall and liner between the ribs, the inner surface of the wall having a relatively smooth finish for high heat emissivity and the outer surface of the liner having a relatively rough finish for high heat absorptivity, the liner being made of a material of relatively high coefficient of thermal conductivity as compared to the airfoil; the airfoil having a base isolated from the flow passing the airfoil and including an inlet for the cooling gas, the liner extending into the base.

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