

July 23, 1957

J. B. WHEATLEY ET AL  
COMPRESSOR INLET DE-ICING

2,800,273

Filed April 30, 1952

2 Sheets-Sheet 1

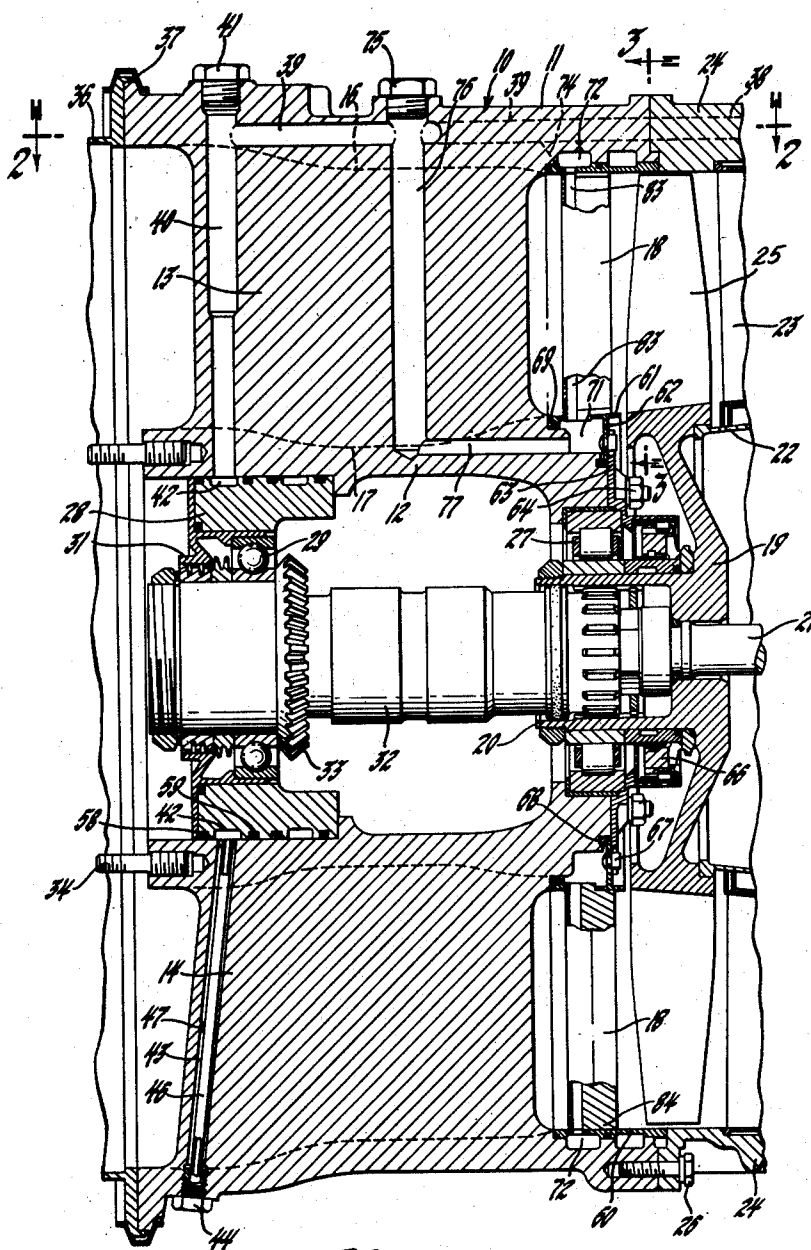


Fig. 1

Inventors  
John B. Wheatley  
Arthur W. Gaudatz &  
Fred W. Short  
By  
Willie H. Baillie  
Attorneys

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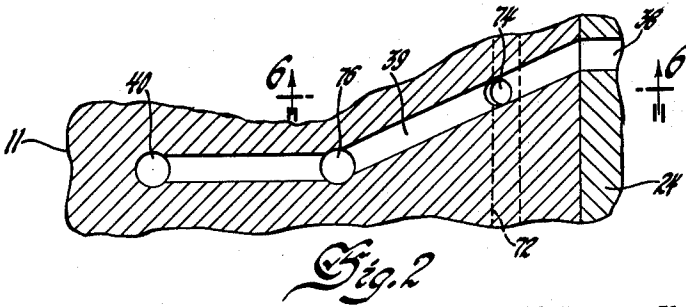


Fig. 2

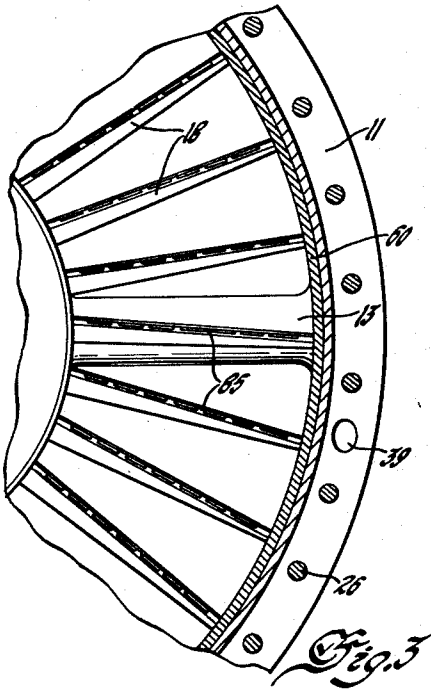


Fig. 3

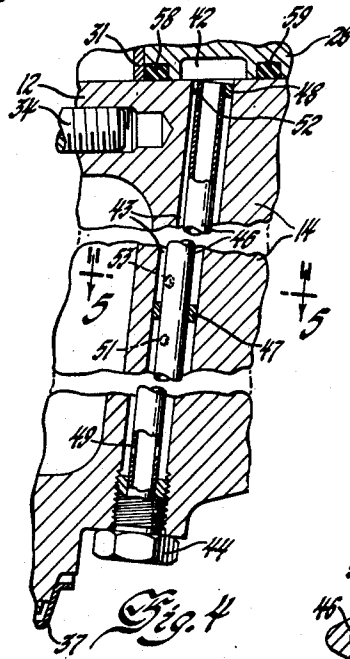


Fig. 4

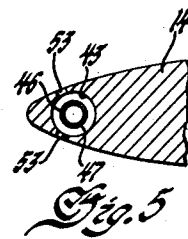


Fig. 5

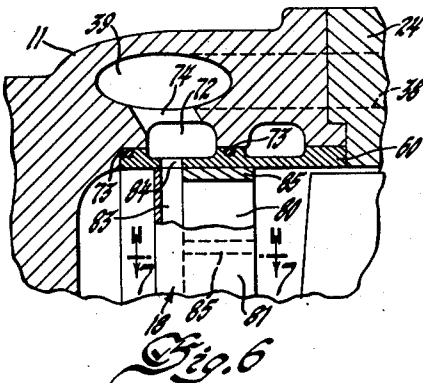


Fig. 6

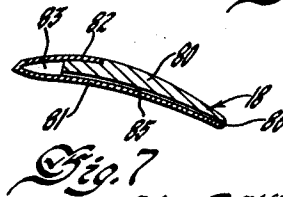


Fig. 7

Inventors  
John B. Wheatley  
Arthur W. Gaubatz &  
Fred H. Short  
By  
Willis Helwig & Baillie  
Attorneys

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## COMPRESSOR INLET DE-ICING

John B. Wheadley, Arthur W. Gaubatz, and Fred R. Short,  
Indianapolis, Ind., assignors to General Motors Corporation,  
Detroit, Mich., a corporation of Delaware

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10 Claims. (Cl. 230—132)

Our invention relates to the heating of atmospheric air intakes so as to prevent deposition of ice therein, and is particularly directed to the elimination of ice formation in the inlets of gas turbine aircraft engines.

Such engines require large quantities of air for their operation, and at times must operate under ambient conditions such that moisture in the air entering the engine may condense in the form of ice or frost, forming deposits which may seriously obstruct or completely block the air inlet, thus disabling the engine. Such icing ordinarily occurs on any structure which offers an obstruction of flow of air or causes the air to change its direction of flow, such as the struts which commonly extend across the air inlet or the inlet guide vanes of an axial flow compressor. The difficulty does not exist in the succeeding stages of the compressor because of the heating of the air by compression.

It is possible to prevent the accumulation of ice on these parts of the compressor by heating them. The provision of adequate arrangements for heating is a problem which has not hitherto been satisfactorily solved.

Our invention is primarily directed to improved arrangements for supplying an adequate amount of heat at the critical locations where icing may occur, so that, when the ambient conditions are such that icing begins to occur or may be expected, heat may be supplied to these parts to eliminate the danger of failure of the engine arising from ice accumulation.

The invention is described herein in relation specifically to its preferred embodiment in an engine of the turboprop type comprising an axial flow compressor. It will be apparent to those skilled in the art from the succeeding description that many of the principles and features of the invention are applicable to other situations where similar problems arise.

The principal object of the invention is to provide means for heating the inlet of a compressor and, more specifically, the struts and guide vanes in the inlet, or either. A further object is to provide a structurally sound and efficient mechanism for heating which will employ the heat to best advantage and which presents no substantial interference with the operation of the engine.

The preferred manner in which these and subsidiary objects of the inventions are accomplished and the advantages thereof will be more fully apparent from the succeeding detailed description and the accompanying drawings, in which Figure 1 is a sectional view of the inlet end of the compressor of a turboprop engine, this section being taken on planes intersecting on the axis of the engine and passing through struts in the inlet; Figure 2 is a fragmentary sectional view taken on the plane indicated in Figure 1; Figure 3 is a partial transverse sectional view taken on the plane indicated in Figure 1; Figure 4 is a broken sectional view of a portion of Figure 1 to a larger scale; Figure 5 is a detail section taken on the plane indicated in Figure 4; Figure 6 is a radial sectional view of a portion of the discharge end of the compressor inlet casing; and Figure 7 is a transverse sec-

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tion of an inlet guide vane taken on the plane indicated in Figure 6.

Referring first to Figure 1, the compressor inlet is defined by a body 10 commonly known as a forward frame, which may be a cast body comprising an outer shell 11, an inner shell 12, and struts 13, 14 extending between the shells. The number of struts may vary; in the particular embodiment described there are eight, only two of which are illustrated. Air enters the left-hand end of the frame and passes between the outer and inner shells through the duct or passage defined by the inner surface 16 of the outer shell and the outer surface 17 of the inner shell. Ordinarily the inlet body is cylindrical but it is not necessarily so.

An annular row of guide vanes 18 mounted at the discharge end of the air inlet imparts swirl to the air entering the compressor. Only the extreme forward portion of the compressor is shown, since the remainder thereof is immaterial to the invention. The particular compressor illustrated is of the multistage axial flow type comprising a forward wheel or disk 19, integral with a stub shaft 20, and a tie-bolt 21 the head of which engages the forward face of the wheel 19. Sealing rings 22 are provided between the successive disks of the rotor. Each of the wheels mounts a circular row of blades 20, and fixed rings of stator blades 23 are disposed between the stages of rotor blades. The stator rings 23 are mounted in a compressor case 24 which is fixed to the compressor inlet case by cap screws 26. The inner shell 12 of the forward frame supports a roller bearing 27 within which the stub shaft 20 rotates. A bearing support ring 28 fitted into the inner shell 12 supports a ball bearing 29 and a seal 31. A shaft 32 splined at its rear end to engage internal splines in the stub shaft 20 is supported in the bearing 29. A gear 33 on this shaft may drive engine auxiliaries through additional gearing (not shown). The forward end of the shaft 32 may be internally splined for coupling to a power output shaft of the engine or for connection to an engine auxiliary mounted on the forward face of the inlet frame. Stud 34 may provide for the mounting of a housing for the power output shaft or for the mounting of engine driven auxiliaries. The air may be supplied to the inlet through a conduit 36 secured to a flange on the forward end of the outer seal by a commercial clamp 37. The arrangement of this duct is, of course, a matter of design of the aircraft and is immaterial to the present invention.

As previously indicated, the parts of the inlet on which ice is most likely to form are the leading edges of the struts 13 and the inlet guide vanes 18. Hot air for heating these parts may be brought to the inlet case through passages 38, preferably two in number, within the wall of the compressor case 24. It may be drawn from an intermediate or late stage of the compressor where the air is heated due to compression and is under sufficient pressure to insure adequate circulation through the parts to be heated. Our invention is not concerned with the source of the heating fluid nor with the arrangements which may be provided for shutting off the heating fluid when it is not needed. The passages 38 are aligned with passages 39 (Figs. 1, 2, 3 and 6) extending forwardly through the outer shell of the inlet case. Approximately the forward half of the passage 39 is aligned with the strut 13 through which is drilled a radial passage 40 adjacent the leading edge of the strut. The outer end of this passage is closed by a plug 41 and its inner end communicates with an annular distributing chamber 42 defined by a groove in the outer surface of the bearing support ring 28. Hot air flowing inwardly through the passage 40 thus warms the leading edges of the struts 13, which are preferably two in number. Hot air is distributed from the chamber 42 through passages in the leading edges of

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the struts 14, which in this particular example are the other six struts. O-rings 58 and 59 seal the chamber 42 against leakage.

Referring to Figures 1, 4, and 5, the struts 14 are each provided with a radial bore 43 adjacent the leading edge extending from the chamber 42 to the exterior of the inlet case, which bore is threaded at its outer end to receive a plug 44 closing the outer end of the bore. The plug 44 is brazed or otherwise fixed to a tube 46 which extends to the inner end of the passage 43. An annular collar 47, which is a sliding fit within the bore 43, is fixed to the tube 46 approximately at the middle of its length. A broken collar or projections 48 are fixed to the tube 46 at its inner end to locate it in the bore, the openings 52 in the collar 48 allowing for passage of hot air. The bore 43 and tube 46 thus define two concentric passages for the heating fluid. Approximately half of the fluid flows through the entire length of the tube 46 to ports 49 at the outer end thereof from which it flows inwardly through the outer concentric duct and is discharged through small openings 51 extending from the passage 43 through the side wall of the strut 14. The remainder of the hot air passes through the openings 52 in the collar 48 and flows through the annular passage outside the tube 46 to openings 53 likewise extending through the wall of the strut. The collar 47 separates the two flows. The sizes of the openings 49, 51, 52, and 53 may be readily varied to obtain the desired rate of flow of the hot air and to balance the flow between the inner and outer ends of the struts. As will be apparent, by causing the air to flow through the passage 43 from both ends toward the middle, a more even distribution of heat is obtained than would result if the air flowed in one direction only through the strut. The provision of the tube 46 also forces the heating air to move close to the surface of the passage 43 and causes more effective heat transfer with the minimum flow of hot air. This is important to the efficiency of the engine, since any withdrawal of air for heating represents a loss of power.

The inlet guide vane assembly comprises a ring of radial guide vanes 18 fixed to an outer shroud ring 60 (Figs. 1, 3, and 6) and an inner shroud ring 61. The outer ring 60 slides into the outer shell 11 and may be retained by the forward face of the compressor casing 24. The inner shroud ring 61 is piloted on the shell 12 of the inlet case and comprises an inwardly directed flange 62 held in place by a ring 63 mounted by studs and nuts 64. The ring 63 also serves to mount an oil seal 66 for the bearing 27. The heads 67 of rivets fixed in the flange 62 fit in radial slots in the ring 63 to hold the vane assembly against rotation. An O-ring seal 68 is fitted between the flange 62 and the rear face of the inner shell 12. A second O-ring seal 69 is disposed in a groove in the forward edge of the inner shroud 61. A hot air manifold 71 is thus defined between the inner shell 12 and the shroud ring 61, sealed by the O-rings 68 and 69. An outer fluid manifold 72 is defined by an annular groove in the inner wall of the outer shell 11 in communication with the outer shroud ring 60. O-rings 73 mounted in the shroud ring 60 seal this manifold. A short drilled passage 74 extends between each hot fluid conduit 39 and the manifold 72. A radial passage 76 (Figs. 1 and 2) in the strut 13, which is closed at the outer end by plug 75, leads hot air from the duct 39 to a passage 77 extending rearwardly through the inner shell 12 to the inner hot air manifold 71. Hot air is thus supplied from the ducts 39 to both the outer and inner ends of the guide vanes 18.

Referring particularly to Figures 6 and 7, the inlet guide vanes, which are of airfoil shape, comprise a body 80 and a sheet metal facing 81 which is brazed to the body at 82, the facing 81 extending forwardly from the body 81 to define a radial air passage 83 within the leading edge of the vane. The vanes are welded or otherwise

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fixed to the shroud rings with the passages 83 aligned with holes 84 in the outer shroud rings. The vanes project through openings in the inner shroud ring 61 and are welded or otherwise fixed thereto. The passages 83 in the vanes are thus in communication with both the outer manifold 72 and the inner manifold 71. The facing 81 extends completely over the high pressure face of the body 80, being spaced therefrom by a number of ribs 85 on the face of the body so as to define passages 85 through which the gas flows rearwardly, from the space 83 at the leading edge, under the facing 81 to an outlet 86 at the trailing edge of the blade. This outlet extends the entire length of the blade except that it is broken at a few points by the ribs 85. Thus, the hot air under pressure entering the conduit 39 flows through passage 74 into the manifold 72 and through passages 76 and 77 into manifold 71. It then flows into both ends of the blade, and from the chamber 83 at the forward edge, flows under the surface 81 of the concave face of the blade. This surface and the leading edge of the blade are the points at which icing is to be expected and thus this entire critical area is adequately heated by the hot air flowing behind the thin sheet metal facing 81. The body 80 provides additional rigidity to the vane, supports the sheet metal, and concentrates the flow at the critical points.

It will be seen from the foregoing that the invention is particularly well adapted to secure effective flow of hot air immediately at the areas which are critical with respect to deposition of ice and to heat these areas with a minimum expenditure of hot air. It will also be apparent that the invention does not compromise the performance of the engine. The heating air is discharged from the guide vanes in a direction concordant with that of the inlet air flowing past the vanes, and the contour of the struts need not be modified to accommodate the provisions for heating.

While the preferred mode of employing the invention has been described in detail in order to explain the principles thereof, it will be apparent to those skilled in the art that numerous modifications may be made within the principles and scope of the invention.

We claim:

1. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet passage to the compressor, an annular row of inlet guide vanes mounted at the downstream end of the body, the guide vanes extending between the said shells and being provided with fluid inlets at the outer ends thereof and a discharge opening for fluid, means defining a fluid manifold in the outer shell communicating with the said fluid inlets, a heating fluid supply passage extending longitudinally of the outer shell connected to the manifold therein, a duct extending through one of the struts from the said passage, a distributing chamber in the inner shell connected with and supplied by the said duct, and heating fluid passages in others of said struts connected with and supplied from the distributing chamber.

2. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet passage to the compressor, an annular row of inlet guide vanes mounted at the downstream end of the body, the guide vanes extending between the said shells and being provided with fluid inlets at the ends thereof and a discharge opening for fluid, means defining fluid manifolds in each shell communicating with the said fluid inlets, a heating fluid supply passage extending longitudinally of the outer shell connected to the manifold therein, a conduit passing through one of the struts to deliver fluid from the passage to the manifold in the inner shell, a duct extending through one of the struts adjacent the leading edge thereof from the said passage, a distributing chamber in the inner shell connected with and supplied by the said

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duct, and heating fluid passage in others of said struts connected with and supplied from the distributing chamber.

3. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet passage to the compressor, means defining an annular distributing chamber for hot fluid in one of said shells, fluid passages extending from said chamber through said struts adjacent the leading edges thereof and closed at the ends of the struts remote from the chamber, a tube extending through each passage open to the distributing chamber and discharging into the remote end of the fluid passage, means blocking the said passages intermediate the ends thereof, and fluid outlets from the passage at each side of the blocking means.

4. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet passage to the compressor, means defining an annular distributing chamber for hot fluid within the said inner shell, fluid passages extending through said struts adjacent the leading edges thereof and closed at the outer ends of the struts, a tube extending through each passage open to the distributing chamber and discharging into the outer end of the fluid passage, means connecting the inner ends of the passages with the distributing chamber, means blocking the said passages intermediate the ends thereof, and fluid outlets from the passage at each side of the blocking means.

5. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet to the compressor, a fluid supply conduit for hot fluid extending through at least one of said struts adjacent the leading edge thereof, means defining an annular distributing chamber within the said inner shell supplied by the said conduit, fluid passages extending through others of said struts adjacent the leading edges thereof, the inner ends of the passages being connected with the distributing chamber, means blocking the said passages intermediate the ends thereof, and fluid outlets from the passages into the inlet.

6. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet to the compressor, a fluid supply conduit for hot fluid extending through at least one of said struts adjacent the leading edge thereof, means defining an annular distributing chamber within the said inner shell supplied by the said conduit, fluid passages extending through others of said struts adjacent the leading edges thereof and closed at the outer ends of the struts, a tube extending through each passage open to the distributing chamber and discharging into the outer end of the fluid passage, means connecting the inner ends of the passages with the distributing chamber, means blocking the said passages intermediate the ends thereof, and fluid outlets from the passage at each side of the blocking means.

7. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet to the compressor, a fluid supply conduit for hot fluid extending through at least one of said struts adjacent the leading edge thereof, a ring mounted in the inner shell, an annular distributing chamber defined by the said inner shell and ring supplied by the said conduit, fluid passages extending through others of said struts adjacent the leading edges thereof and closed at the outer ends of the struts, a tube extending through each passage open to the distributing chamber and discharging into the outer end of the fluid passage, means connecting the inner ends of

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the passages with the distributing chamber, means blocking the said passages intermediate the ends thereof, and fluid outlets from the passage at each side of the blocking means.

8. A compressor inlet comprising, in combination, a body comprising an outer shell, an inner shell, and struts extending between the shells, the shells defining an inlet passage to the compressor, an annular row of inlet guide vanes mounted at the downstream end of the body, the guide vanes extending between the said shells and being provided with fluid inlets at both ends thereof and a discharge opening for fluid intermediate the ends thereof, means defining fluid manifolds in each shell communicating with the said fluid inlets, a heating fluid supply passage extending longitudinally of the outer shell connected to the manifold therein, and a conduit passing through one of the struts to deliver fluid from the passage to the manifold in the inner shell.

9. A compressor inlet comprising, in combination, structure including inner and outer substantially coaxial shells defining an annular inlet duct and an annular row of inlet guide vanes on and extending between the shells in the inlet duct, each guide vane comprising a rigid body, the body being the principal structural element of the vane, and a facing substantially thinner than the body and spaced therefrom along the leading edge of the vane and over the pressure face of the vane, the body and facing defining between them a fluid passage extending the length of the leading edge of the vane and a shallow passage under the pressure face of the vane extending from the first-mentioned passage and discharging from the vane through the space between the body and facing at the trailing edge of the vane, the shallow passage constituting the sole outlet from the first-mentioned passage, and fluid supply means in both said shells communicating with both ends of the vanes and adapted to introduce a fluid into both ends of the first-mentioned passage.

10. A compressor inlet comprising, in combination, structure including inner and outer substantially coaxial shells defining an annular inlet duct and an annular row of inlet guide vanes mounted on and extending between the shells in the inlet duct, each guide vane comprising a rigid body, the body being the principal structural element of the vane, ribs on the body extending chordwise of the vane adjacent the pressure face of the vane, and a facing substantially thinner than the body and spaced therefrom along the leading edge of the vane and over the pressure face of the vane, the facing engaging the said ribs, the body and facing defining between them a fluid passage extending the length of the leading edge of the vane and a shallow passage under the pressure face of the vane extending from the first-mentioned passage and discharging from the vane through the space between the body and facing at the trailing edge of the vane, the shallow passage constituting the sole outlet from the first-mentioned passage, and fluid supply means in both said shells communicating with the vanes and adapted to introduce a fluid into the first-mentioned passage.

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