

[54] **COOLED AIRFOIL**

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

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

[56] **References Cited**

UNITED STATES PATENTS

3,032,314	5/1962	David.....	416/96 X
3,635,587	1/1972	Giesman et al.	416/97

FOREIGN PATENTS OR APPLICATIONS

491,903	4/1953	Canada.....	416/96
1,222,565	2/1971	Great Britain.....	416/97

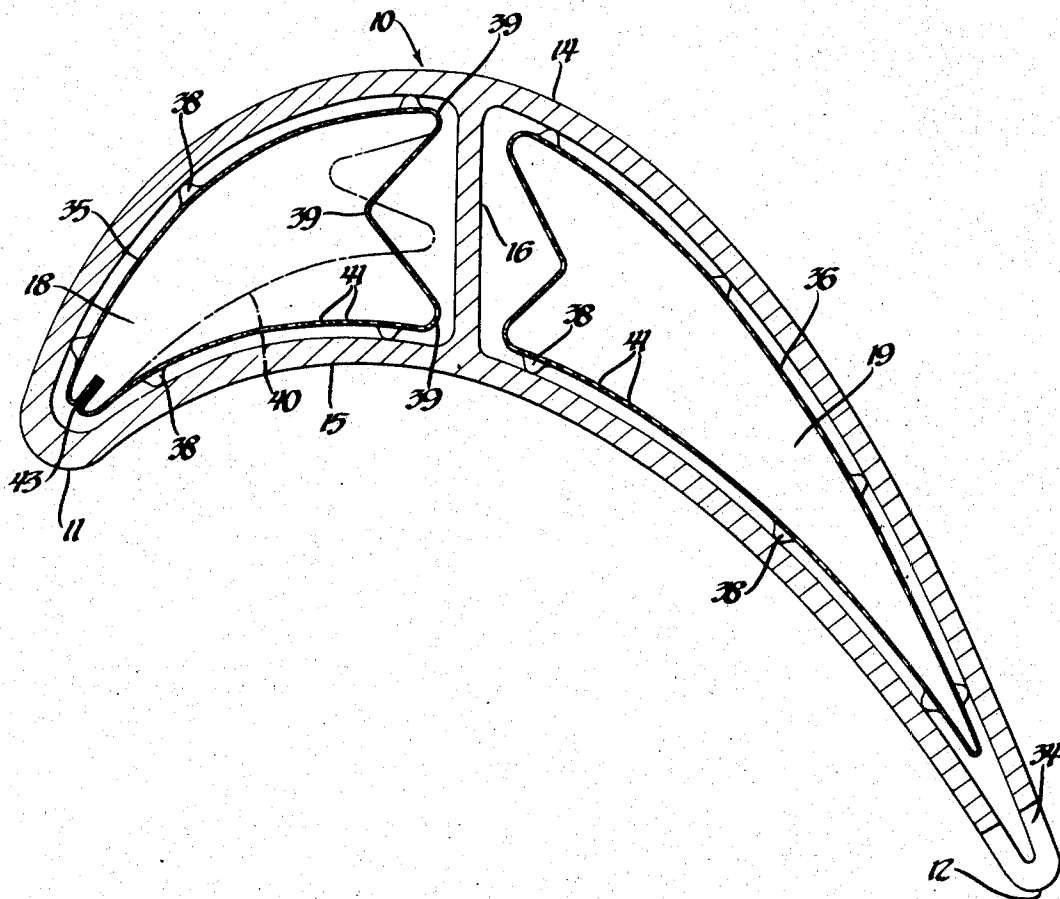
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[57]

ABSTRACT

A hollow air-cooled turbine blade has a web extending from face to face of the blade to divide the interior of the blade into two spanwise-extending chambers. A thin sheet metal liner is disposed in each chamber, the liner having perforations distributed over its surface and having projections to space it from the blade wall. The liner is flexible and may be folded substantially flat for insertion into the end of the blade. At the leading edge of the blade, the liner walls are recurved to define a generally parallel-walled slot nozzle extending spanwise of the blade. Additional holes are placed along the outlet from this nozzle to flow additional air for entrainment by the jet emerging from the slot nozzle to improve cooling of the leading edge. Cooled air enters the liners through the blade stalk and is discharged preferably through the tip and trailing edge of the blade.

5 Claims, 6 Drawing Figures



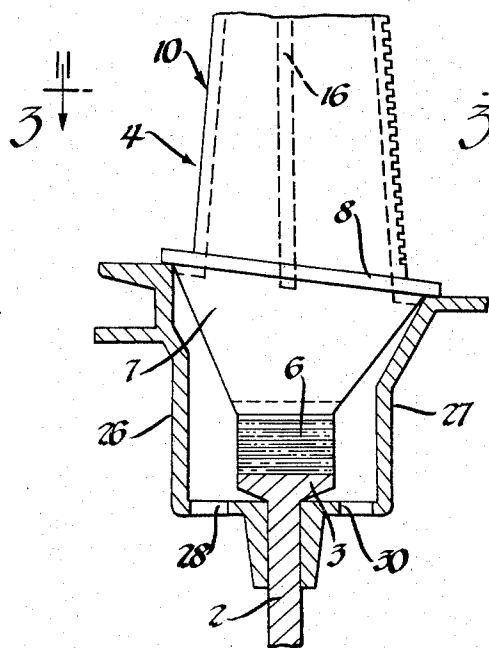


Fig. 1

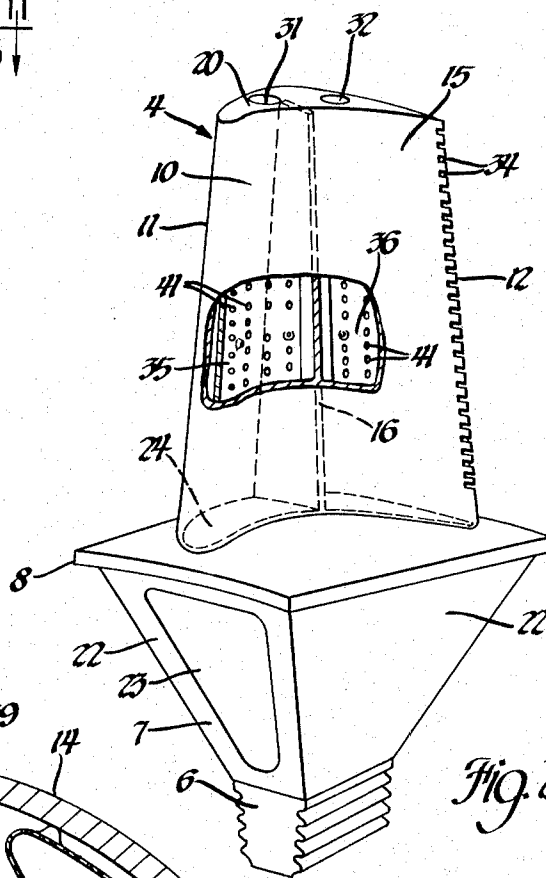


Fig. 2

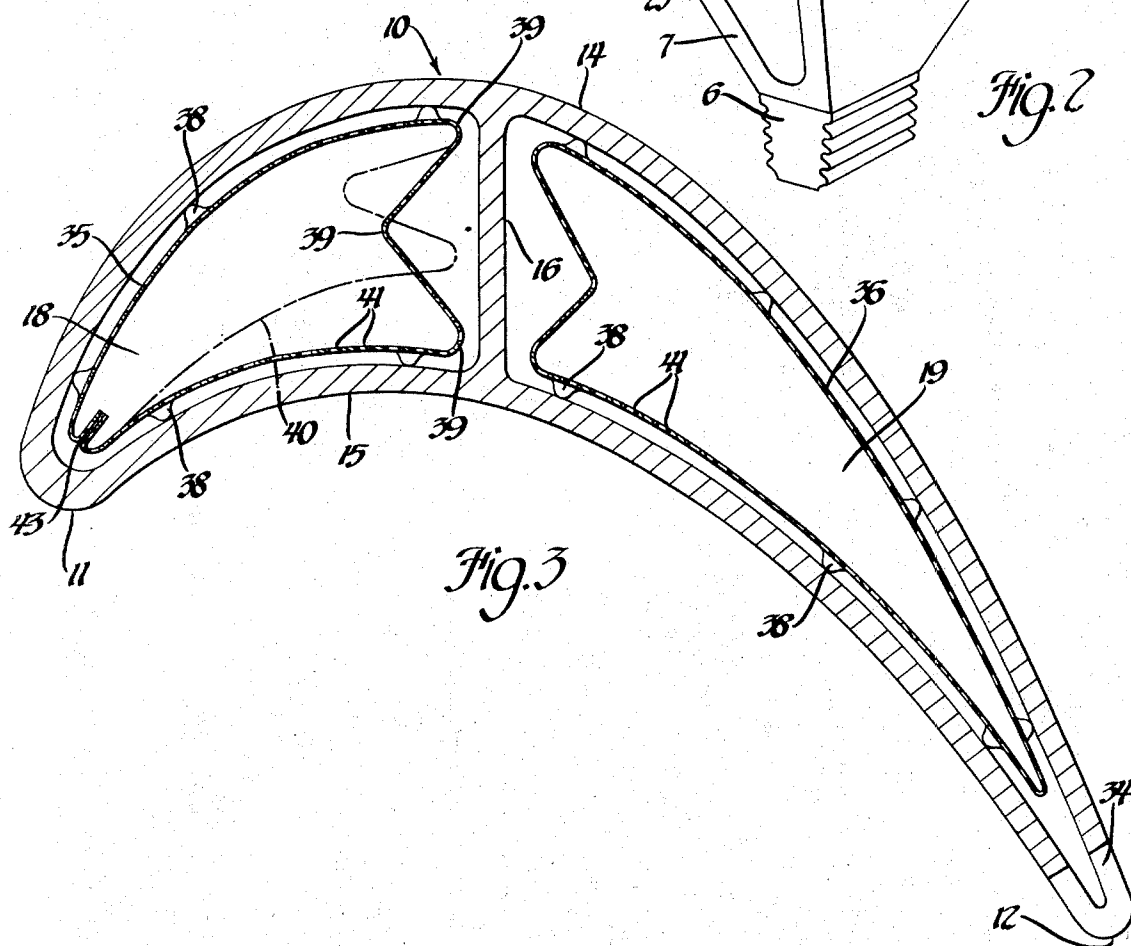
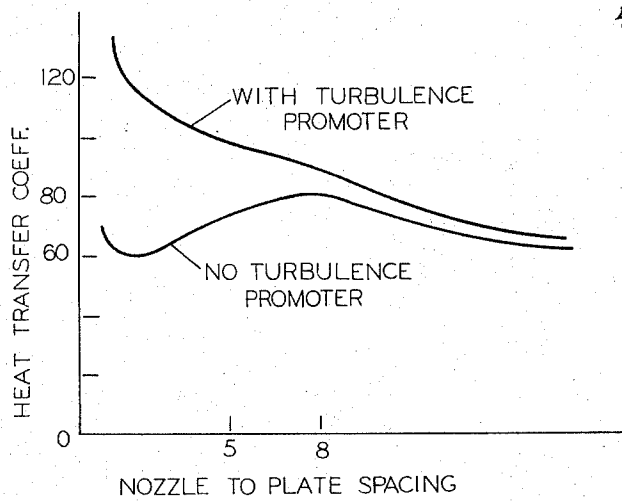
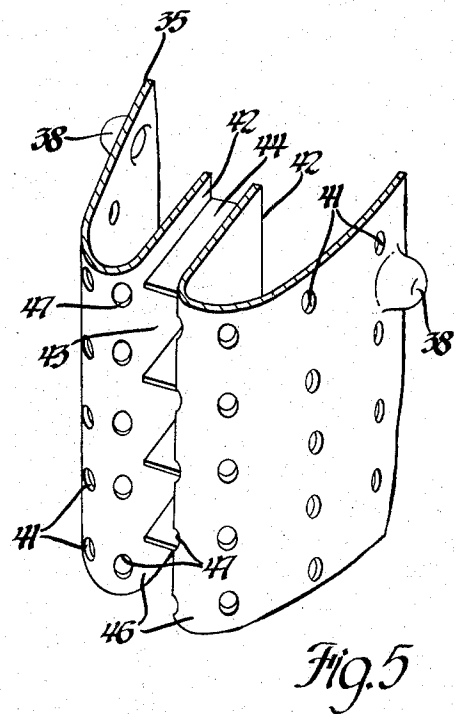
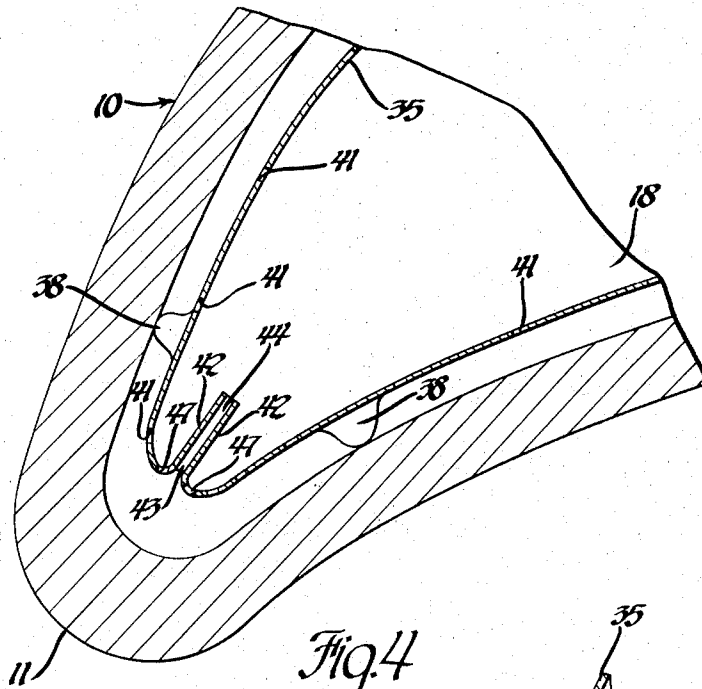


Fig. 3



COOLED AIRFOIL

DESCRIPTION

My invention is directed to improved cooled turbine blades and the like. My invention is particularly directed to improved structures employing the principles of convection and impingement cooling. As used here, the term convection cooling refers to the transfer of heat from the interior of a blade wall to a cooling medium flowing along the wall. Impingement cooling is a variation of convection cooling in which the cooling medium is directed as a sheet or jet toward the wall to be cooled, thereby improving the efficiency of the heat transfer or providing for increased heat transfer in particular localities such, for example, as the leading edge of a blade. The invention is particularly concerned with improvements of the cooling of the blade leading edge and with improved structure of a blade liner for this purpose. It is also concerned with a blade liner which may readily be installed in a previously completed turbine blade such as a cast blade, for instance.

Convection cooling of a blade wall, as distinguished from impingement cooling, is described in Zimmerman U.S. Pat. No. 2,859,011, Nov. 4, 1958, and Emmerson et al, U.S. Pat. No. 3,446,480, May 27, 1969. Impingement cooling by air spouting from blade liners against the wall of a blade is described in Weise et al, U.S. Pat. No. 2,873,944, Feb. 17, 1959. A blade including a liner with special provisions for jetting air to the leading edge of the blade for impingement cooling is disclosed in Giesman et al, U.S. Pat. No. 3,635,587, Jan. 18, 1972.

The general object of my invention is to provide improved structure to accomplish the sort of cooling described in these prior art patents and to provide a structure particularly suited to fabrication.

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

FIG. 1 is a fragmentary sectional view of a turbine wheel with a blade mounted thereon.

FIG. 2 is an axonometric view of a turbine blade.

FIG. 3 is a transverse sectional view of the blade taken on the plane indicated by the line 3—3 in FIG. 1.

FIG. 4 is a greatly enlarged view of the leading edge portion of FIG. 3.

FIG. 5 is a fragmentary axonometric view of the blade liner.

FIG. 6 is a graph illustrating certain parameters of impingement cooling.

Referring first to FIGS. 1 and 2, there is illustrated a turbine wheel 2 having a rim 3 on which are mounted a ring of fluid-reacting members or blading members 4, commonly known as blades. Each blade comprises a dovetail root 6, a stalk 7, a platform 8, and a blade proper or airfoil 10. The airfoil, as shown most clearly in FIG. 3, is hollow and has a leading edge at 11, a trailing edge at 12, a convex face 14, and a concave face 15, these faces extending from one edge to the other. A web 16 adjacent the maximum thickness zone of the blade joins the two faces or walls to define with the blade wall a chamber 18 extending from the leading edge to the web 16 and a chamber 19 extending from the web 16 to the trailing edge. These chambers extend

spanwise of the blade through the platform and to the tip of the blade which is partially closed by a tip closure 20.

The stalk 7 is made up of two webs 22 diverging from the root to the platform which define between them an air space 23 having openings at the forward and rear faces of the stalk. The space within the stalk communicates through the open inner end 24 of the blade with the chambers 18 and 19.

The blade root 6 is mounted in a suitably serrated slot in the wheel rim 3. The blade is retained and flow of fluid between the wheel rim and platforms is prevented by two cover plates or rings of cover plates 26 and 27. These cover plates may be unitary or segmented. The details are immaterial to the invention. Such plates are shown in U.S. Pat. No. 3,446,480 referred to above, and in White U.S. Pat. No. 3,034,298, May 15, 1962, for example. Holes 28 in the plate 26 and 30 in the plate 27 provide for entry of cooling air or other medium from a suitable source (not illustrated) into the space between the cover plates and the blade stalk, from which the fluid flows into the blade stalk and thus into the passages 18 and 19. The fluid ultimately exhausts through openings 31 and 32 in the blade tip closure forward and rearward of the web 16, respectively. Also, preferably, the trailing edge of the blade is formed with outlets such as slots 34 for exhaust of cooling air at this point.

The structure as so far described may be considered part of the known state of the art. To indicate generally the scale of the drawings, the specific blade shown has a chord of about two inches.

To provide for air impingement and better flow of the cooling air along the interior of the surface of the blade wall, blade liners 35 and 36 are provided extending spanwise of the blade in chambers 18 and 19, respectively. These liners are open at the platform end of the blade and closed at the tip of the blade, and are made of very thin flexible heat resisting sheet metal, preferably about three to five thousandths inch thick. The liners are preferably spaced about twenty-five thousandths inch from the blade wall, the spacing being accomplished by embossed projections 38 extending outwardly from the liner. The liners have folds as indicated at 39 in the liner 35 and correspondingly in the liner 36. With these folds, the liner may be flattened or collapsed as indicated generally by the broken line 40 so that the flattened liner may be inserted into the air space 23 in the blade stalk and pushed on into the chamber 18 or 19. The liners may be made of such thin flexible material because they are not a structural element of the blade and are contained or supported by the walls of the blade and the internal air pressure. After insertion, the liner may be expanded into contact with the blade wall by forcing a blast of fluid into the liner. Each liner has numerous small perforations distributed over its surface as indicated generally at 41 in FIGS. 2, 4, and 5. Air which flows from the liner through these holes impinges against the inner surface of the blade wall and flows between the blade wall and liner to the outlets at 31, 32, and 34. These perforations may be about seven thousandths inch in diameter.

Considering now the structure of the liner 35 at the leading edge of the blade (FIGS. 4 and 5), the two sides or faces of the liner are recurved to define the side walls 42 of a slot nozzle 43. As shown most clearly in FIG. 5, these side walls are united by spacers 44 which

are strips extending between the two walls 42 and brazed, welded, or otherwise fixed to them. The slot nozzle at its discharge end thus terminates in generally cylindrical outwardly flaring wall sections 46. A row of holes 47 extends through each of these wall sections 46 in position to deliver cooling air into the sheet of air issuing from the slot nozzle 43.

The distance from slot 43 to the interior of the leading edge of the blade may be about fifty thousandths of an inch and the width of the slot preferably at least as great as one-eighth that distance, preferably about seven thousandths. The jet issuing from the slot nozzle has a greater penetrating power than that issuing from a simple hole such as 41 through the sheet metal. However, the distance from the holes 41 to the blade wall is less.

With the flat jet issuing from the nozzle 43, this moving sheet of air tends to draw air from the holes 47 in the flaring part of the slot nozzle, which air mixes with the flow from the slot nozzle and creates a greater mass flow, greater momentum, and greater turbulence at the point of impingement for greater removal of heat from the blade leading edge.

FIG. 6 shows curves of heat transfer coefficient as a function of the ratio of nozzle to plate spacing to nozzle width, the upper curve indicating conditions with the turbulence promoter (additional air through 47). It will be noted that the heat transfer coefficient is significantly higher with the turbulence promoter, particularly as nozzle to plate spacing decreases below eight times the width of the nozzle.

The impingement tubes 35 and 36 may be fixed to the nozzle by welding, diffusion bonding, or a brazing operation at the area of the platform 8. Preferably, the margins of the liner are spread to lie under the platform and are electron beam welded to the platform at that point. Alternatively, the liners may be welded to the interior of the blade at its base. While it is considered less feasible, it should be noted that the spacing of the liner from the blade may be accomplished by protrusions from the inside of the blade rather than from the projections 38 on the liner.

As a matter of fabrication, it is also possible to diffusion bond the liner to the interior of the blade or airfoil and thereafter fix the blade to the base or other mounting structure. In the case of a turbine nozzle, which may be regarded as a special case in which the blades are stationary, the attachment of the blade to the shrouds or other structure defining the flow path through the turbine may follow known practice. In this case, since there is no centrifugal force on the vane, retention of the liner is easier. If the liner is open at both ends, and the vane is supplied with air from both ends, there is not even any gas pressure tending to displace the liner.

The detailed description of the preferred embodiment 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 turbine blading element comprising, in combination, a hollow blade having leading and trailing edges and defining a spanwise-extending chamber, and a perforated blade liner disposed in the chamber, the end of the blade defining an opening for insertion of the liner, the liner conforming generally to

the contour of the interior of the blade and being spaced from the blade wall, the liner including means defining a spanwise-extending slot nozzle for discharge of a cooling fluid directed at the leading edge of the blade and generally cylindrical diverging walls at the outlet of the nozzle, and defining perforations through the said diverging walls for flow of additional cooling fluid for entrainment by the flow through the slot nozzle.

2. An internally cooled turbine blading element comprising, in combination, a hollow blade having leading and trailing edges and a web disposed intermediate the said edges, so that the blade defines two spanwise-extending chambers, one at each side of the web, and a perforated blade liner disposed in each chamber, the end of the blade defining openings for insertion of the liners, each liner conforming generally to the contour of the interior of the blade and being spaced from the blade wall, the liner at the leading edge of the blade including means defining a spanwise-extending slot nozzle for discharge of a cooling fluid directed at the leading edge of the blade and generally cylindrical diverging walls at the outlet of the nozzle, and defining perforations through the said diverging walls for flow of additional cooling fluid for entrainment by the flow through the slot nozzle.

3. An internally cooled fluid-reacting member for a turbomachine comprising, in combination, wall means defining a blade with a central chamber having an opening at one end of the blade, a tubular perforated liner of thin flexible sheet metal disposed in the chamber, and spacer means maintaining a separation between the liner and the wall means over the major portion of the area of the liner, the liner being collapsible for insertion into the chamber through the said opening and being expandable by air pressure after such insertion to the extent allowed by the spacer means, the liner including means at the leading edge of the blade defining a spanwise-extending slot nozzle for a discharge of a cooling fluid directed at the leading edge of the blade and generally cylindrical diverging walls at the outlet of the nozzle, and defining perforations through the said diverging walls for flow of additional cooling fluid for entrainment by the flow through the slot nozzle.

4. An internally cooled turbine blading element comprising, in combination, a root, a stalk, and a hollow blade extending from the stalk, the blade having leading and trailing edges and defining a spanwise-extending chamber, and a perforated blade liner disposed in the chamber, the stalk and the stalk end of the blade defining openings for insertion of the liner, the liner conforming generally to the contour of the interior of the blade and being spaced from the blade wall, the liner including means defining a spanwise-extending slot nozzle for discharge of a cooling fluid directed at the leading edge of the blade and generally cylindrical diverging walls at the outlet of the nozzle, and defining perforations through the said diverging walls for flow of additional cooling fluid for entrainment by the flow through the slot nozzle.

5. An internally cooled turbine blading element comprising, in combination, a root, a stalk, and a hollow blade extending from the stalk, the blade having leading and trailing edges and a web disposed intermediate the said edges, so that the blade defines two spanwise-extending chambers, one at each side of the web, and

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a perforated blade liner disposed in each chamber, the stalk and the stalk end of the blade defining openings for insertion of the liners, each liner conforming generally to the contour of the interior of the blade and being spaced from the blade wall, the liner at the leading edge of the blade including means defining a spanwise-extending slot nozzle for discharge of a cooling fluid di-

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rected at the leading edge of the blade and generally cylindrical diverging walls at the outlet of the nozzle, and defining perforations through the said diverging walls for flow of additional cooling fluid for entrainment by the flow through the slot nozzle.

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