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(54) **BLADE FOR A GAS TURBINE AND ELECTRIC POWER PRODUCTION PLANT COMPRISING SAID BLADE**

(57) A blade for a gas turbine (5) provided with an airfoil (18) extending along a span wise direction (S) from a base (21) to a tip (22); the airfoil (18) comprising an outer wall (23) defining a leading edge (27), a trailing edge (28), a pressure side (24) and a suction side (25); the airfoil (18) enclosing at least one cooling duct (36; 36a, 36b, 36c) extending along the span wise direction (S) and fed, in use, with a cooling fluid; the tip (22) being

provided with a rim (29) following the tip cross sectional profile at least along the leading edge (27), the suction side (25) and the pressure side (24); the airfoil (18) is provided with a cooling channel (42) connecting the at least one cooling duct (36; 36a) with an opening (44) at the trailing edge (28) and with at least one primary rim cooling hole (45) connected to the cooling channel (42) and arranged on the rim (29).

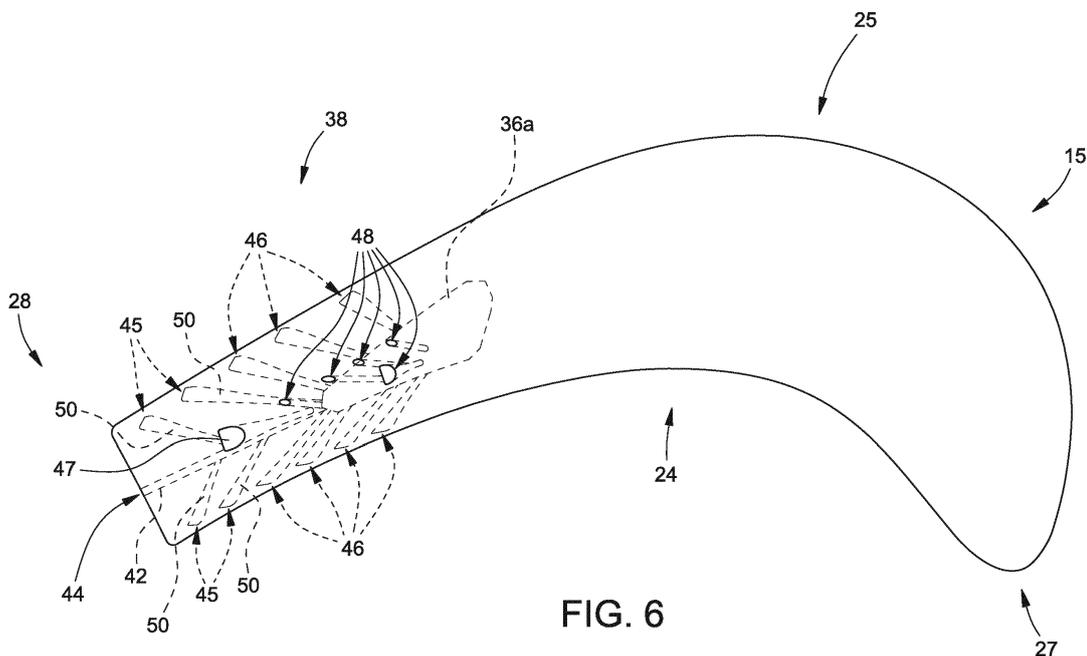


FIG. 6

Description

TECHNICAL FIELD

[0001] The present invention relates to a blade for a gas turbine and to an electric power production plant comprising said blade. In particular, the present invention relates to an improved cooling of the blades of a gas turbine. Preferably the electric power production plant is connected to an electrical grid.

BACKGROUND

[0002] During the operation of the electrical energy production plants, the blades of gas turbines are constantly exposed to a hot gas flow coming from the combustion chamber.

The temperature of the hot gas flowing in the gas turbine affects the performance of the plant. In particular, performances of the plant increase with an increasing temperature of the hot gas flowing inside the turbine. However, the increase of the temperature of the hot gas flowing in the gas turbine is limited by the thermal resistance of the material constituting the blades.

To overcome this kind of limitation, in recent years, a cooling system for the blades has been adopted. Normally cooling air extracted from the compressor or coming from a dedicated cooling air source is driven through the blades. Particularly exposed to the hot gases is the tip region of the blade. A leakage flow of hot gases, in fact, is normally present at the tip of the blades. To reduce said leakage, tip shrouds are often used. However using tip shrouds is not efficient as the shrouds increase the weight of the blade and can also cause aero dynamical losses. Therefore, it is known to use blades wherein the tip is provided with a rim shaped so as to reduce the hot gas leakage. Examples of blades provided with a rim at the tip of the blade are disclosed in documents US 2017/0284207 or US 2005/0232771.

[0003] However, as the leakage reduction is obtained by creating hot gas vortexes at the tip region, heating problems at the tip portion often arises.

SUMMARY

[0004] The object of the present invention is therefore to provide a blade having an optimized tip cooling system, capable of improving the thermal resistance of the blades, allowing a further increase of the temperature of the gases flowing in the gas turbine and reducing the thermodynamic losses thus consequently improving the plant performances.

[0005] According to the present invention, there is provided a blade for a gas turbine comprising an airfoil extending along a span wise direction from a base to a tip; the airfoil comprising an outer wall defining a leading edge, a trailing edge, a pressure side and a suction side; the airfoil enclosing at least one cooling duct extending

along the span wise direction and fed, in use, with a cooling fluid; the tip being provided with a rim following the tip cross sectional profile at least along the leading edge, the suction side and the pressure side;

5 the airfoil being provided with a cooling channel connecting the at least one cooling duct with an opening at the trailing edge and with at least one primary rim cooling hole connected to the cooling channel and arranged on the rim.

10 **[0006]** Thanks to the presence of at least on primary rim cooling hole the cooling of the rim is improved. As the efficiency of the cooling of the rim is increased, a lower cooling fluid flow rate can be drawn for cooling the blades. This lead to a significant increase in the efficiency of the plant as the cooling fluid is normally drawn from the compressor of the plant. Moreover also the leakage of the hot gas working fluid at the tip of the blade is reduced, improving the efficiency of the plant.

15 **[0007]** According to a preferred embodiment of the present invention, the cooling channel extends transversally with respect to the span wise direction. In particular, the angle between the axis of the cooling channel 42 and the span wise direction facing the tip is comprised between 20° and 90°.

20 **[0008]** In this way the cooling channel could perform an efficient cooling action in a portion of the blade which is not normally cooled and, at the same time, is positioned so as to allow a proper connection with the primary rim cooling holes.

25 **[0009]** According to a preferred embodiment of the present invention, wherein the at least one primary rim cooling hole is arranged along the pressure side. In this way a proper cooling of the rim on the pressure side is obtained. According to a preferred embodiment of the present invention, wherein the at least one primary rim cooling hole is arranged along the suction side. In this way a proper cooling of the rim on the suction side is obtained. According to a preferred embodiment of the present invention, the rim defines a tip cavity having a bottom; the bottom being provided with at least one primary bottom cooling hole connected to the cooling channel. In this way a proper cooling of the bottom of tip cavity formed by the rim is obtained.

30 **[0010]** According to a preferred embodiment of the present invention, the rim extends along the tip cross sectional profile leaving an aperture at the trailing edge. In this way the leakage flow of hot gas working fluid entered in the tip cavity could flow out through the aperture. According to a preferred embodiment of the present invention, the blade comprises at least one secondary rim cooling hole connected to the cooling duct and arranged on the rim. Preferably the at least one secondary rim cooling hole is arranged along the pressure side and/or along the suction side. In this way the cooling of the rim is improved.

35 **[0011]** According to a preferred embodiment of the present invention, the blade comprises at least one secondary bottom cooling hole connected to the cooling duct

and arranged on the bottom of the tip cavity. In this way the cooling of the tip is improved.

[0012] According to a preferred embodiment of the present invention, the cooling channel has an elliptical cross section. In this way the space occupied by the channel is minimum and, at the same time, the drilling phase for obtaining said channel is simple and less expensive. According to a preferred embodiment of the present invention, at least one primary cooling hole is connected to the cooling channel by a connecting channel having an inlet portion connected to the cooling channel and an outlet portion connected to the primary cooling hole; the outlet portion having a cross section diverging towards the primary cooling hole. Preferably, the inlet portion has a constant cross section. In this way the cooling fluid exiting the primary cooling holes has the proper fluid-dynamic properties so as to create vortexes able to reduce the leakage of the hot gas working fluid into the tip cavity.

[0013] It is furthermore another object of the present invention to provide a plant for electric power production having an improved power efficiency.

[0014] According to said object the present invention relates to a plant for electric power production comprising at least one gas turbine, which extends along a longitudinal axis and comprises at least one row of blades circumferentially spaced and extending radially outwardly from a respective supporting disc of the gas turbine; at least one of the blades of the row being of the type claimed in anyone of the claims 1-14.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The present invention will now be described with reference to the accompanying drawings, which illustrate some non-limitative embodiment, in which:

- Figure 1 is a schematic representation, with parts removed for clarity and parts in section, of an electric power production plant comprising a blade according to the present invention;
- Figure 2 is a schematic perspective view, with parts removed for clarity, of a blade according to the present invention;
- Figure 3 is a schematic front perspective view, with parts removed for clarity, of a first detail of the blade of figure 2;
- Figure 4 is a schematic rear perspective view, with parts removed for clarity, of the first detail of the blade of figure 2;
- Figure 5 is a section view along the plane V-V of the blade of figure 2;
- Figure 6 is a schematic view, with parts in section and parts removed for clarity, of a second detail of the blade of figure 2;
- Figure 7 is a schematic view, with parts in section and parts removed for clarity, of a third detail of the

blade of figure 2;

- Figure 8 is a schematic view, with parts in section and parts removed for clarity, of a fourth detail of the blade of figure 2.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0016] In figure 1, reference numeral 1 indicates a gas turbine plant for electrical energy production comprising a compressor 3, a combustor 4, a gas turbine 5 and a generator 7, which transforms the mechanical power supplied by turbine 5 into electrical power to be supplied to an electrical grid 8, connected to the generator 7 via a switch 9.

[0017] A variant not shown provides for plant 1 to be of the combined cycle type and including, in addition to the gas turbine 5 and generator 7, also a steam turbine.

[0018] The gas turbine 5 extends along a longitudinal axis A and is provided with a shaft 10 (also extending along axis A) to which compressor 3 and generator 7 are also connected.

[0019] Gas turbine 5 comprises an expansion channel 12 wherein the hot gas working fluid coming from the combustor 4 flows in a direction D.

[0020] The expansion channel 12 has a section, which radially increases along the axis A in the direction D.

[0021] In the expansion channel 12 a plurality of stages 13 spaced along the longitudinal axis A is arranged. Each stage 13 comprises a row of fixed blades and a row of rotating blades (not illustrated in figure 1). Each row comprises circumferentially spaced blades extending radially outwardly from a respective supporting disc.

[0022] In figure 2 a blade 15 of a stage 13 of the gas turbine 5 is represented.

[0023] Preferably, blade 15 is a rotating blade.

[0024] The blade 15 comprises a root 17, an airfoil 18 and a platform 20.

[0025] The root 17 is configured to be coupled to a supporting disc (not illustrated in the accompanying figures) of the gas turbine 5. In particular, the disc has a plurality of axial seats, which are circumferentially spaced and engaged by respective roots 17 of the rotating blades 15.

[0026] The airfoil 18 extends along a span wise direction S from the root 17 and is provided with a base 21 coupled to the root 17 and a tip 22 which is opposite to the base 21 along the span wise direction S.

[0027] In use, when the blade 15 is coupled to the supporting disc, the span wise direction S is substantially radially arranged with respect to the axis A of the gas turbine 5.

[0028] The airfoil 18 is completely housed in the expansion channel 12 and defines the aerodynamic profile of the rotating blade 15.

[0029] The airfoil 18 comprises an outer wall 23, which defines externally a concave pressure side 24, a convex suction side 25, a leading edge 27 and a trailing edge 28.

[0030] In use, the pressure side 24 and the suction side 25 extend axially between the leading edge 27 and the trailing edge 28 and radially between the base 21 and the tip 22.

[0031] In use, the leading edge 27 is arranged upstream of the trailing edge 28 along the direction D of the hot working fluid in the expansion channel 12.

[0032] The platform 20 is arranged between the root 17 and the airfoil 18.

[0033] With reference to figures 2, 3 and 4, blade 15 comprises also a rim 29 at the tip 22.

[0034] In particular, the rim 29 follows the tip cross sectional profile at least along the leading edge 27, the suction side 25 and the pressure side 24 and, preferably, leaves an aperture 30 at the trailing edge 28. With the expression "cross sectional profile" is intended the profile of the airfoil 18 obtained by crossing the airfoil 18 at the tip 22 with a plane perpendicular to the span wise direction S.

[0035] The rim 29 protrudes from the tip 22.

[0036] In this way, the rim 29 defines a tip cavity 31 having a bottom 32. The bottom 32 is the tip surface.

[0037] Preferably, the rim 29 protrudes from the tip 22 in span wise direction S at the leading edge 27, while the rim 29 extends outwardly from the tip 22 at least in a region of the suction side 25 proximal to the trailing edge 28 and at least in a region of the pressure side 24 proximal to the trailing edge 28.

[0038] In this way the rim 29 defines a tip 22 having a substantially Y-shape at the trailing edge 28 (figure 3).

[0039] Preferably, the rim 29 is made integral with the tip 22.

[0040] With reference to figure 2, blade 15 is provided with a cooling system 35.

[0041] The cooling system 35 comprises a plurality of feeding channels (not shown) made in the root 17, at least one cooling duct 36 (visible in figures 3 and 6), made in the airfoil 18 and fed with the cooling fluid coming from the feeding channels in the root 17, and a rim cooling arrangement 38 (figure 6).

[0042] The feeding channels are supplied with a cooling fluid coming from a cooling fluid source 39. Preferably, the cooling fluid source 39 is a portion of the compressor 3. In figure 1 a suction line 40 dedicated to the suction of cooling air from the compressor 3 and connected to the gas turbine 5 is shown.

[0043] With reference to figure 5, the cooling arrangement 29 comprises preferably a plurality of cooling ducts 36 in the airfoil 18, which are enclosed by the outer wall 23.

[0044] In particular, the cooling arrangement 29 comprises at least one cooling duct 36a arranged at the trailing edge 28, one cooling duct 36b arranged at the leading edge 27 and at least one cooling duct 36c arranged between the cooling duct 36a and the cooling duct 36b.

[0045] In the non-limiting example here disclosed and illustrated, the cooling arrangement 29 comprises six cooling ducts 36: one cooling duct 36a arranged at the

trailing edge 28, two cooling ducts 36b arranged at the leading edge 27 and three cooling ducts 36c arranged between the cooling duct 36a and the cooling ducts 36b.

[0046] With reference to figure 5 and 6, the rim cooling arrangement 38 comprises also a cooling channel 42 connecting at least one cooling duct 36 with an opening 44 at the trailing edge 28, at least one primary rim cooling hole 45 connected to the cooling channel 42 and arranged on the rim 29 and, preferably, at least one secondary rim cooling hole 46 and at least one primary bottom cooling hole 47.

[0047] Preferably, the cooling channel 42 is connected to at least the cooling duct 36a arranged at the trailing edge 28.

[0048] The cooling channel 42 extends transversally with respect to the span wise direction S.

[0049] Preferably, the angle α formed between the axis \bigcirc of the cooling channel 42 and the span wise direction S and facing the tip 22 is comprised between 20° and 90° (see figure 7).

[0050] Preferably, cooling channel 42 has an elliptical cross section.

[0051] According to a variant not shown, the cross section of the cooling channel 42 can be rectangular or circular.

[0052] With reference to figures 3 and 4, the rim cooling arrangement 38 comprises a plurality of primary rim cooling holes 45.

[0053] Preferably, the primary rim cooling holes 45 are arranged on the rim 29 along the pressure side 24 and/or along the suction side 25.

[0054] In particular, the primary rim cooling holes 45 are arranged on the rim 29 along the pressure side 24 and/or along the suction side 25 in the proximity of the trailing edge 28.

[0055] With reference to figure 3, the primary rim cooling holes 45 arranged on the pressure side 24 are positioned at a distance DP_{PS} from the outer surface 43 of the rim 29. Distance DP_{PS} is measured from the outer surface 43 of the rim 29 to the center of the primary rim cooling holes 45 along THE span wise direction S.

[0056] Preferably the distance DP_{PS} is comprised between 1%-4% of the span wise height H of the airfoil 18 (see figure 2).

[0057] In the non-limiting example here disclosed and illustrated the distance DP_{PS} is 2,5% of the span wise height H of the airfoil 18. With reference to figure 4, the primary rim cooling holes 45 arranged on the suction side 25 are positioned at a distance DP_{SS} from the outer surface 43 of the rim 29. Distance DP_{SS} is measured from the outer surface 43 of the rim 29 to the center of the primary rim cooling holes 45 along the span wise direction S.

[0058] Preferably the distance DP_{SS} is comprised between 1%-4% of the span wise height H of the airfoil 18 (see figure 2).

[0059] In the non-limiting example here disclosed and illustrated the distance DP_{SS} is 2,5% of the span wise

height H of the airfoil 18.

[0060] The secondary rim cooling hole 46 is arranged on the rim 29 and is connected to the cooling duct 36a.

[0061] Preferably, the rim cooling arrangement 38 comprises a plurality of secondary rim cooling holes 46 arranged on the rim 29 along the pressure side 24 and/or along the suction side 25.

[0062] Preferably, the secondary rim cooling holes 46 on the rim 29 along the pressure side 24 are aligned with the primary rim cooling holes 45 arranged on the pressure side 24.

[0063] Preferably, the secondary rim cooling holes 46 on the rim 29 along the suction side 25 are aligned with the primary rim cooling holes 45 arranged on the suction side 25.

[0064] In the non limiting example here disclosed and illustrated, the rim cooling arrangement 38 comprises also a plurality of tertiary rim cooling holes 49 connected to at least one of the cooling ducts 36 and arranged on the rim 29 along the pressure side 24 and/or along the suction side 25.

[0065] Preferably, the tertiary rim cooling holes 49 are connected to the cooling ducts 36b and 36c.

[0066] Preferably, the tertiary rim cooling holes 49 are aligned with the secondary rim cooling holes 46 and the primary rim cooling holes 45 arranged on the pressure side 24 or on the suction side 25.

[0067] Preferably, the secondary rim cooling holes 46 on the rim 29 along the suction side 25 are aligned with the primary rim cooling holes 45 arranged on the suction side 25.

[0068] The primary bottom cooling hole 47 is arranged on the bottom 32 of the tip cavity 31 and connected to the cooling channel 42. Preferably the primary bottom cooling hole 47 is arranged on the bottom 32 of the tip cavity 31 in the proximity of the trailing edge 28.

[0069] Preferably, the rim cooling arrangement 38 comprises also at least one secondary bottom cooling hole 48, arranged on the bottom 32 of the tip cavity 31 and connected to the cooling duct 36a.

[0070] In the non-limitative example here disclosed and illustrated, the rim cooling arrangement 38 comprises a plurality of secondary bottom cooling holes 48.

[0071] With reference to figures 6 and 8, the primary cooling holes 45 are connected to the cooling channel 42 by a connecting channel 50. The connecting channel 50 extends along an axis B and has an inlet portion 51 connected to the cooling channel 42 and an outlet portion 52 connected to the primary cooling hole 45; the outlet portion 52 has a cross section diverging towards the primary cooling hole 45, while the inlet portion 51 has a constant cross section.

[0072] The inlet portion 51 has an axial length L_c , while the connecting channel 50 has an axial length L .

[0073] Preferably, the ratio L_c/L is comprised between 0,1 and 0,3.

[0074] Preferably, the outlet portion 52 has diverging sides 53 which forms an angle β with a direction parallel

to axis B.

[0075] Preferably, the angle β is comprised between 5° and 10° .

[0076] In use, the cooling fluid coming from the cooling fluid source 39 is fed to the cooling ducts 36. The cooling fluid in cooling duct 36a, in particular, is discharged through the primary rim cooling holes 45 connected to the cooling channel 4, the secondary rim cooling holes 46, the primary bottom cooling holes 47 and the secondary bottom cooling holes 48.

[0077] In this way, an optimal cooling of the rim 29 is obtained. Moreover, the cooling fluid exiting through the primary rim cooling holes 45 and the secondary rim cooling holes 46 creates vortexes able to block the leakage of the hot gas working fluid into the tip cavity 31.

[0078] Finally, it is clear that modifications and variants can be made to the blade and the gas turbine described herein without departing from the scope of the present invention, as defined in the appended claims.

Claims

1. Blade for a gas turbine (5) comprising:

an airfoil (18) extending along a span wise direction (S) from a base (21) to a tip (22); the airfoil (18) comprising an outer wall (23) defining a leading edge (27), a trailing edge (28), a pressure side (24) and a suction side (25); the airfoil (18) enclosing at least one cooling duct (36; 36a, 36b, 36c) extending along the span wise direction (S) and fed, in use, with a cooling fluid; the tip (22) being provided with a rim (29) following the tip cross sectional profile at least along the leading edge (27), the suction side (25) and the pressure side (24); the airfoil (18) being provided with a cooling channel (42) connecting the at least one cooling duct (36; 36a) with an opening (44) at the trailing edge (28) and with at least one primary rim cooling hole (45) connected to the cooling channel (42) and arranged on the rim (29).

2. Blade according to claim 1, wherein the cooling channel (42) extends transversally with respect to the span wise direction (S).

3. Blade according to the claim 2, wherein in the angle between the axis of the cooling channel 42 and the span wise direction (S) facing the tip (22) is comprised between 20° and 90° .

4. Blade according to anyone of the foregoing claims, wherein the at least one primary rim cooling hole (42) is arranged along the pressure side (24).

5. Blade according to anyone of the foregoing claims,

wherein the at least one primary rim cooling hole (45) is arranged along the suction side (25).

6. Blade according to anyone of the foregoing claims, wherein the rim (29) defines a tip cavity (31) having a bottom (32); the bottom (32) being provided with at least one primary bottom cooling hole (47) connected to the cooling channel (42). 5
7. Blade according to anyone of the foregoing claims, wherein the rim (29) extends along the tip cross sectional profile leaving an aperture (30) at the trailing edge (27). 10
8. Blade according to anyone of the foregoing claims, comprising at least one secondary rim cooling hole (46) connected to the cooling duct (42) and arranged on the rim (29). 15
9. Blade according to anyone of the foregoing claims, wherein the at least one secondary rim cooling hole (46) is arranged along the pressure side (24). 20
10. Blade according to anyone of the foregoing claims, wherein the at least one secondary rim cooling hole (46) is arranged along the suction side (25). 25
11. Blade according to anyone of the claims from 6 to 10, comprising at least one secondary bottom cooling hole (48) connected to the cooling duct (36; 36a) and arranged on the bottom (32) of the tip cavity (32). 30
12. Blade according to anyone of the foregoing claims, wherein the cooling channel (42) has an elliptical cross section. 35
13. Blade according to anyone of the foregoing claims, wherein the at least one primary cooling hole (45) is connected to the cooling channel (42) by a connecting channel (50) having an inlet portion (51) connected to the cooling channel (42) and an outlet portion (52) connected to the primary cooling hole (45); the outlet portion (52) having a cross section diverging towards the primary cooling hole (45). 40
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14. Blade according to claim 13, wherein the inlet portion (51) has a constant cross section.
15. Plant for electric power production comprising at least one gas turbine (5), which extends along a longitudinal axis (A) and comprises at least one row of blades (15) circumferentially spaced and extending radially outwardly from a respective supporting disc of the gas turbine (5); at least one of the blades (15) of the row being of the type claimed in anyone of the foregoing claims. 50
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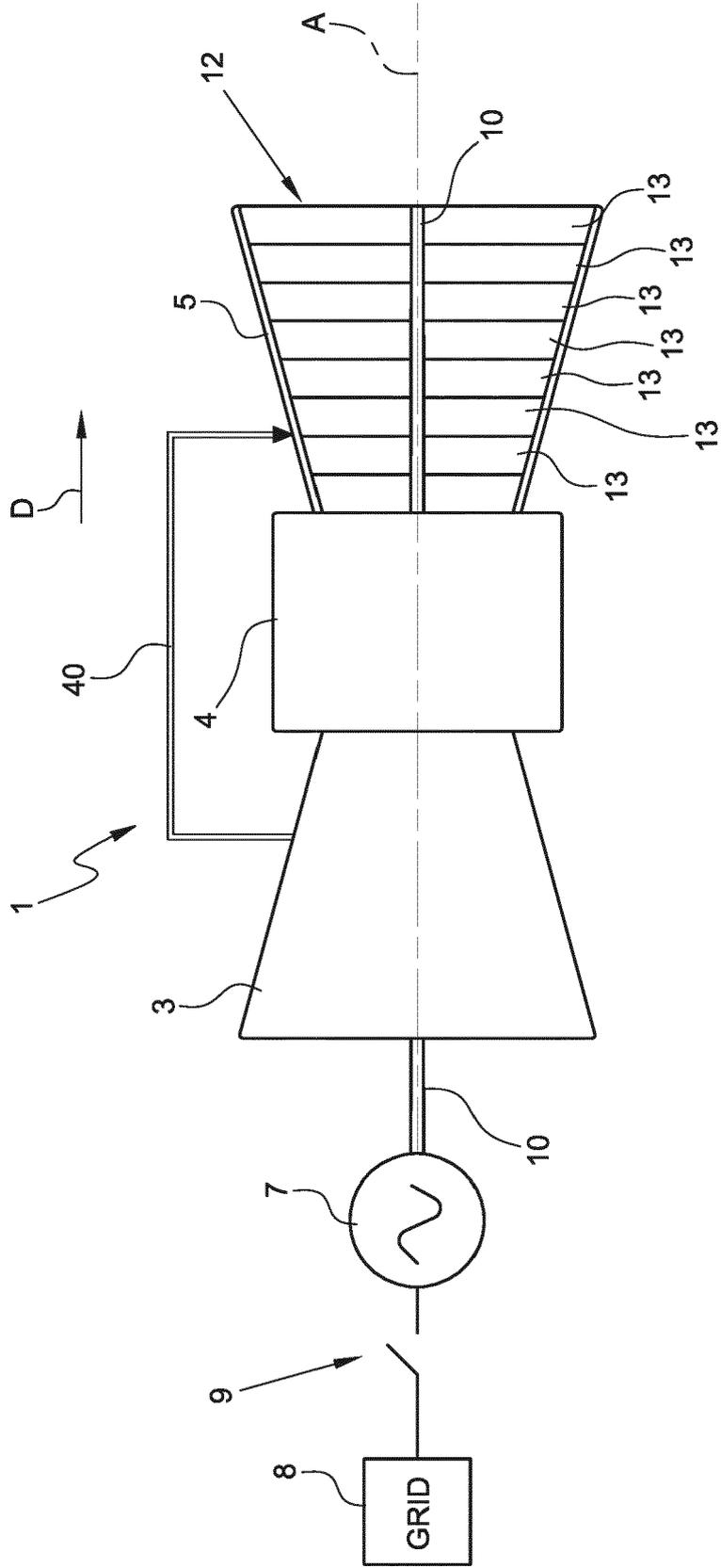


FIG. 1

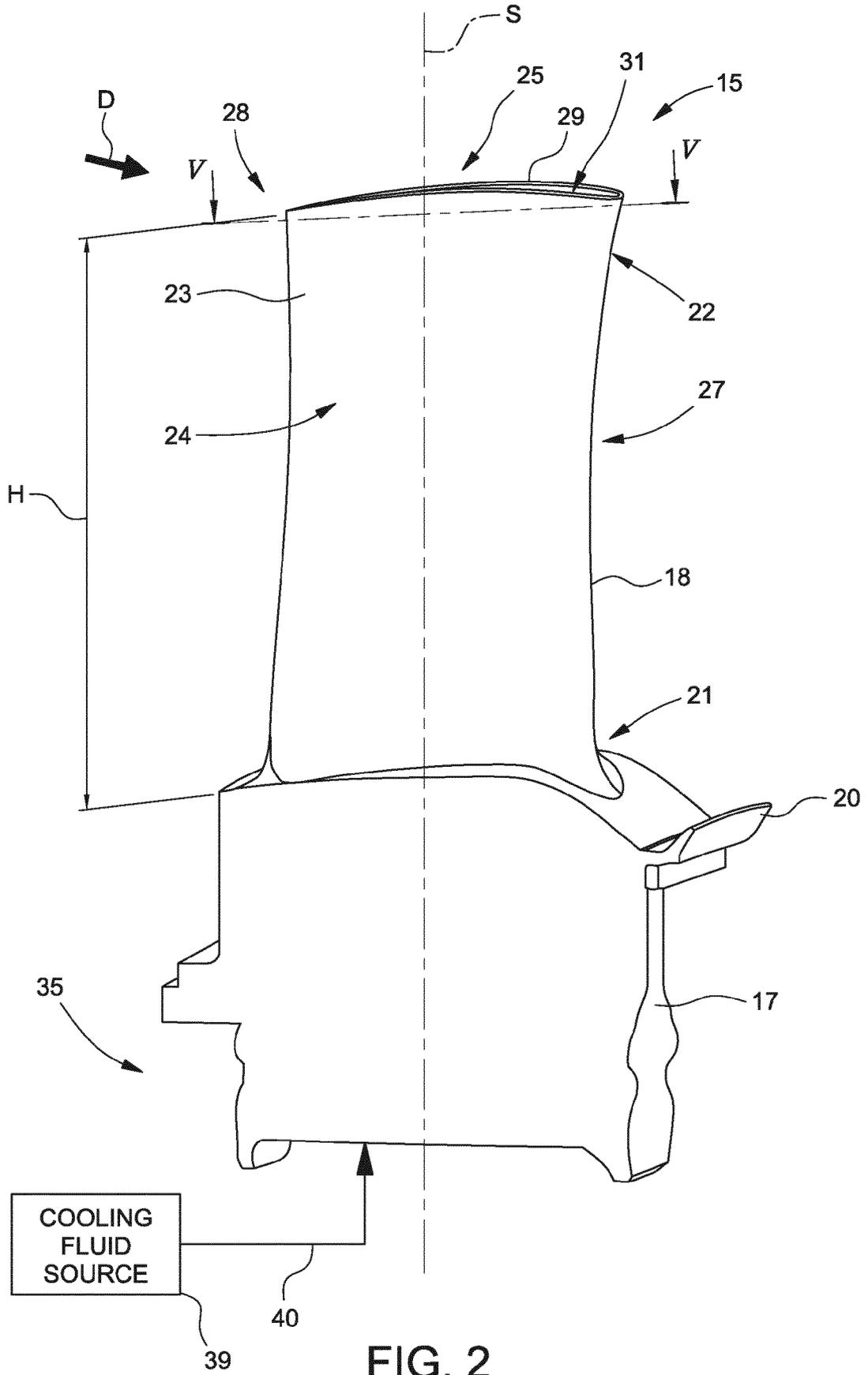


FIG. 2

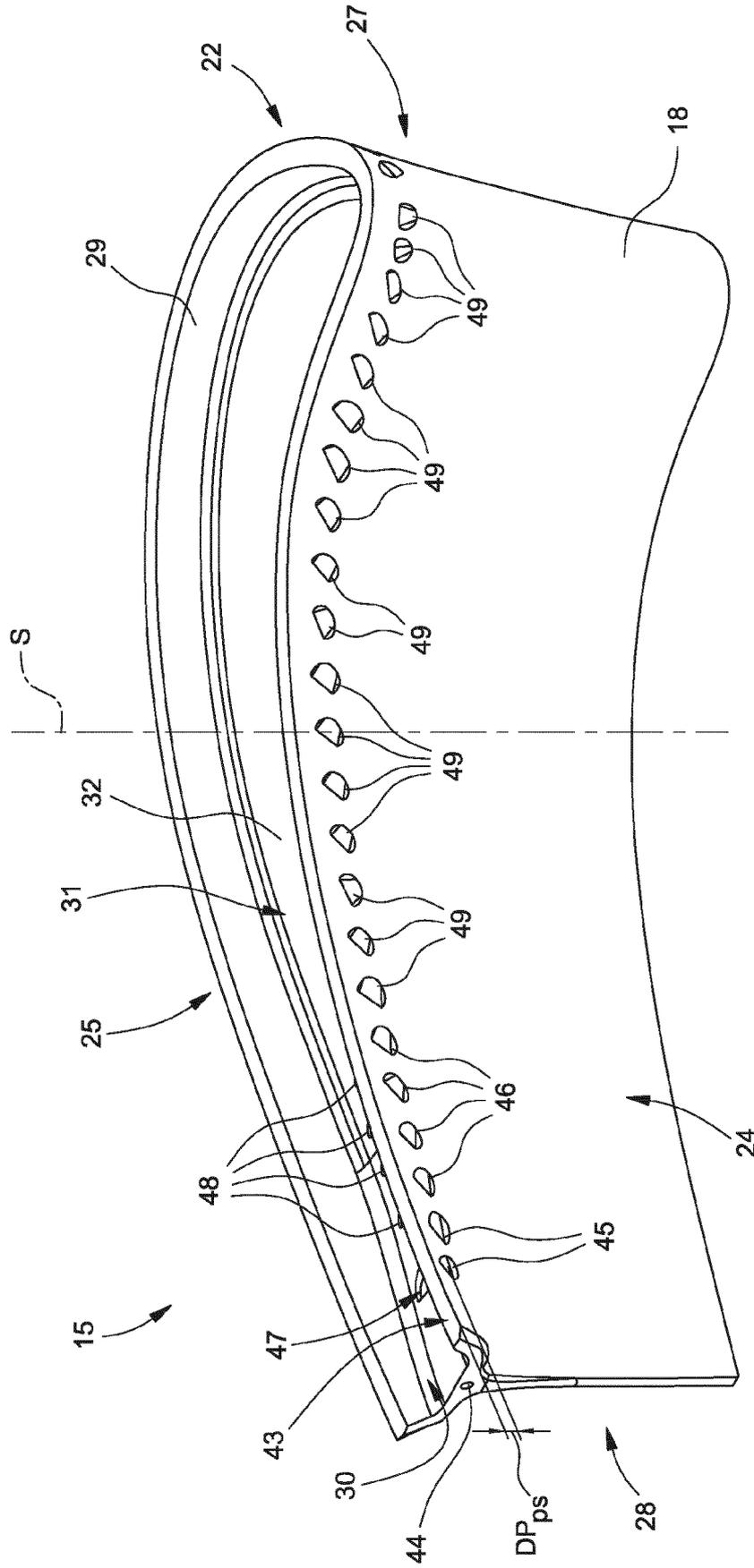


FIG. 3

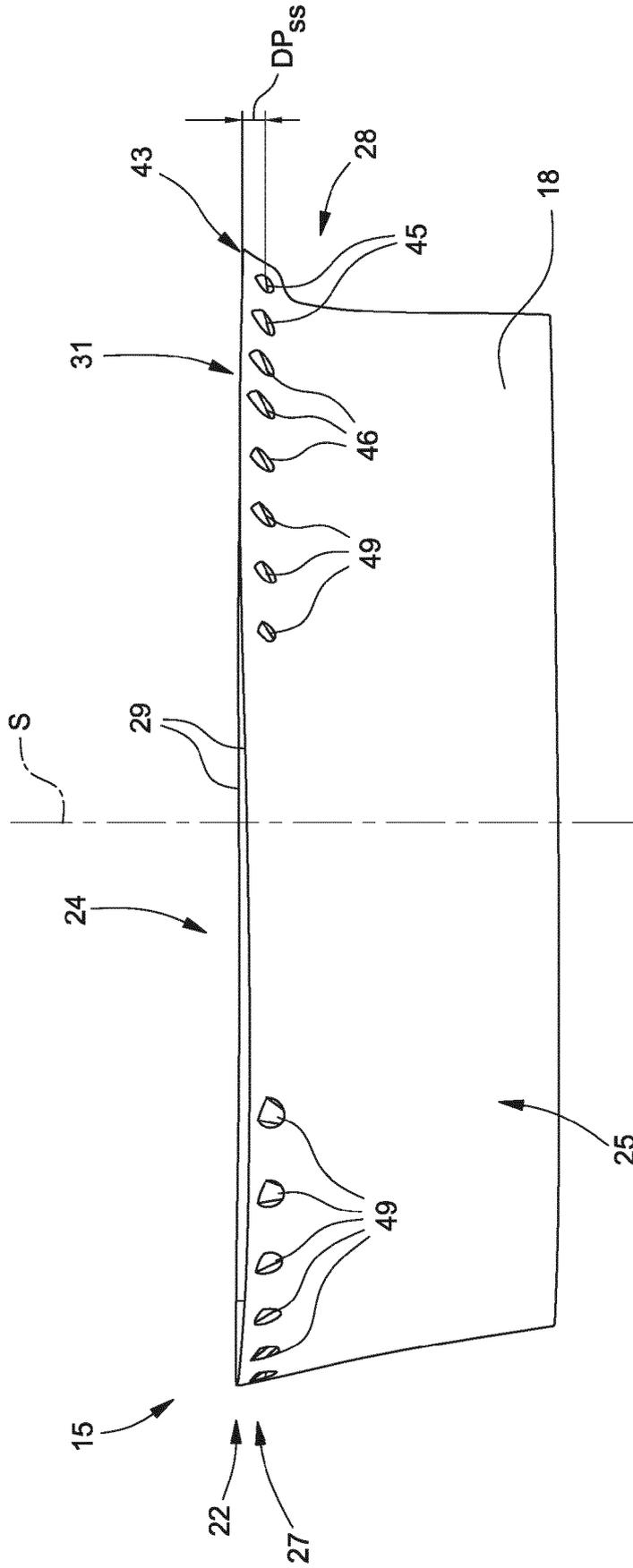


FIG. 4

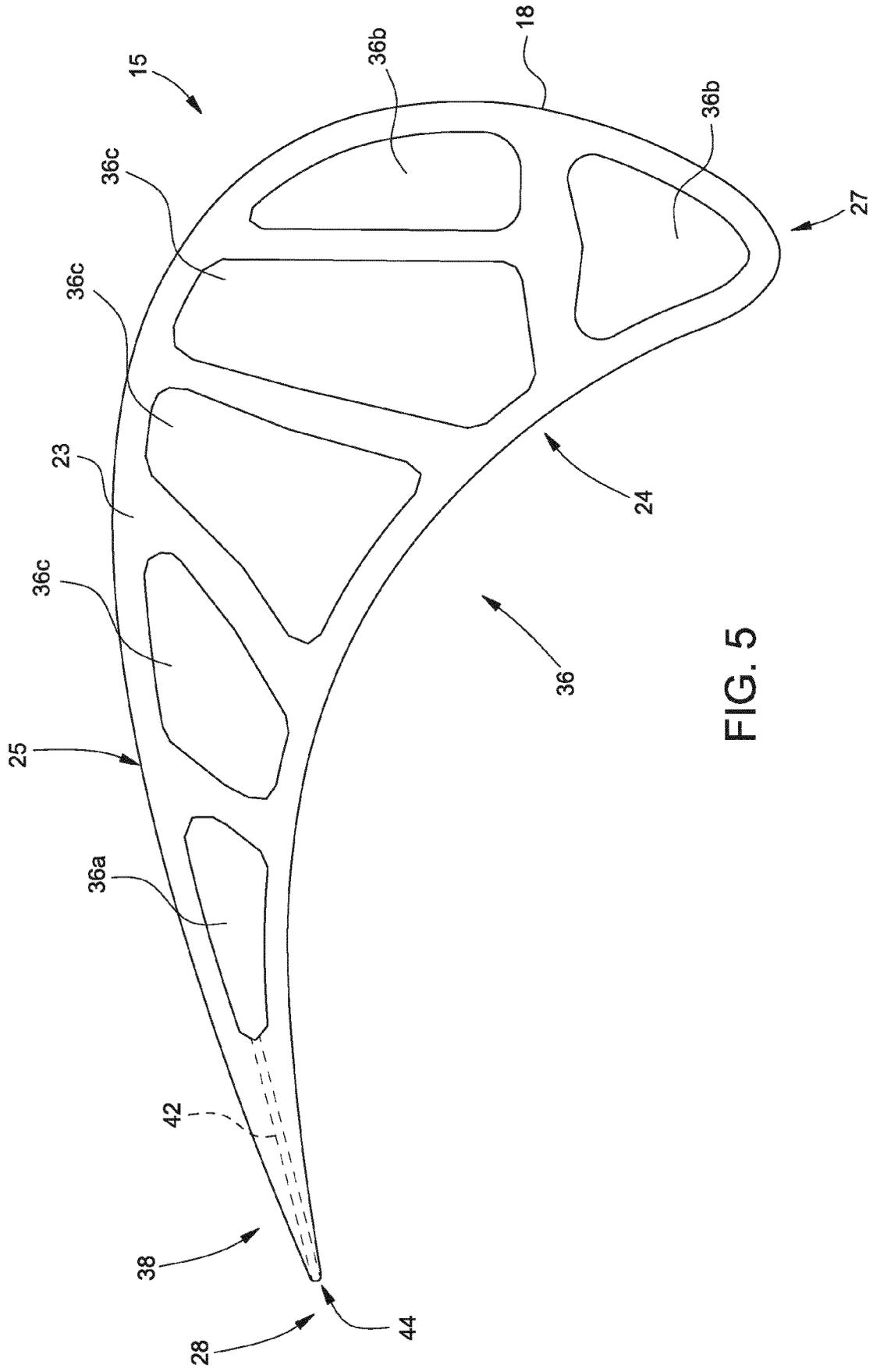


FIG. 5

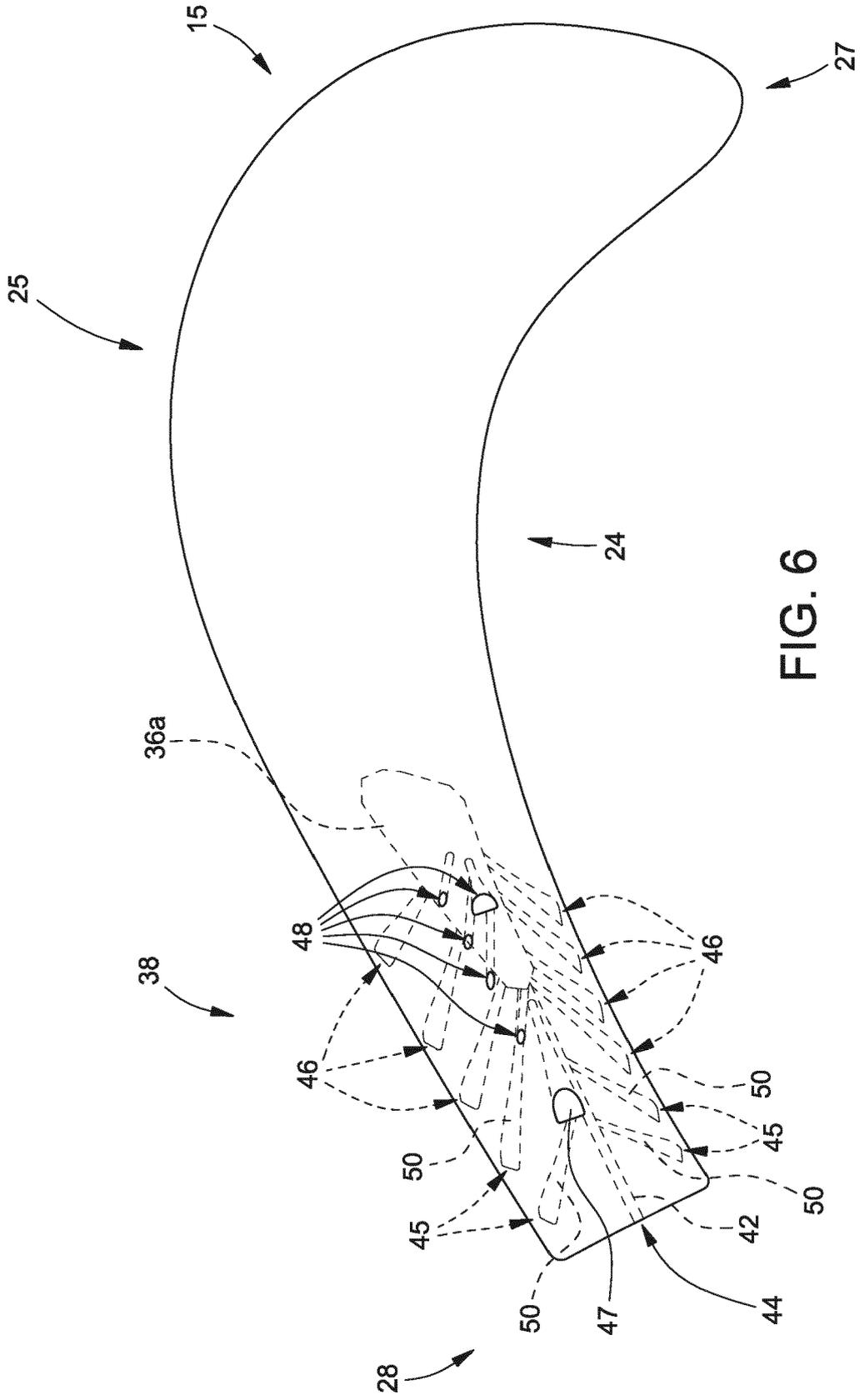


FIG. 6

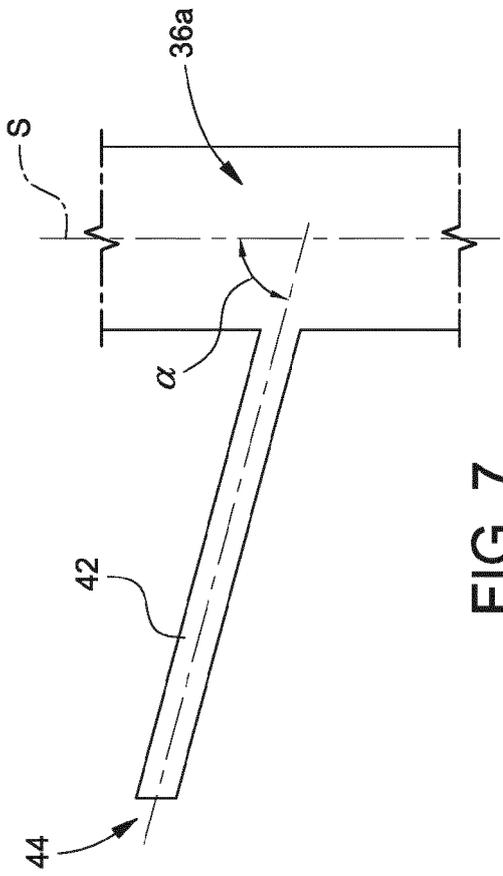


FIG. 7

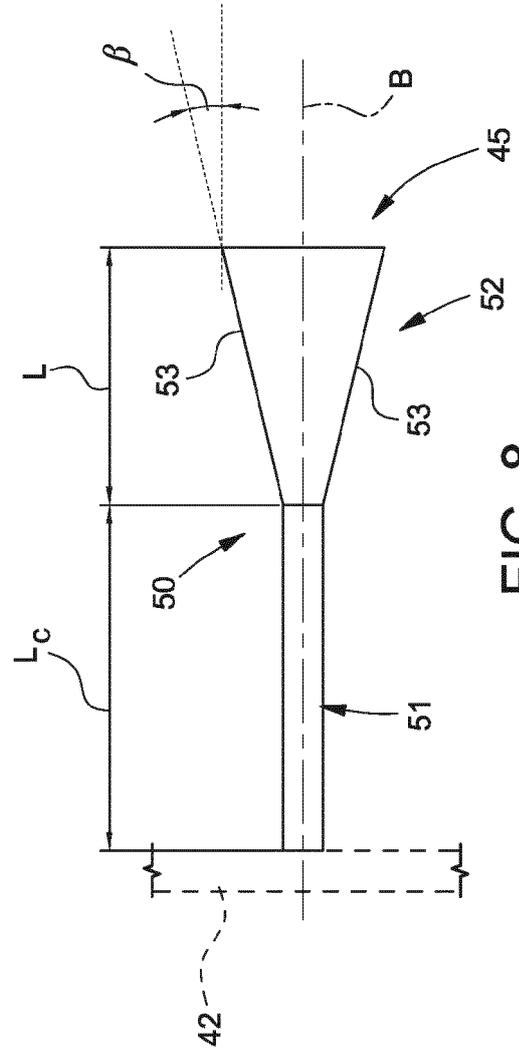


FIG. 8



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Application Number
EP 19 21 2001

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