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(54) **Nozzle segment for turbine system**

(57) A nozzle (24) for a turbine system (10) is disclosed. The nozzle (24) includes an airfoil (40), an inner sidewall (42), and an outer sidewall (44). The airfoil (40) includes exterior surface defining a pressure side (52) and a suction side (54) extending between a leading edge (56) and a trailing edge (58). The airfoil further defines a tip (62) and a root. The inner sidewall (44) is connected to the airfoil (40) at the tip (62). The outer sidewall (44) is connected to the airfoil (40) at the root. The inner sidewall (42) and outer sidewall (44) each includes a peripheral edge (70,80) defining a pressure side slash face (72,82), a suction side slash face (74,84), a leading edge face (76,86), and a trailing edge face (78,88). At least one of the inner sidewall pressure side slash face (72), the inner sidewall suction side slash face (74), the outer sidewall pressure side slash face (82), or the outer sidewall suction side slash face (84) has a generally curvilinear profile.

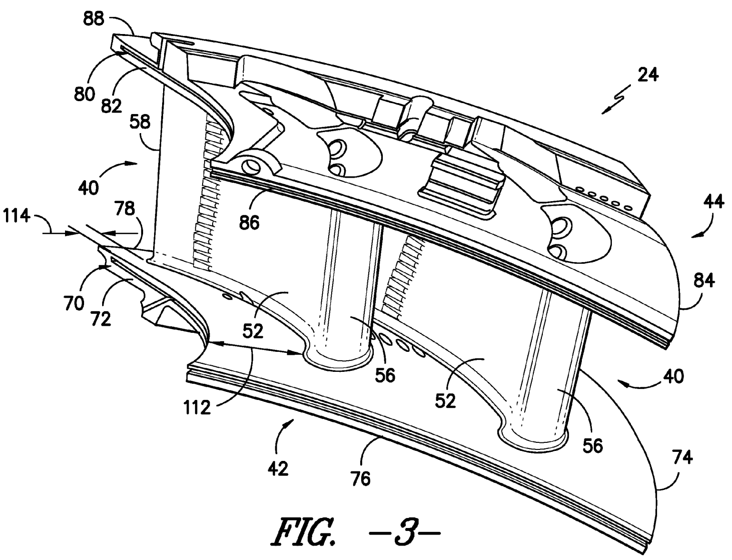

FIG. —3—

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Description

FIELD OF THE INVENTION

[0001] The present disclosure relates in general to turbine systems, such as gas turbine systems, and more particularly to nozzles in turbine systems.

BACKGROUND OF THE INVENTION

[0002] Turbine systems are widely utilized in fields such as power generation. For example, a conventional gas turbine system includes a compressor, a combustor, and a turbine. During operation of the gas turbine system, various components in the system are subjected to high temperature flows, which can cause the components to fail. Since higher temperature flows generally result in increased performance, efficiency, and power output of the gas turbine system, the components that are subjected to high temperature flows should be cooled to allow the gas turbine system to operate at increased temperatures, increased efficiency, and/or reduced emissions.

[0003] As discussed, during operation of a turbine system, the various components thereof are subjected to high temperatures and otherwise subjected to high stress environments. In many cases, this can lead to cracking of various components. One component that is of particular concern is the nozzle. A typically turbine section nozzle includes an airfoil portion extending between inner and outer sidewall. The peripheral edges, and in particular the pressure side and suction side slash faces, of the sidewalls have linear profiles. For example, some edges have singular linear profiles that extend throughout the entire edge. Other profiles are "dogleg" profiles, which include two linear portions that meet to define an angle therebetween. In dogleg profiles in particular, the intersection between the linear portions creates a high stress concentration region. Relief radii have been introduced at the intersections, but only slightly reduce the stress concentration level. Singular linear profiles eliminated the high stress concentrations at the intersection. However, the construction of a slash face with a singular linear profile requires that the slash face be in close proximity to the leading edge and/or trailing edge of the airfoil, thus creating additional high stress concentration regions.

[0004] Accordingly, an improved nozzle for use in a turbine system is desired in the art. In particular, a nozzle design that reduces or eliminates stress concentrations in the sidewalls thereof would be advantageous.

BRIEF DESCRIPTION OF THE INVENTION

[0005] Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0006] In one aspect of the invention, a nozzle for a turbine system is provided. The nozzle includes an airfoil, an inner sidewall, and an outer sidewall. The airfoil includes exterior surface defining a pressure side and a suction side extending between a leading edge and a trailing edge. The airfoil further defines a tip and a root. The inner sidewall is connected to the airfoil at the tip. The inner sidewall includes a peripheral edge defining a pressure side slash face, a suction side slash face, a leading edge face, and a trailing edge face. The outer sidewall is connected to the airfoil at the root. The outer sidewall includes a peripheral edge defining a pressure side slash face, a suction side slash face, a leading edge face, and a trailing edge face. At least one of the inner sidewall pressure side slash face, the inner sidewall suction side slash face, the outer sidewall pressure side slash face, or the outer sidewall suction side slash face has a generally curvilinear profile.

[0007] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

FIG. 1 is a schematic view of a gas turbine system according to one embodiment of the present disclosure;

FIG. 2 is a cross-sectional view of a turbine section of a gas turbine system according to one embodiment of the present disclosure;

FIG. 3 is perspective embodiment of a nozzle according to one embodiment of the present disclosure;

FIG. 4 is a profile view of a nozzle according to one embodiment of the present disclosure;

FIG. 5 is a schematic view of a curve utilized to define a curvilinear profile of a nozzle peripheral edge according to one embodiment of the present disclosure; and

FIG. 6 is a schematic view of a curve utilized to define a curvilinear profile of a nozzle peripheral edge according to another embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0010] FIG. 1 is a schematic diagram of a gas turbine system 10. It should be understood that the turbine system 10 of the present disclosure need not be a gas turbine system 10, but rather may be any suitable turbine system 10, such as a steam turbine system or other suitable system. The gas turbine system 10 may include a compressor section 12, a combustor section 14, and a turbine section 16. The compressor section 12 and turbine section 16 may be coupled by a shaft 18. The shaft 18 may be a single shaft or a plurality of shaft segments coupled together to form shaft 18.

[0011] As is generally known in the art, air or another suitable working fluid is flowed through and compressed in the compressor section 12. The compressed working fluid is then supplied to the combustor section 14, wherein it is combined with fuel and combusted, creating hot gases of combustion. After the hot gases of combustion are flowed through the combustor section 14, they may be flowed into and through the turbine section 18.

[0012] FIG. 2 illustrates one embodiment of portions of a turbine section 18 according to the present disclosure. A hot gas path 20 may be defined within the turbine section 18. Various hot gas path components, such as shrouds 22, nozzles 24, and buckets 26, may be at least partially disposed in the hot gas path 20.

[0013] For example, as shown, the turbine section 18 may include a plurality of buckets 26 and a plurality of nozzles 24. Each of the plurality of buckets 26 and nozzles 24 may be at least partially disposed in the hot gas path 20. Further, the plurality of buckets 26 and the plurality of nozzles 24 may be disposed in one or more annular arrays, each of which may define a portion of the hot gas path 20.

[0014] The turbine section 16 may include a plurality of turbine stages. Each stage may include a plurality of buckets 26 disposed in an annular array and a plurality of nozzles 24 disposed in an annular array. For example, in one embodiment, the turbine section 16 may have three stages, as shown in FIG. 2. For example, a first stage of the turbine section 16 may include a first stage nozzle assembly 31 and a first stage bucket assembly 32. The nozzles assembly 31 may include a plurality of nozzles 24 disposed and fixed circumferentially about the shaft 18. The bucket assembly 32 may include a plurality of buckets 26 disposed circumferentially about the shaft 18 and coupled to the shaft 18. A second stage of the turbine section 16 may include a second stage nozzle assembly 33 and a second stage buckets assembly 34. The nozzles 24 included in the nozzle assembly 33 may be disposed and fixed circumferentially about the shaft 18. The buckets 26 included in the bucket assembly 34 may be disposed circumferentially about the shaft 18 and coupled to the shaft 18. The second stage nozzle assembly 33 is thus positioned between the first stage bucket assembly 32 and second stage bucket assembly 34 along the hot gas path 20. A third stage of the turbine section 16 may include a third stage nozzle assembly 35 and a third stage bucket assembly 36. The nozzles 24 included in the nozzle assembly 35 may be disposed and fixed circumferentially about the shaft 18. The buckets 26 included in the bucket assembly 36 may be disposed circumferentially about the shaft 18 and coupled to the shaft 18. The third stage nozzle assembly 35 is thus positioned between the second stage bucket assembly 34 and third stage bucket assembly 36 along the hot gas path 20.

[0015] It should be understood that the turbine section 16 is not limited to three stages, but rather that any number of stages are within the scope and spirit of the present disclosure.

[0016] It should be understood that hot gas path components according to the present disclosure are not limited to components in turbine sections 16. Rather, hot gas path components may be components at least partially disposed in flow paths for compressor sections 12 or any other suitable sections of a system 10.

[0017] FIGS. 3 and 4 illustrate embodiments of a nozzle 24 for a system 10. In exemplary embodiments, the nozzle 24 is utilized in the turbine section 18 of the system 10, and is thus included in a nozzle assembly. Further, the nozzle 24 is in exemplary embodiments a first stage nozzle 24, thus utilized in a first stage nozzle assembly 31. In other embodiments, however, the nozzle 24 could be a second stage nozzle 24 utilized in a second stage nozzle assembly 33, a third stage nozzle 24 utilized in a third stage nozzle assembly 35, or any other suitable nozzle utilized in any suitable stage or other assembly, in a turbine section 18, compressor section 12, or otherwise.

[0018] As shown, a nozzle 24 according to the present disclosure includes one or more airfoils 40, an inner sidewall 42, and an outer sidewall 44. The airfoil 40 extends between the inner and outer sidewalls 42, 44 and is connected thereto. The airfoil 40 includes exterior surfaces defining a pressure side 52, a suction side 54, a leading edge 56, and a trailing edge 58. As is generally know, the pressure side 52 and the suction side 54 each generally extend between the leading edge 56 and the trailing edge 58. The airfoil 40 further defines and extends between a tip 62 and a root 64. The inner sidewall 42 is connected to the airfoil 40 at the tip 62, while the outer sidewall 44 is connected at the root 64.

[0019] As discussed, the sidewalls 42, 44 are connected to the airfoil 40. In some embodiments, the nozzle 24 is formed as a single, unitary component, such as through casting, and the sidewalls 42, 44 and airfoil 40 are thus connected. In other embodiments, the airfoil 40 and sidewalls 42, 44 are formed separately. In these embodiments, the airfoil 40 and sidewalls 42, 44 may be welded, mechanically fastened, or otherwise connected together.

[0020] As discussed, each nozzle 24 includes one or more airfoils 40. Each airfoil 40 extends between and is connected to the sidewalls 42, 44. One, two (as shown), three, four or more airfoils 40 may thus be included in a nozzle 24. Further, as discussed, the nozzle 24 may be included in an annular array of nozzles 24 as a nozzle assembly.

[0021] The inner sidewall 42 includes a peripheral edge 70. The peripheral edge 70 defines the periphery of the inner sidewall 42. In exemplary embodiments, a peripheral edge 70 may thus include and define various faces which correspond to the various surfaces of the airfoil(s) 40. For example, as shown, a peripheral edge 70 may define a pressure side slash face 72, a suction side slash face 74, a leading edge face 76, and a trailing edge face 78.

[0022] Similarly, the outer sidewall 44 includes a peripheral edge 80. The peripheral edge 80 defines the periphery of the outer sidewall 44. In exemplary embodiments, a peripheral edge 80 may thus include and define various faces which correspond to the various surfaces of the airfoil(s) 40. For example, as shown, a peripheral edge 80 may define a pressure side slash face 82, a suction side slash face 84, a leading edge face 86, and a trailing edge face 88.

[0023] As discussed above, nozzle 24 peripheral edges with reduced or eliminated stress concentration regions are desired. As such, in exemplary embodiments, one or more of the inner sidewall 42 pressure side slash face 72, the inner sidewall 42 suction side slash face 74, the outer sidewall 44 pressure side slash face 82, or the outer sidewall 44 suction side slash face 84 has a generally curvilinear profile. Having a curvilinear profile means that, in a profile view such as that shown in FIG. 4, the subject slash face 72, 74, 82 and/or 84 is curved throughout generally the entire length thereof. A profile view, as shown in FIG. 4, is a top or bottom view of the nozzle 24.

[0024] The use of a curvilinear profile for a slashface 72, 74, 82, 84 is particularly advantageous. For example, intersections between linear portions are eliminated, thus eliminating high stress concentration regions that are caused by such intersections. Further, by curving the profile, the subject slashface 72, 74, 82, 84 is spaced from the leading edge 56 and/or trailing edge 58 of the nozzle airfoil 40 by an increased distance (discussed below) relative to a singular linear profile. This thus reduces the associated high stress concentration regions at these locations. Additionally, curving of the profiles as described herein provides a variety of other advantages. For example, such curving provides a relatively more optimum aerodynamic shape to the inner sidewall 42 and/or outer sidewall 44. Thus, the nozzles 24 in general have improved aerodynamics. Further, the relative positioning of the various adjacent slashfaces of adjacent nozzles is relatively more optimum, as discussed below.

[0025] As discussed, any one or more slash faces 72, 74, 82, 84 of a nozzle 24 may have curvilinear profiles. In exemplary embodiments, all of the slash faces 72, 74, 82, 84 have curvilinear profiles. Further, in exemplary embodiments, each nozzle 24 in a nozzle assembly has mating slash face 72, 74, 82, 84 profiles, which may be curvilinear. Thus, for example, the inner sidewall 42 pressure side slash face 72 may mate with the inner sidewall 42 suction side slash face 74 of an adjacent nozzle 24, the inner sidewall 42 suction side slash face 74 may mate with the inner sidewall 42 pressure side slash face 72 of an adjacent nozzle 24, the outer sidewall 44 pressure side slash face 82 may mate with the outer sidewall 44 suction side slash face 84 of an adjacent nozzle 24, and the outer sidewall 44 suction side slash face 84 may mate with the outer sidewall 44 pressure side slash face 82 of an adjacent nozzle 24. Such mating, and the use of seals (not shown) therebetween, may facilitate sealing of the nozzle assembly, thus preventing hot gas or cooling flow leakage therethrough.

[0026] FIGS. 5 and 6 illustrate schematic views of a curve 100 utilized to define a curvilinear profile of a nozzle 24 peripheral edge 70, 80, such as a slash face 72, 74, 82, 84 thereof, according to various embodiments of the present disclosure. In some embodiments, as shown in FIG. 5 the curve 100 is created using a single centerpoint 102 and a single radius 104 extending from the centerpoint. The curvilinear profile of a slash face 72, 74, 82, 84 may thus be defined by this single centerpoint 102 and a single radius 104. In other embodiments, the curve 100 is created using multiple centerpoints 102 and multiple radii 104 extending therefrom, with a radius 104 extending from each centerpoint 102. The curvilinear profile of a slash face 72, 74, 82, 84 may thus be defined by these multiple centerpoints 102 and a radii 104. For example, in exemplary embodiments, the curve is a spline, and the curvilinear profile is thus a spline profile. Any suitable number of centerpoints 102 and radii may be utilized according to the present disclosure, such as one, two, three, four, five, ten, 20, 50, 100, etc. Further, in some embodiments, the curve and curvilinear profile may be designed using any suitable software, such as a suitable computer aided design program. In exemplary embodiments, a suitable computational fluid dynamics program may be utilized.

[0027] In some embodiments, the curve 100 and curvilinear profile of one or more slash faces 72, 74, 82, 84 may be further defined by a minimum distance 112 between the slash face 72, 74, 76, 78 and the leading edge 56 of the airfoil 40 and/or a minimum distance 114 between the slash face 72, 74, 76, 78 and the trailing edge 58 of the airfoil 40. By maintaining a suitable minimum distance 112 and/or 114, stress concentrations at these locations may be reduced and or eliminated. Required minimum distances 112, 114 to reduce stress concentrations below a required level may be determined for a particular nozzle 24 based on the individual characteristics of that nozzle 24, and the curves 100 and curvilinear profiles, and thus the sidewalls 42, 44, may be designed such the distances 112 and/or 114 are equal to or greater than the required minimum distances. The required minimum distances may be predetermined for a nozzle 24 or determined during design of the nozzle 24, such as through design iterations when designing the curves 100 for the slash face 72, 74, 82, 84 curvilinear profiles. The curves 100 and curvilinear profiles may thus be designed such that the minimum distances 112, 114 are equal to or greater than the required minimum distances.

[0028] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A nozzle (24) for a turbine system (10), the nozzle (24) comprising:

an airfoil (40) comprising exterior surface defining a pressure side (52) and a suction side (54) extending between a leading edge (56) and a trailing edge (58), the airfoil (40) further defining a tip (62) and a root;
an inner sidewall (42) connected to the airfoil (40) at the tip (62) , the inner sidewall (42) comprising a peripheral edge (70) defining a pressure side slash face (72), a suction side slash face (74), a leading edge face (76), and a trailing edge face (78); and
an outer sidewall (44) connected to the airfoil (40) at the root, the outer sidewall (44) comprising a peripheral edge (80) defining a pressure side slash face (82), a suction side slash face (84), a leading edge face (86), and a trailing edge face (88),
wherein at least one of the inner sidewall pressure side slash face (72), the inner sidewall suction side slash face (74), the outer sidewall pressure side slash face (82), or the outer sidewall suction side slash face (84) has a generally curvilinear profile.

2. The nozzle of claim 1, wherein the inner sidewall pressure side slash face (72) and the outer sidewall pressure side slash face (82) each has a generally curvilinear profile.

3. The nozzle of claim 1 or 2, wherein the inner sidewall suction side slash face (74) and the outer sidewall suction side slash face (74) each has a generally curvilinear profile.

4. The nozzle of any of claims 1 to 3, wherein the inner sidewall pressure side slash face (72), the outer sidewall pressure side slash face (82), the inner sidewall suction side slash face (74) and the outer sidewall suction side slash face (84) each has a generally curvilinear profile.

5. The nozzle of any of claims 1 to 4, wherein the curvilinear profile is defined by a single centerpoint (102) and a single radius (104) extending from the centerpoint (102).

6. The nozzle of any of claims 1 to 4, wherein the curvilinear profile is defined by a plurality of centerpoints (102) and a plurality of radii (104), each of the plurality of radii (104) extending from one of the plurality of centerpoints (102).

7. The nozzle of claim 6, wherein the curvilinear profile is further defined by a minimum distance (112,114) between the one of the inner sidewall pressure side slash face (72), the inner sidewall suction side slash face (74), the outer sidewall pressure side slash face (82), or the outer sidewall suction side slash face (84) and the leading edge (56) and trailing edge (58) of the airfoil (40).

8. The nozzle of any preceding claim, wherein the airfoil is a plurality of airfoils (40).

9. A nozzle assembly (31) for a turbine system (10), the nozzle assembly comprising:

a plurality of nozzles (24) disposed in an annular array and defining a hot gas path (20), each of the plurality of nozzles (24) as recited in any of claims 1 to 8.

10. The nozzle assembly of claim 9, wherein the nozzle (24) is a first stage nozzle.

11. A gas turbine system, comprising:

a compressor section (12);

a combustor section (14); and
a turbine section (16), the turbine section (16) comprising a plurality of turbine stages, each of the plurality of turbine stages comprising a nozzle assembly (31,33,35) as recited in claim 9 or 10.

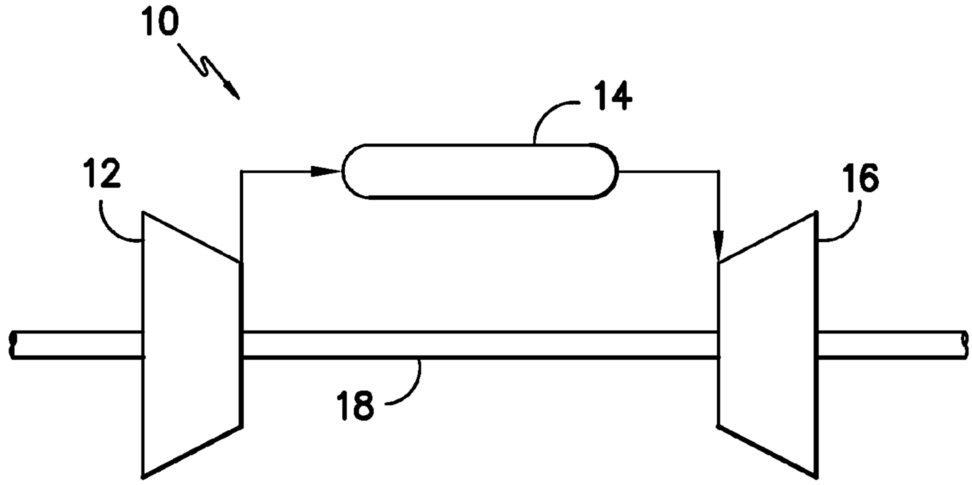

FIG. –1–

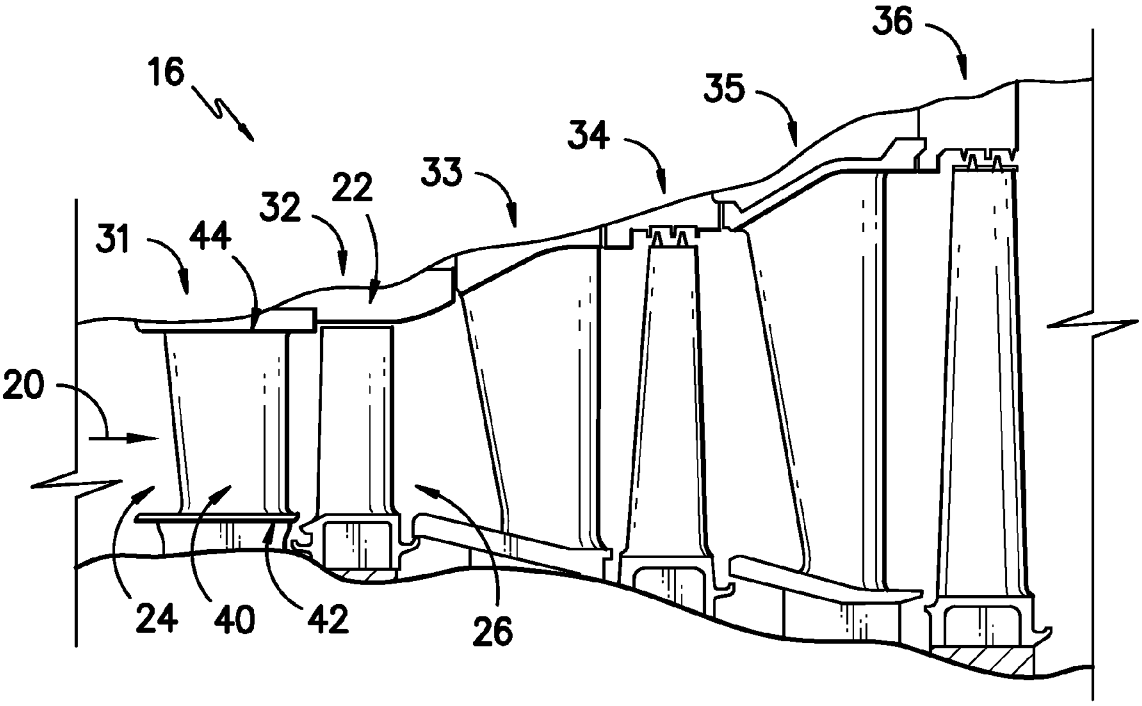

FIG. –2–

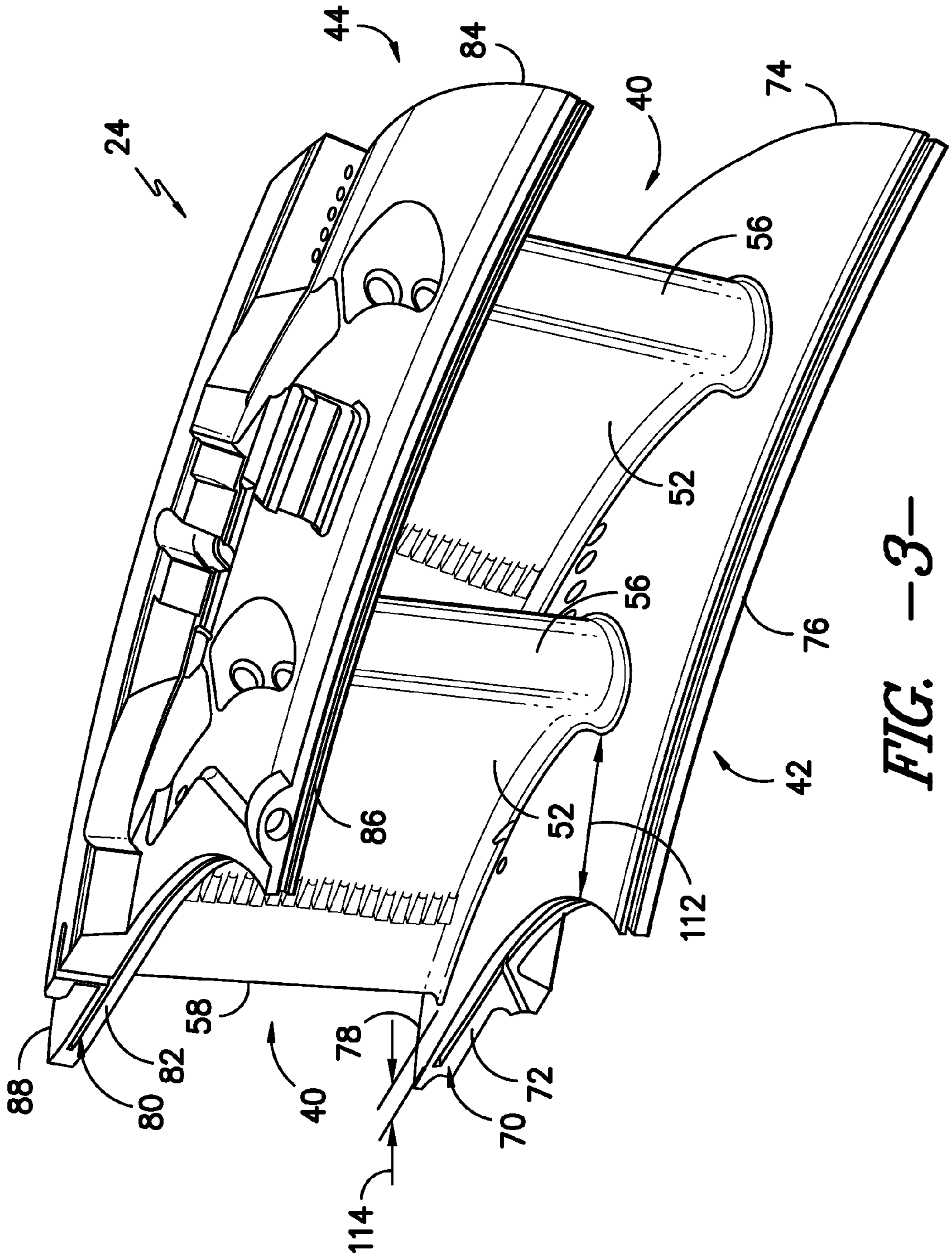

FIG. -3-

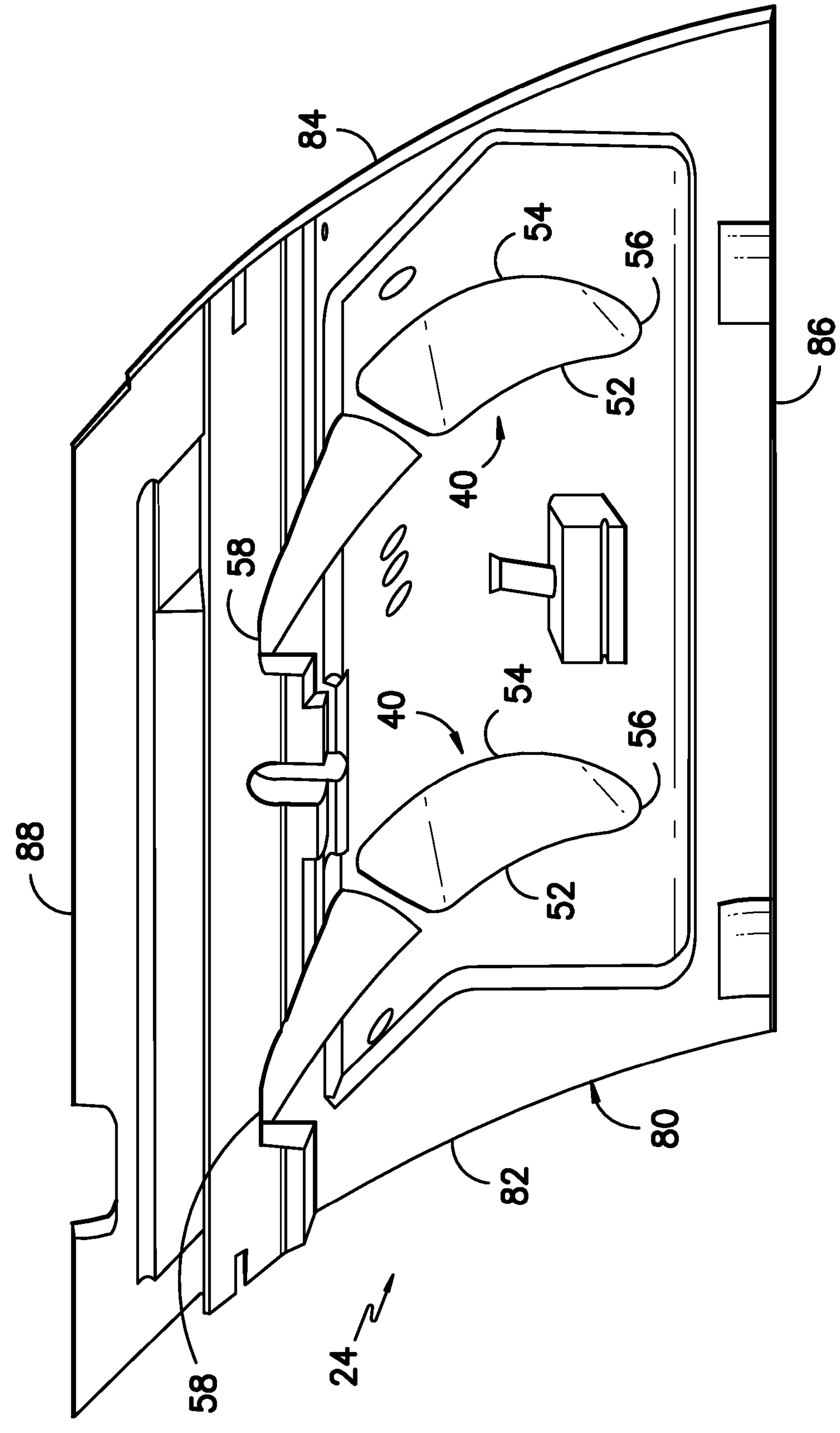

FIG. -4-

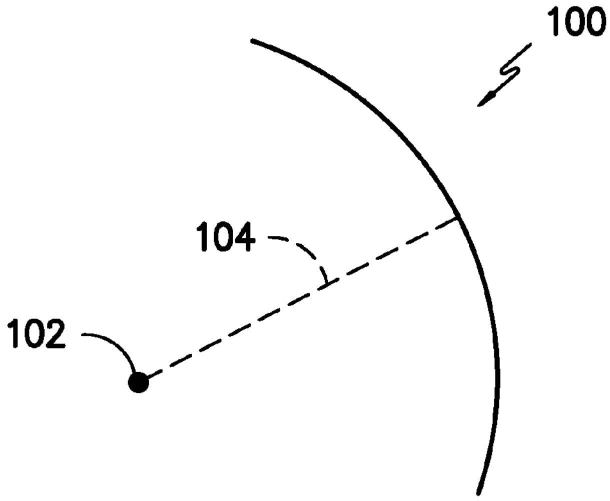

FIG. –5–

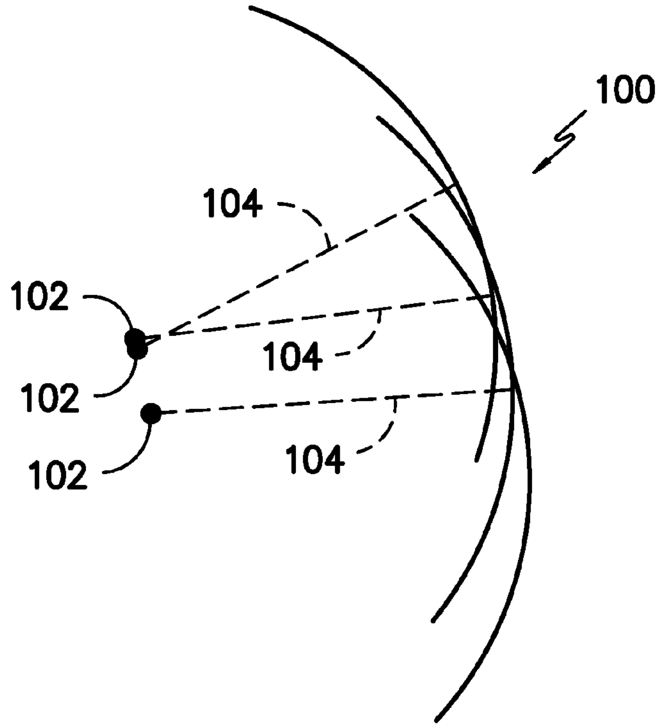

FIG. –6–