United States Patent

Moskowitz

[15] **3,647,316**

[45] **Mar. 7, 1972**

[54] **VARIABLE PERMEABILITY AND OXIDATION-RESISTANT AIRFOIL**

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[73] Assignee: **Curtiss-Wright Corporation**

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[52] **U.S. Cl.** **416/97,** 416/231
[51] **Int. Cl.** **F01d 5/18**
[58] **Field of Search** 416/231, 97, 90, 96

[56] **References Cited**

UNITED STATES PATENTS

2,857,657	10/1958	Wheeler	29/156.8
2,946,681	7/1960	Probst et al.	75/208
3,067,982	12/1962	Wheeler	416/90
3,114,961	12/1963	Chambers et al.	29/156.8 B
3,240,468	3/1966	Watts et al.	416/231
3,402,914	9/1968	Kump et al.	416/231

FOREIGN PATENTS OR APPLICATIONS

722,514	1/1955	Great Britain	416/231

Primary Examiner—Everette A. Powell, Jr.
Attorney—Raymond P. Wallace and Victor D. Behn

[57] **ABSTRACT**

An air-cooled turbine blade for rotor or stator, having a strut member having airflow channels and covered with a sheath of porous mesh material, portions of which are impregnated with a slurry of finely divided metal in a liquid ceramic binder which is then cured in place, to provide a transpiration cooled blade having selected areas of variable resistance to airflow therethrough.

1 Claims, 5 Drawing Figures

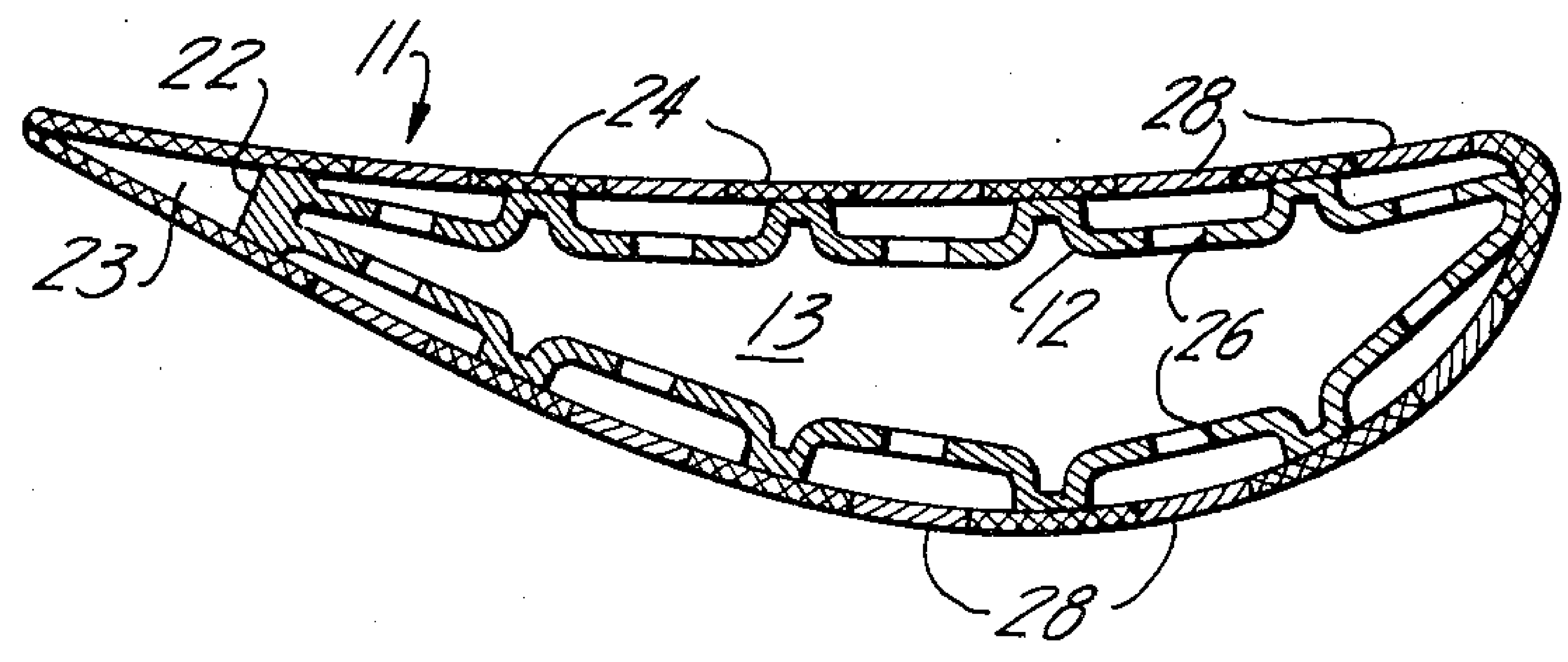

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FIG. 1

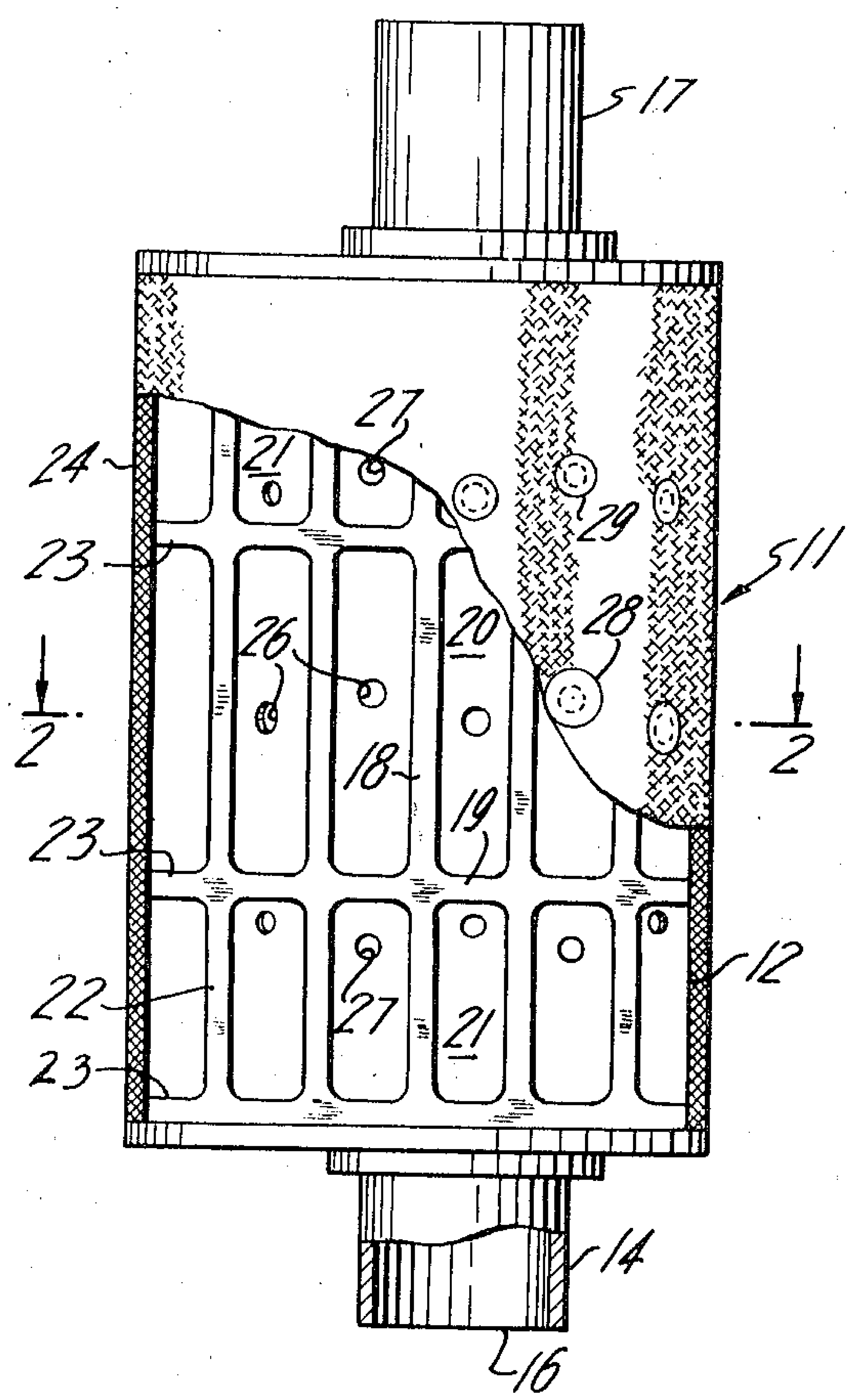

FIG. 2

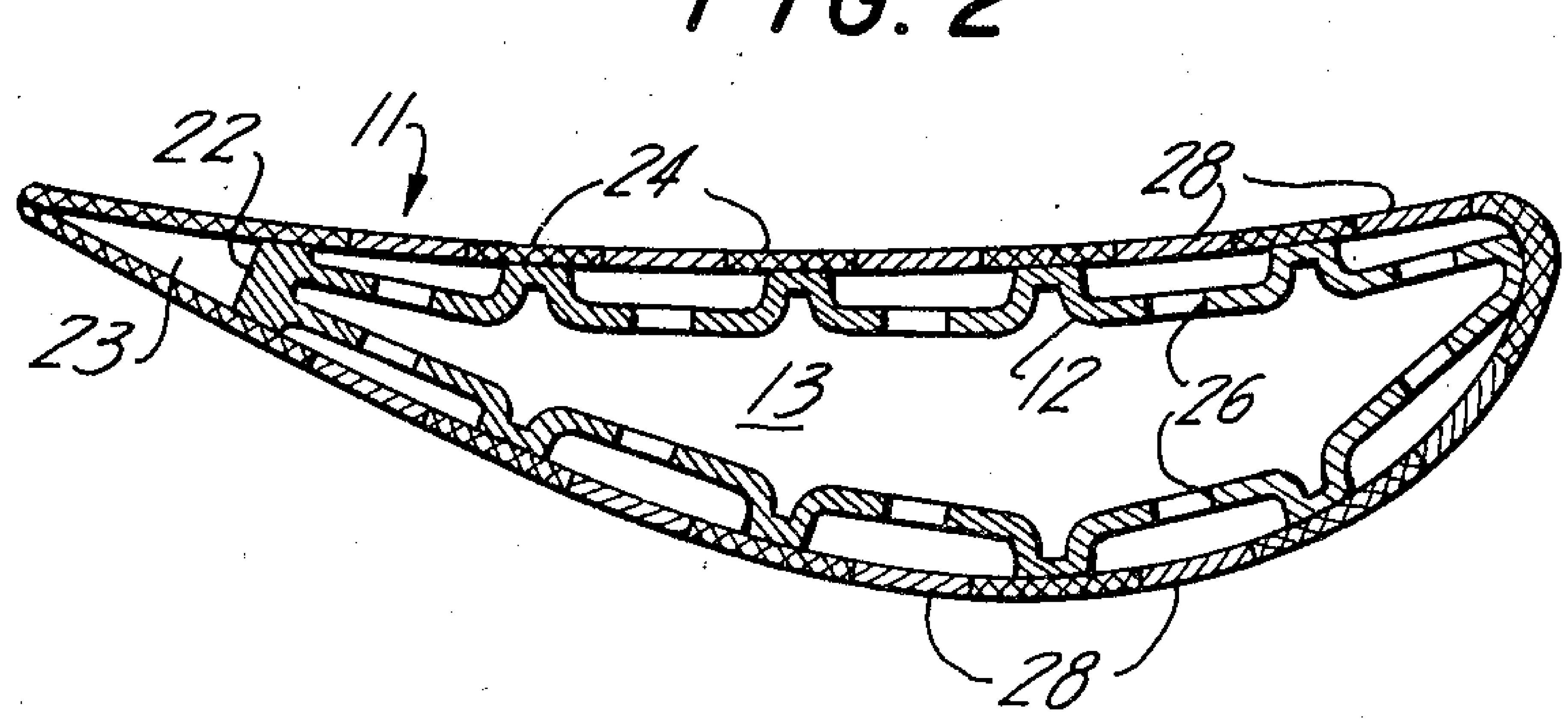

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FIG. 3

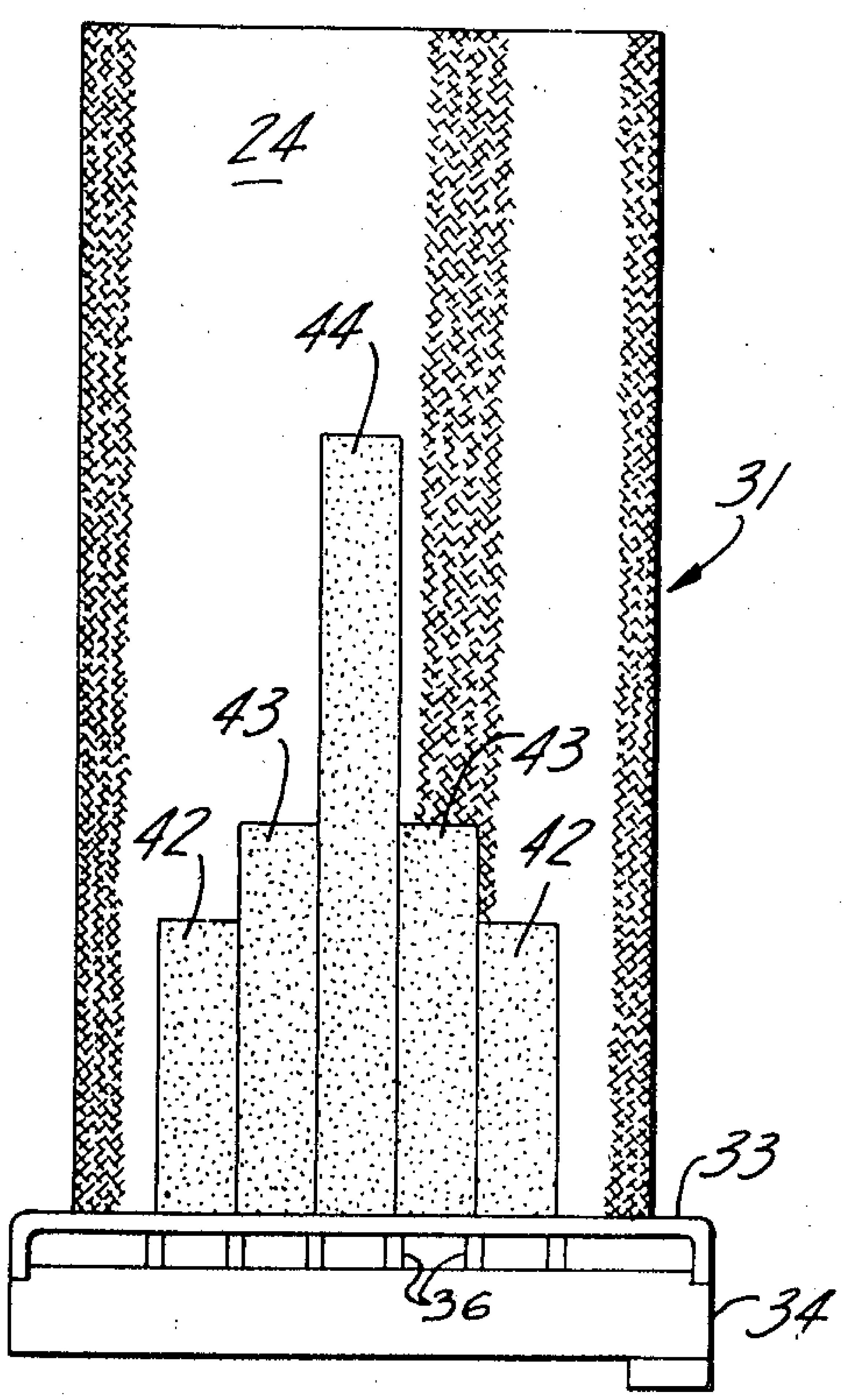


FIG. 4

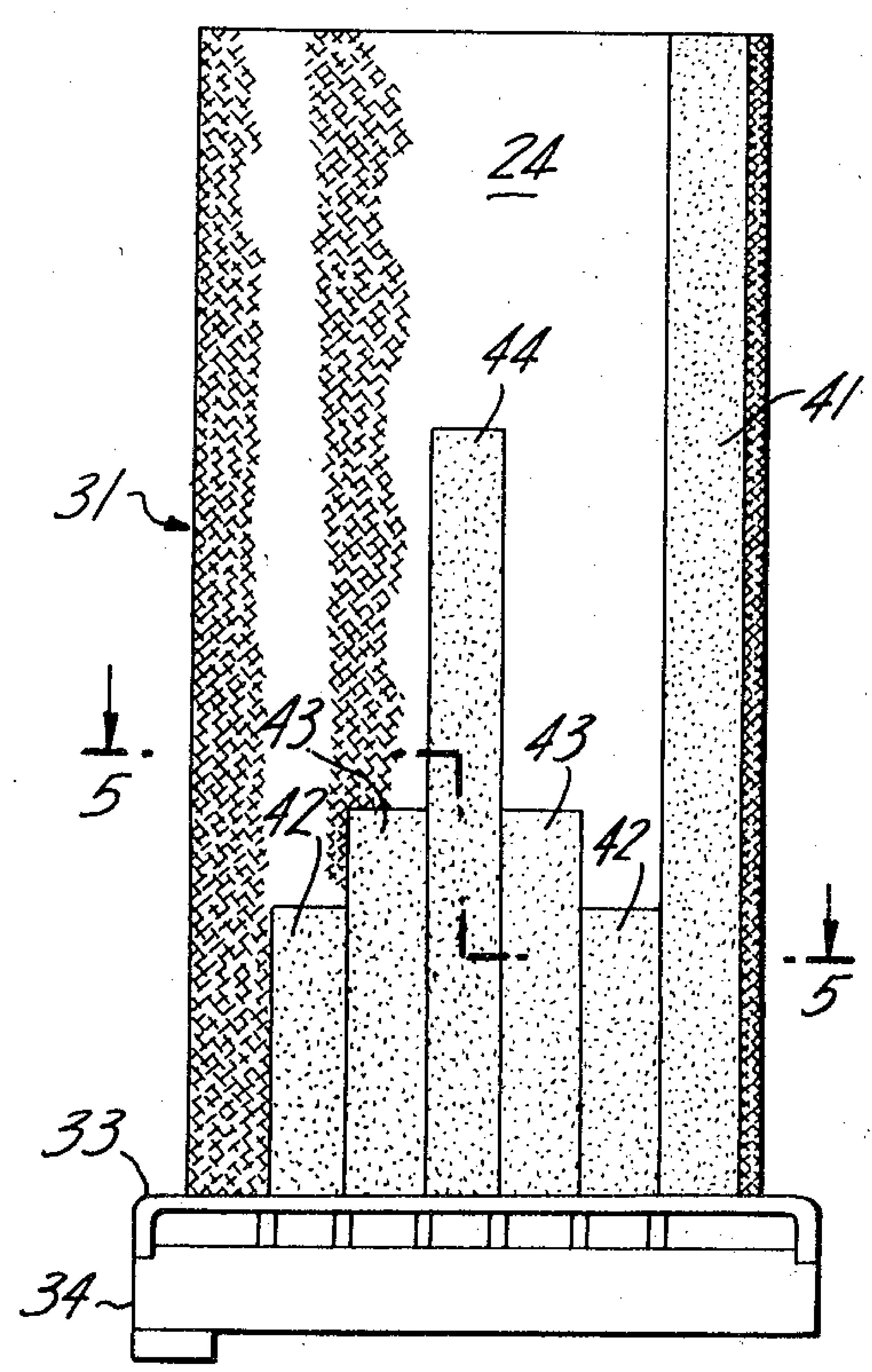
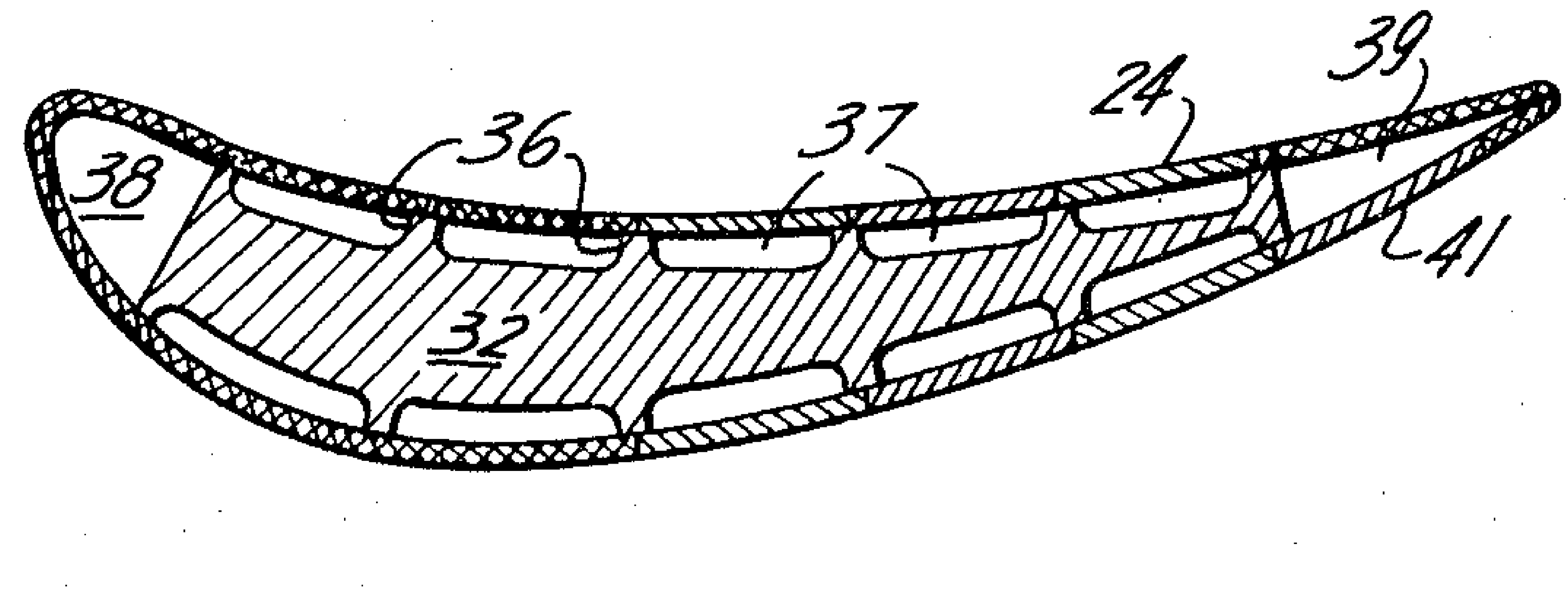


FIG. 5



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VARIABLE PERMEABILITY AND OXIDATION-RESISTANT AIRFOIL

BACKGROUND OF THE INVENTION

This invention relates to transpiration-cooled turbine blades, and more particularly to blades subjected to varying gas temperatures and pressures both spanwise and chordwise, wherein selected portions pass more or less cooling air according to the demands of local gas temperature and pressure conditions. The invention herein described was made in the course of a contract with the Department of the Navy.

Flow distribution of coolant in a transpiration cooled blade is a function of the internal cooling air pressure level and the external gas pressure at the blade surface. Since there may be a large gas pressure gradient in either or both the chordwise or spanwise directions maldistribution of the coolant may occur. In addition, temperature gradients in either the spanwise or chordwise direction may be present, requiring differential cooling in various parts of the blade apart from external pressure considerations. Attempts have been made to solve these problems, as in U.S. Pat. No. 3,240,468, wherein a hollow blade strut is provided with external cells of various sizes and shapes defined by lands disposed in chordwise and spanwise directions, some of which lands may be curved to define cells of other than rectangular configuration. A porous sheath is mounted on these lands, and the cells are fed with cooling air from the interior of the strut through apertures of various sizes and positioning. This results in a blade of great complexity and expense to manufacture, and the multiplicity of lands defining the cells adds considerably to the weight of the blade. Further, air jetting from a strut aperture may simply spurt through the adjacent portion of the porous skin, without distributing throughout the entire cell it is supposed to feed.

Another attempt to solve the problems is shown in U.S Pat. No. 3,402,914, where a simpler strut is provided with only spanwise lands to which a porous sheath is fastened to define air passages fed from the root. The permeability of the sheath is adjusted by flame-spraying various portions of the surface with powdered metal to various thicknesses and porosities. This method results in external surface patches of uneven height, having projecting edges interfering with smooth gas flow and being subject to spalling and erosion. Such problems of cost, complexity, weight, erratic flow, and erosion have been eliminated by the present invention.

SUMMARY

This invention provides a transpiration-cooled turbine blade having a hollow strut and a permeable skin defining air passages with the strut, with cooling air from the interior of the strut supplied at selected locations, and means for reducing the porosity of the skin at noncritical locations for directing airflow to other areas. There is also provision for deflecting air jets coming through the strut apertures so that each air stream is fully distributed over the desired cooling area. These objects and others are accomplished by providing a process for a new use of a known material, whereby the porous material of the skin is impregnated with a ceramometallic composition of matter to reduce porosity in selected portions without substantial increase of skin thickness.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation, partially broken away, of a blade according to the invention;

FIG. 2 is a cross section taken on line 2—2 of FIG. 1;

FIG. 3 is an elevation of the concave side of another embodiment;

FIG. 4 is a similar view of the convex side; and

FIG. 5 is a cross section taken on line 5—5 of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 show a blade **11** having a hollow strut member **12** of generally airfoil configuration, having an inner chamber **13**. The blade is provided with a mounting trunnion at each end or other suitable mounting means, trunnion **14** being hollow and having its lower end **16** open for the introduction of cooling air under pressure. The interior of trunnion **14** communicates with the inner chamber **13** of the strut. Trunnion **17** is closed so that cooling air entering the interior of the blade must bleed through the porous surface.

The exterior of strut **12** is provided with a plurality of generally longitudinal ribs or lands **18** and generally transverse lands **19**, defining a plurality of recesses **20** and **21** in the surface of the strut. As many recesses **21** may be provided in the chordwise direction as required by the operating conditions of the turbine, depending on local pressures and temperatures at various portions of the blade, and the recesses are not necessarily of the same dimensions in various portions of the blade, since it is desirable to provide more or less cooling air at one point or another. It has been found convenient to dispose the lands **19** so that there is a series of three rows of recesses between the two ends of the blade in the spanwise direction, the center row of recesses **20** being of longer spanwise dimension than the two end rows **21**. The trailing edge of the strut is cut short as shown at **22** in FIG. **2**, leaving only a pair of tapered extensions **23** at each end of the blade to support the porous skin of the trailing edge. Ribs **19** may also be provided with such extensions, as shown.

The strut is covered with a skin **24** of permeable sheathing material, which may be formed of powdered metal or cermet pressed and sintered to the desired shape and dimensions, or a metal fabric. A particularly suitable material is a metal mesh fabric composed of the fine filaments compressed and sintered together as is known in the art, and attached to the lands by welding, brazing, or the like.

To introduce cooling air from the interior of the strut to the recesses **20** there are provided apertures **26** through the walls of the strut. The apertures **26** are disposed generally in the center of recesses **20**, but somewhat staggered in positioning across the blade, partly to avoid introducing a line of structural weakness and partly to preclude a straight chordwise band across the blade where no cooling air emerges, since the skin directly over each aperture is to be rendered impermeable. Recesses **21** at each end of the blade are also provided with apertures **27**, but disposed relatively close to the lands **19**. Apertures **26** in the center row of recesses **20** are larger than apertures **27** in the end rows **21**, because more cooling air is required toward the center of the blade span than at the ends, which normally run somewhat cooler. Further, apertures **27** are positioned relatively close to the transverse lands lands **19** in order to exert a cooling effect thereon, and are also staggered, for the same reasons as with apertures **26**.

Over each of the apertures **26** in the strut the porous skin has been rendered impervious to air in a circular area **28** to distribute throughout the recess **20** the high pressure jet of air emerging through aperture **26**. Otherwise the jet tends to discharge locally through the skin without filling its recess, and some of its cooling effect is lost. The impervious spots **28** are approximately twice the diameter of their associated airholes, which has been found a sufficient extent to distribute the air properly. Over each of the smaller apertures **27** in recesses **21** there are also provided impervious areas **29**, again about twice the diameter of their associated airholes. Such impervious spots have another function to perform in recesses where the cooling requirements are minimal, and where without such an impervious area the hole to provide cooling air might be quite small. Such small holes would be liable to plugging from dirt and combustion products. With this invention the holes may be made larger than required to pass the requisite air, and a larger proportion of the skin over such a recess may be rendered impervious. Although the spots **29** are shown as about twice the diameter of their airholes, the spots may be made somewhat larger if it is desired not to bleed through the skin the full quantity of air such a hole might supply.

The impervious areas are produced by masking the blade surface except at the points where such impermeable spots are to be positioned, and spraying or brushing the unmasked surface with a slurry of fine aluminum particles in a ceramic solution, and then curing the deposited infiltration under heat. The actual composition of the deposited material is not a part of this invention, but is one which is sold as a coating material for the purpose of protecting ferrous metals against galvanic corrosion. Although galvanic corrosion is not a factor in turbine blades, it has been found in the present invention that the coating material sold for preventing it can also be used for infiltration into porous sheathing of blades and cured in place to render the skin impervious and resistant to high temperatures. Several such compositions are sold under the trademark SermeTel, a registered trademark belonging to Teleflex, Inc., and their formulations are given in U.S. Pat. No. 3,248,251. One example is as follows:

EXAMPLE

Aluminum particles (spherical, 5–10 microns)	80 g.
Phosphate-chromate-metal-ion solution	100 cc.
The solution is made by mixing:	
H_3PO_4 (85% aqueous solution)	20 cc.
MgO	5 g.
$Mg(H_4PO_4)_2 \cdot 3H_2O$	5 g.
$MgCr_2O_7 \cdot 6H_2O$	15 g.
Water, to 100 cc.	

Such a solution contains approximately 3 mols per liter of phosphate ion, 1 mol per liter of chromate ion, and 2 mols per liter of metal (magnesium) ion. The slurry is painted or sprayed onto the unmasked portions of the blade skin, where it infiltrates by capillary action into the interstices of the porous material. When a sufficient amount has been absorbed that the texture of the surface of the material is smoothed or obscured, the porosity will be completely or substantially completely blocked.

The blade is then subjected to heat to cure the deposit, whereby the water of the slurry is evaporated and the ceramic component is solidly fused, cementing the aluminum particles within the capillary passages and rendering the treated portions impermeable. Heats from about 500° F. to about 1,000° F. may be applied for a period of 5 to 60 minutes. The exact heats and times are not critical, but in general the lower heats require longer curing times. For instance, a period of 15 to 60 minutes at about 600° F. may be employed, or 5 to 10 minutes at about 800° F. For turbine blades no special curing operation need be performed, since the deposit will dry naturally and remain in place, and subsequently cure at the turbine operating temperature in the first run of the machine. In any case, the treated material should be allowed to dry at room temperature or subjected to only gentle heat long enough to dry it before applying the curing temperature. Porous material treated according to this process preserves its smooth and uninterrupted surface, while preventing passage of cooling air through the treated portions.

FIGS. 3–5 show another embodiment of a turbine blade **31** according to the invention, FIG. 3 being the concave side and FIG. 4 the convex side. In this embodiment the blade **31** has a solid strut **32** and a blade shelf **33** spaced slightly above the conventional root member **34**. The strut **32** is provided with longitudinal ribs or lands **36** extending in the spanwise direction and defining air channels **37** therebetween. Cooling air enters the channels **37** through the space under the blade shelf **33**, the opposite end of the blade being closed so that cooling air must bleed through the porous skin **24**. The solid strut **32** stops short at both the leading and trailing edges, so that a hollow channel **38** is formed in the nose portion of the blade, and a similar hollow channel **39** in the trailing section.

In this embodiment, as in the previous one, certain portions of the blade require more cooling than others, and this is accomplished by blocking the permeability of the skin in panels over portions of the underlying air channels. The nose portion of the skin, over the hollow passage **38**, is left in its fully permeable state on both the concave and convex sides of the blade, since this is the portion on which the hot combustion gases first impinge and which therefore requires the full flow of cooling air. On the concave or pressure side of the blade the trailing portion is left unblocked over hollow passage **39**, but on the convex or suction side the trailing portion is blocked over the forward portion of the passage **39** by a panel **41** extending from root to tip of the blade, but leaving a small portion of the trailing edge unblocked, sufficient to allow transpiration cooling adjacent to the folded or welded juncture of the skin at both the concave and convex sides. The reason for blocking the larger portion of the trailing edge on the convex side is that gas pressure is high on the concave side, and if the common passage **39** were unblocked on the suction side all the cooling air might bleed through that portion without passing through the skin of the other side. However, in cases where the configuration of the blade is such that passage **39** cannot be directly fed by an air supply from the root and must be fed from adjacent chambers, involving a pressure drop, the concave or pressure side of the blade at the trailing edge may have a blocking panel to prevent inflow of high-pressure combustion gas, and the convex side of the blade at that portion is left unblocked to allow transpiration of cooling air.

Other panels of blocking are provided where appropriate, such as the panels **42** extending from the root about one-fourth of the span dimension, the panels **43** extending about one-third of the span dimension, and panels **44** extending about two-thirds of the span dimension. Similar panels of appropriate extent may be provided wherever it is desired to reduce the cooling effect of transpiration air and to direct the flow to other portions of the air channel. It will be recognized that although the impermeable panels are shown in a particular configuration in this embodiment, for a blade subject to specific parameters of gas flow and temperature, blades in other engines may well require a different cooling pattern and hence will have their skin porosity blocked in greater or lesser areas in various portions of the blade.

What is claimed is:

1. A transpiration-cooled turbine blade having a hollow strut member having a supply of air under pressure to the interior thereof, the external surface of the strut having a plurality of longitudinal and transverse raised lands thereon defining a plurality of discrete recesses, a porous skin surrounding the strut and attached to the lands to define with the recesses a plurality of plenum chambers, the porous skin having capillary passages therethrough for flow of cooling air, each of the recesses having an aperture through the strut wall communicating with the hollow interior thereof and transmitting a jet of cooling air to the plenum chamber impinging on the inner surface of the skin, the porous skin having its capillary passages blocked over each strut aperture by an impervious spot approximately twice the diameter of its associated aperture to divert the air jet and distribute the cooling air throughout the respective plenum chamber before bleeding through the skin, the spots being formed by filling the capillary passages of the skin with aluminum particles cemented in place by a ceramic binder composition to leave the skin with a smooth external aerodynamic surface.

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