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(54) **METHODS AND APPARATUS FOR COOLING GAS TURBINE NOZZLES**

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See application file for complete search history.

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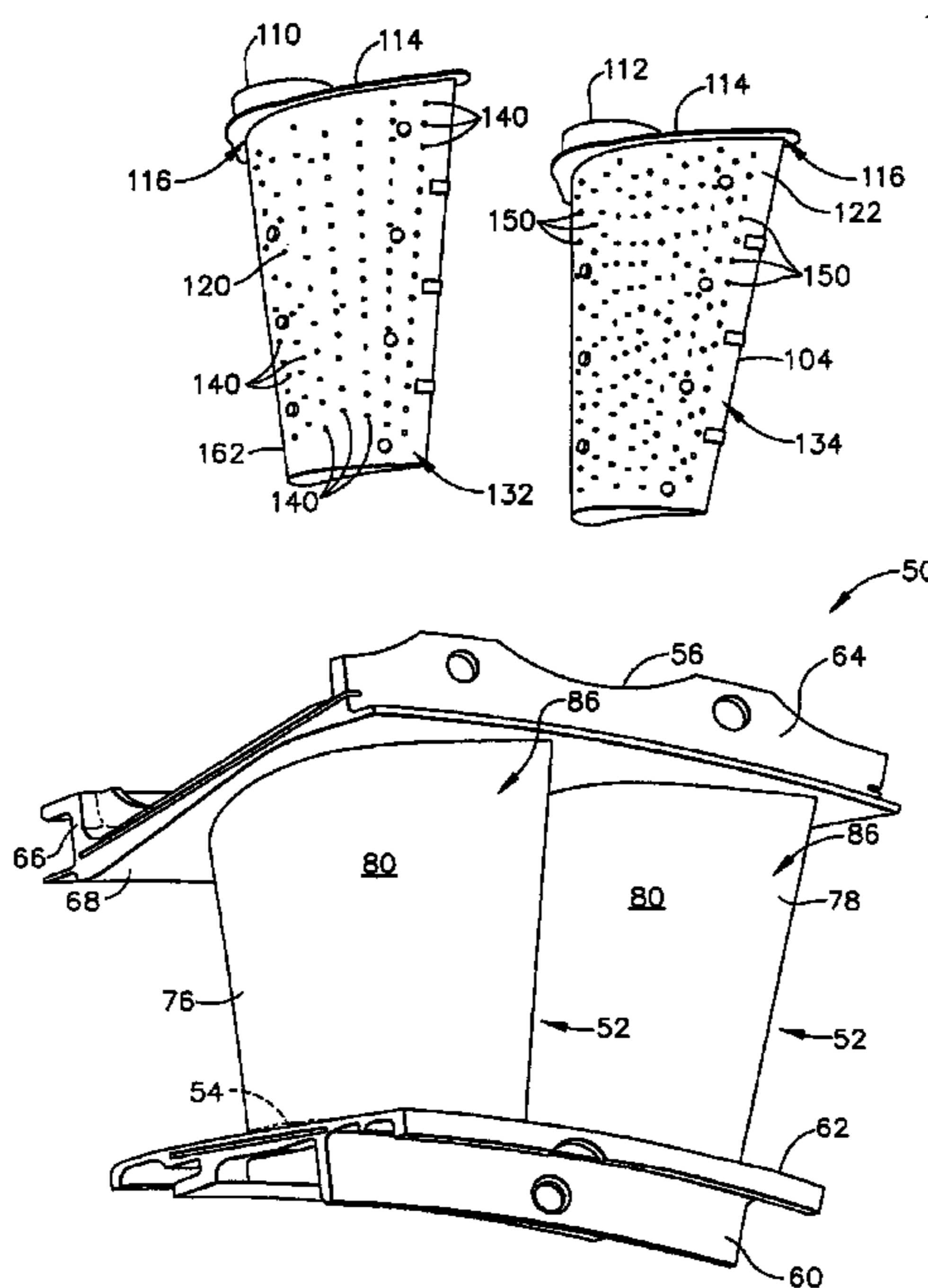
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(57) **ABSTRACT**

A method for assembling a turbine nozzle for a gas turbine engine facilitates improving cooling efficiency of the turbine nozzle. The method includes providing a hollow doublet including a leading airfoil and a trailing airfoil coupled by at least one platform, wherein each airfoil includes a first sidewall and a second sidewall that extend between a respective leading and trailing edge. The method also includes inserting an insert into at least one of the airfoils, wherein the insert includes a first sidewall including a first plurality of cooling openings that extending therethrough, and a second sidewall including a second plurality of cooling openings extending therethrough, and wherein the first plurality of cooling openings facilitate more cooling of the airfoil than the second plurality of cooling openings.

24 Claims, 3 Drawing Sheets



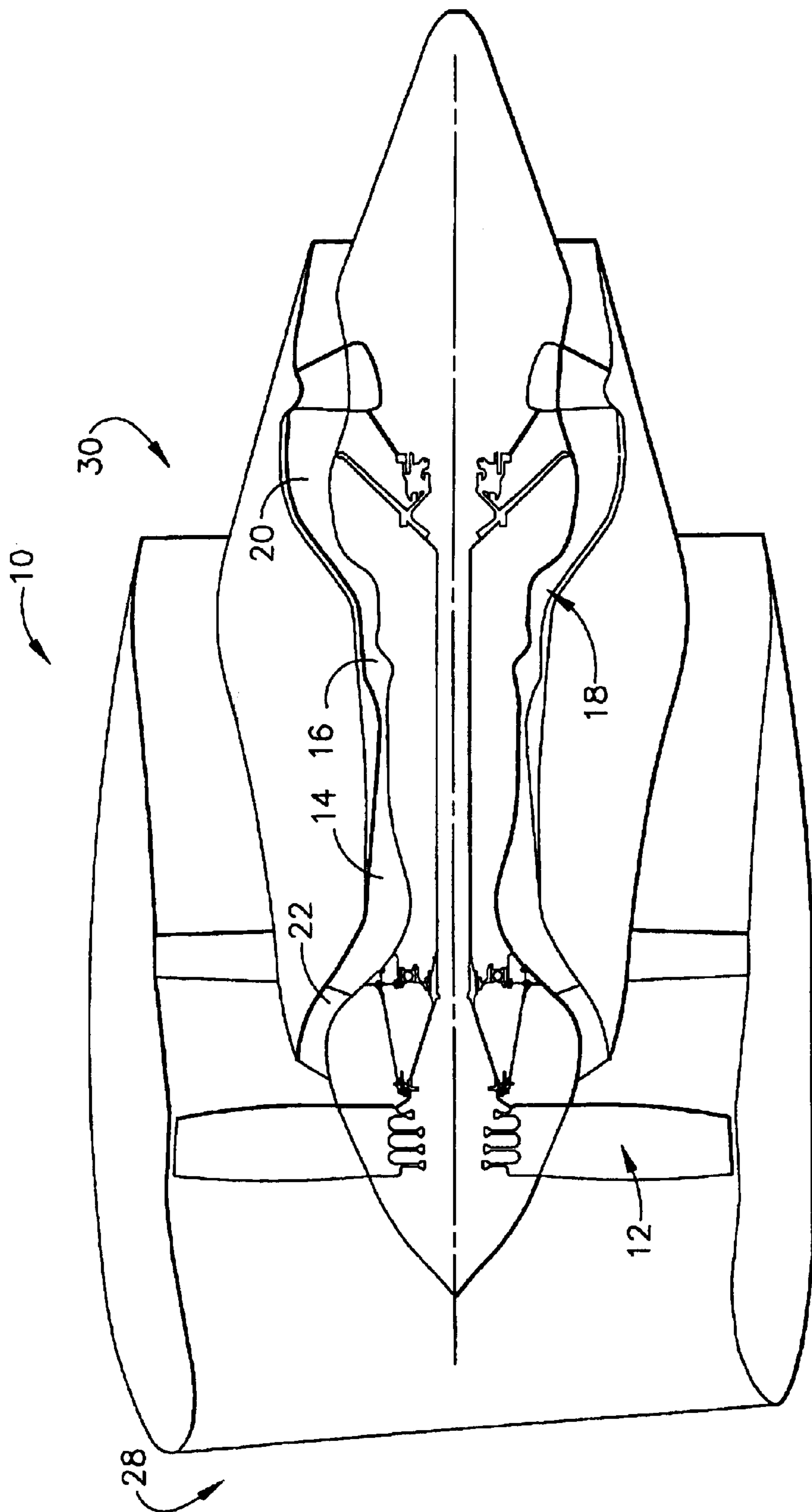


FIG. 1

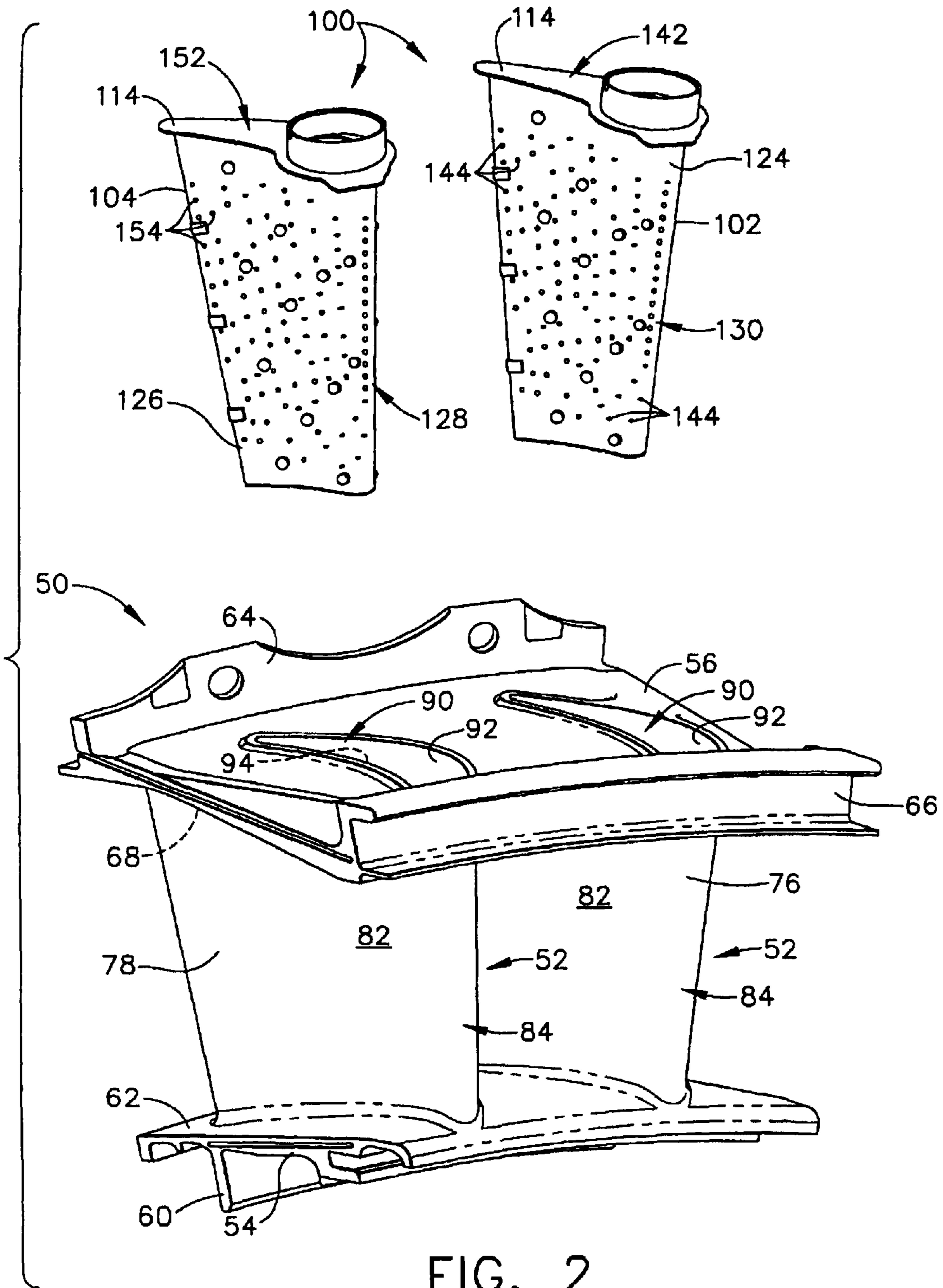


FIG. 2

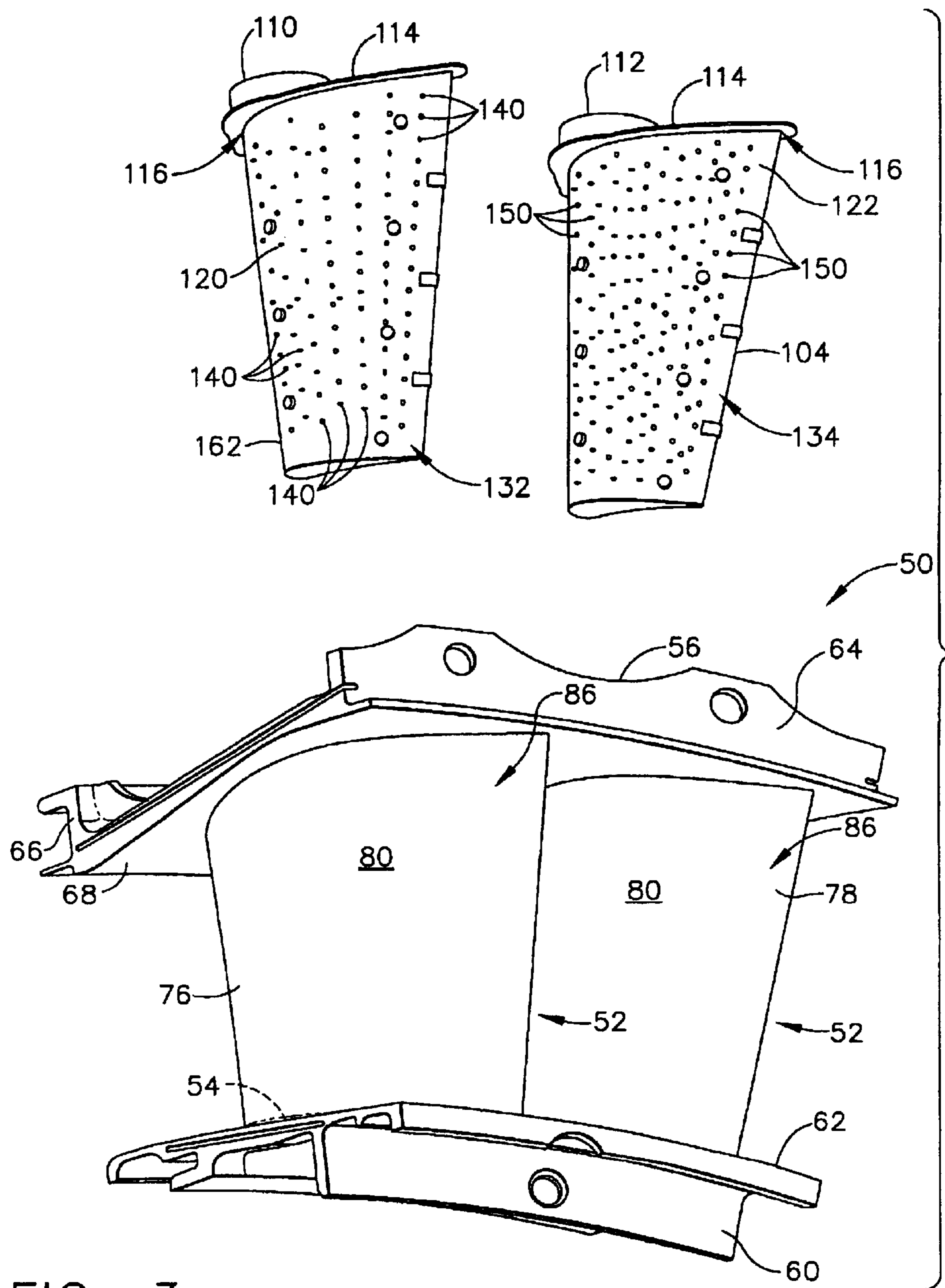


FIG. 3

METHODS AND APPARATUS FOR COOLING GAS TURBINE NOZZLES

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

This invention relates generally to gas turbine engine nozzles and more particularly, to methods and apparatus for cooling gas turbine engine nozzles.

Gas turbine engines include combustors which ignite fuel-air mixtures which are then channeled through a turbine nozzle assembly towards a turbine. At least some known turbine nozzle assemblies include a plurality of nozzles arranged circumferentially and configured as doublets. A turbine nozzle doublet includes a pair of circumferentially-spaced hollow airfoil vanes coupled by integrally-formed inner and outer band platforms.

The doublet type turbine nozzles facilitate improving durability and reducing leakage in comparison to non-doublet turbine nozzles. Furthermore, turbine nozzle doublets also facilitate reducing manufacturing and assembly costs. In addition, because such turbine nozzles are subjected to high temperatures and may be subjected to high mechanical loads, at least some known doublets include an identical insert installed within each airfoil vane cavity to distribute cooling air supplied internally to each airfoil vane. The inserts include a plurality of openings extending through each side of the insert.

In a turbine nozzle, the temperature of the external gas is higher on the pressure-side than on the suction-side of each airfoil vane. Because the openings are arranged symmetrically between the opposite insert sides, the openings facilitate distributing the cooling air throughout the airfoil vane cavity to facilitate achieving approximately the same operating temperature on opposite sides of each airfoil. However, because of the construction of the doublet, mechanical loads and thermal stresses may still be induced unequally across the turbine nozzle. In particular, because of the orientation of the turbine nozzle with respect to the flowpath, typically the mechanical and thermal stresses induced to the trailing doublet airfoil vane are higher than those induced to the leading doublet airfoil vane. Over time, continued operation with an unequal distribution of stresses within the nozzle may shorten a useful life of the nozzle.

BRIEF SUMMARY OF THE INVENTION

In one aspect of the invention, a method for assembling a turbine nozzle for a gas turbine engine is provided. The method includes providing a hollow doublet including a leading airfoil vane and a trailing airfoil vane coupled by at least one platform, wherein each airfoil vane includes a first sidewall and a second sidewall that extend between a respective leading and trailing edge. The method also includes inserting an insert into at least one of the airfoil vanes, wherein the insert includes a first sidewall including a first plurality of cooling openings that extend therethrough, and a second sidewall including a second plurality of cooling openings extending therethrough.

In another aspect, a method of operating a gas turbine engine is provided. The method includes directing fluid flow through the engine using at least one turbine airfoil nozzle that includes a leading airfoil and a trailing airfoil coupled by at least one platform that is formed integrally with the

leading and trailing airfoils, and wherein each respective airfoil includes a first sidewall and a second sidewall that extend between respective leading and trailing edges to define a cavity therein. The method also includes directing cooling air into the turbine airfoil nozzle such that the nozzle trailing airfoil is cooled more than the leading airfoil.

In a further aspect of the invention, a turbine nozzle for a gas turbine engine is provided. The nozzle includes a pair of identical airfoil vanes coupled by at least one platform formed integrally with the airfoil vanes. Each airfoil vane includes a first sidewall and a second sidewall that are connected at a leading edge and a trailing edge, such that a cavity is defined therebetween. The nozzle also includes at least one insert that is configured to be inserted within the airfoil vane cavity and includes a first sidewall and a second sidewall. The insert first sidewall includes a first plurality of openings extending therethrough for directing cooling air towards at least one of the airfoil vane first and second sidewalls. The insert second sidewall includes a second plurality of openings that extend therethrough for directing cooling air towards at least one of the airfoil vane first and second sidewalls. The first plurality of openings are configured to facilitate lower metal temperatures therefrom than the second plurality of openings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a gas turbine engine;

FIG. 2 is an exploded perspective forward-looking-aft view of turbine nozzle that may be used with the gas turbine engine shown in FIG. 1; and

FIG. 3 is an exploded perspective aft-looking-forward view of the turbine nozzle shown in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a schematic illustration of a gas turbine engine 10 including a fan assembly 12, a high-pressure compressor 14, and a combustor 16. Engine 10 also includes a high-pressure turbine 18 and a low-pressure turbine 20. Engine 10 has an intake, or upstream, side 28 and an exhaust, or downstream, side 30. In one embodiment, engine 10 is a CF6-80 engine commercially available from General Electric Aircraft Engines, Cincinnati, Ohio.

In operation, air flows through fan assembly 12 and compressed air is supplied to high-pressure compressor 14. The highly compressed air is delivered to combustor 16. Airflow from combustor 16 is discharged through a turbine nozzle assembly (not shown in FIG. 1) that includes a plurality of nozzles (not shown in FIG. 1) and used to drive turbines 18 and 20. Turbine 20, in turn, drives fan assembly 12, and turbine 18 drives high-pressure compressor 14.

FIG. 2 is an exploded perspective forward-looking-aft view of turbine nozzle 50 that may be used with gas turbine engine 10 (shown in FIG. 1). FIG. 3 is an exploded perspective aft-looking-forward view of turbine nozzle 50. Nozzle 50 is known as a doublet and includes a pair of circumferentially-spaced airfoil vanes 52 coupled together by an arcuate radially outer band or platform 56 and an arcuate radially inner band or platform 54. More specifically, in the exemplary embodiment, each band 54 and 56 is formed integrally with airfoil vanes 52.

Inner band 54 includes a retention flange 60 that extends radially inwardly therefrom. More specifically, flange 60 extends substantially perpendicularly from band 54 with respect to a radially outer surface 62 of flange 60. Outer band 56 also includes a retention flange 64 that extends radially

outwardly therefrom, and a leading edge flange **66** that also extends radially outwardly therefrom. More specifically, outer band retention flange **64** and leading edge flange **66** extend substantially perpendicularly from band **56** with respect to a radially inner surface **68** of band **56**. Surfaces **62** and **68** define a radially outer and radially inner boundary for a flowpath through nozzle **50**.

Airfoil vanes **52** are identical and include a leading airfoil vane **76** and a trailing airfoil vane **78**. Each airfoil vane **52** includes a first sidewall **80** and a second sidewall **82**. First sidewall **80** is convex and defines a suction side of each airfoil vane **76** and **78**, and second sidewall **82** is concave and defines a pressure side of each airfoil vane **76** and **78**. Sidewalls **80** and **82** are joined at a leading edge **84** and at an axially-spaced trailing edge **86** of each airfoil vane **76** and **78**. More specifically, each airfoil trailing edge **86** is spaced chordwise and downstream from each respective airfoil leading edge **84**.

First and second sidewalls **80** and **82**, respectively, extend longitudinally, or radially outwardly, in span from radially inner band **54** to radially outer band **56**. Additionally, first and second sidewalls **80** and **82**, respectively, define a cooling chamber **90** within each airfoil vane **52**. More specifically, chamber **90** is bounded by an inner surface **92** and **94** of each respective sidewall **80** and **82**, and extends through each band **54** and **56**.

Each cooling chamber **90** is sized to receive an insert **100** therein. More specifically, lead airfoil chamber **90** is sized to receive a lead insert **102**, and trailing airfoil chamber **90** is sized to receive a trailing insert **104** therein. Inserts **102** and **104** are substantially similar and each includes a respective key feature **110** and **112**, and an identical attachment flange **114**. Flange **114** extends from a radially outer end **116** of each insert **102** and **104**, and enables each insert **102** and **104** to be secured within each respective cooling chamber **90**. In one embodiment, flange **114** is brazed to radially outer band **56**. In another embodiment, flange **114** is welded to radially outer band **56**.

Key features **110** and **112** extend through flange **114** at each insert radially outer end **116**. Specifically, key features **110** and **112** are unique to each respective insert **102** and **104**, and are sized to be received in a mating slot (not shown) that extends through nozzle radially outer band **56**. More specifically, key features **110** and **112** prevent lead insert **102** from being inadvertently inserted within trailing airfoil vane **78**, and prevent trailing insert **104** from being inadvertently inserted within leading airfoil vane **76**.

Each insert **102** and **104** has a cross sectional profile that is substantially similar to that of a respective airfoil vane **76** and **78**. More specifically, each insert **102** and **104** includes a first sidewall **120** and **122**, respectively, and a second sidewall **124** and **126**. Accordingly, each insert first sidewall **120** and **122** is adjacent each respective airfoil vane first sidewall **80** when each insert **102** and **104** is installed within each respective cooling chamber **90**. Each insert first sidewall **120** and **122** is convex and defines a suction side of each respective insert **102** and **104**, and each insert second sidewall is concave and defines a pressure side of each respective insert **102** and **104**. Respective pairs of insert sidewalls **120** and **124**, and **122** and **126**, are joined at respective leading edges **128** and **130**, and at respective trailing edges **132** and **134**.

Lead insert first sidewall **120** defines a suction side of lead insert **102** and includes a first plurality of openings **140** that extend therethrough to a cavity **142** defined therein. Lead insert second sidewall **124** includes a second plurality of openings **144** that extend therethrough to cavity **142**. First

and second sidewall openings **140** and **144** of insert **102** are biased to facilitate cooling a suction side **80** of lead airfoil vane **76**, more than a pressure side **82** of lead airfoil vane **76**. In the exemplary embodiment, the plurality of first sidewall openings **140** are greater than that required to achieve substantially equal surface temperatures when compared to the plurality of second sidewall openings **144**. The ratio of ninety first sidewall openings **140** to ninety-seven second sidewall openings **144** results in biased cooling and is in contrast to known inserts which have a ratio of seventy-six first sidewall openings to one hundred thirty-seven second sidewall openings which results in cooling all four airfoil sidewalls substantially equally. In an alternative embodiment, the larger volume of air is facilitated because insert first sidewall **120** includes openings **140** which are larger in diameter than corresponding openings **144** extending through insert second sidewall **124**. It should be noted that the arrangement of openings **140** and **144** with respect to each respective sidewall **120** and **124** is variable. Furthermore, the number and size of openings **140** and **144** is also variable.

Trailing insert first sidewall **122** defines a suction side of trailing insert **104** and includes a first plurality of openings **150** that extend therethrough to a cavity **152** defined therein. Trailing insert second sidewall **126** includes a second plurality of openings **154** that extend therethrough to cavity **152**. First sidewall openings **150** permit a larger volume of cooling air to pass therethrough than second sidewall openings **154**. More specifically, insert **104** is biased to facilitate cooling a suction side **80** of trailing airfoil vane **78**, more than a pressure side **82** of trailing airfoil vane **78**. In the exemplary embodiment, the larger volume of air is facilitated because the plurality of first sidewall openings **150** outnumber the plurality of second sidewall openings **154**. More specifically, in the exemplary embodiment, first sidewall **122** includes one hundred forty-two openings **150**, and second sidewall **126** includes ninety-seven openings **154**. In an alternative embodiment, the larger volume of air is facilitated because insert first sidewall **122** includes openings **150** which are larger in diameter than corresponding openings **154** extending through insert second sidewall **126**. It should be noted that the arrangement of openings **150** and **154** with respect to each respective sidewall **122** and **126** is variable. Furthermore, the number and size of openings **150** and **154** is also variable.

Each nozzle **50** is in flow communication with a cooling system (not shown) that directs cooling air into each airfoil vane cooling chamber **90** for internal cooling of nozzle airfoil vanes **52**. Specifically, the cooling system directs cooling air into each airfoil vane insert **100**, which in-turn, channels the cooling air for cooling airfoil vanes **52**. In addition to being biased to facilitate cooling a suction side of each respective airfoil vane **76** and **78**, nozzle inserts **100** are biased to facilitate cooling trailing airfoil vane **78** more than lead airfoil vane **76**. More specifically, trailing insert openings **150** and **154** are biased such that a larger volume cooling air is directed towards trailing airfoil vane **78** through trailing insert **104** than is directed through lead insert **102** towards lead airfoil vane **76**. In the exemplary embodiment, the larger volume of air is facilitated because the plurality of trailing airfoil vane first sidewall openings **150** outnumber the plurality of, lead airfoil vane first sidewall openings **140**. In an alternative embodiment, the larger volume of air is facilitated by varying the size of trailing airfoil vane openings **150** in comparison to lead airfoil vane openings **140**.

During operation, cooling air is routed through the cooling system into nozzle **50**, which may not be thermally

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loaded or mechanically stressed equally between adjacent airfoil vanes 76 and 78. More specifically, due to gas loading, thermal variations, and mechanical loading, more mechanical and thermal stresses are induced and transmitted through trailing airfoil vane 78 than through lead airfoil vane 76. Because nozzle inserts 102 and 104 provide nozzle 50 with a cooling scheme that may be customized to particular applications, cooling air supplied to nozzle 50 is allocated more to a suction side 80 of the airfoil vanes 52 than to a pressure side 82 of the airfoil vanes 52. Accordingly, as cooling air is channeled into nozzle 50, inserts 102 and 104 direct cooling air towards a respective nozzle airfoil vane 76 and 78. The cooling air exits outwardly from each nozzle airfoil vane 52 through a plurality of airfoil trailing edge openings (not shown), and thermal stresses induced within each individual airfoil vane 76 and 78 are facilitated to be reduced. Furthermore, by biasing the cooling airflow to cool trailing airfoil vane 78 more than lead airfoil vane 76, thermal stresses across nozzle 50 are facilitated to be controlled. As a result, although a maximum temperature on each airfoil vane concave surface is increased, the thermal stresses induced in nozzle 50 are facilitated to be controlled to counteract the mechanical stresses, thus facilitating increasing a useful life of nozzle 50.

The above-described turbine nozzle includes a pair of inserts that enable a cooling scheme for the nozzle to be customized to particular applications. Specifically, the inserts bias the distribution of cooling air supplied to the nozzle more to the suction side of each of the airfoil vanes, and more to the trailing airfoil vane in the doublet. As a result, the inserts facilitate controlling thermal stresses induced within the nozzle, and thus, facilitate increasing the useful life of the nozzle in a cost-effective and reliable manner.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A method for assembling a turbine nozzle for a gas turbine engine, said method comprising:

providing a hollow doublet including a leading airfoil vane and a trailing airfoil vane coupled by at least one platform, wherein each airfoil vane includes a first sidewall and a second sidewall that extend between a respective leading and trailing edge;

inserting an insert into at least one of the airfoil vanes, wherein the insert includes a first sidewall including a first plurality of cooling openings that extending therethrough, and a second sidewall including a second plurality of cooling openings extending therethrough, and wherein the first plurality of cooling openings facilitate cooling the airfoil more than the second plurality of cooling openings;

inserting second insert into the remaining airfoil vane, wherein the first and second inserts non-identical.

2. A method in accordance with claim 1 wherein each airfoil vane includes a pressure side and a suction side, inserting an insert into at least one of the airfoil vanes further comprises inserting an insert into at least one of the airfoil vanes to facilitate biasing cooling air towards the suction side of the airfoil vane.

3. A method in accordance with claim 1 wherein the first sidewall of each airfoil vane is convex, and the second sidewall of each airfoil vane is concave, inserting an insert into at least one of the airfoil vanes further comprises inserting an

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insert into at least one of the airfoil vanes to facilitate biasing cooling air towards the convex side of the airfoil vane.

4. A method in accordance with claim 1 wherein inserting an insert into at least one of the airfoil vanes further comprises inserting a first insert into the leading airfoil vane and a second insert into the trailing airfoil vane to facilitate cooling the trailing airfoil vane more than the leading airfoil vane.

5. A method in accordance with claim 1 wherein inserting an insert into at least one of the airfoil vanes further comprises inserting a first insert into the leading airfoil vane and a second insert into the trailing airfoil vane to facilitate reducing thermal stresses within the airfoil nozzle.

6. A method of operating a gas turbine engine, said method comprising:

directing fluid flow through the engine using at least one turbine airfoil nozzle that includes a leading airfoil and a trailing airfoil coupled by at least one platform that is formed integrally with the leading and trailing airfoils, and wherein each respective airfoil includes a first sidewall and a second sidewall that extend between respective leading and trailing edges to define a cavity therein; and

directing cooling air into the turbine airfoil nozzle such that the nozzle trailing airfoil is cooled more than the leading airfoil.

7. A method in accordance with claim 6 wherein directing cooling air into the turbine airfoil nozzle further comprises directing airflow into each respective airfoil cavity through an insert installed within the turbine nozzle to facilitate reducing thermal stresses within the turbine airfoil nozzle.

8. A method in accordance with claim 6 wherein directing cooling air into the turbine airfoil nozzle further comprises directing airflow through at least one insert installed within the turbine nozzle that includes a first plurality of cooling openings in flow communication with the airfoil first sidewall, and a second plurality of cooling openings in flow communication with the airfoil second sidewall, wherein the first plurality of cooling openings facilitate cooling the airfoil more than the second plurality of cooling openings.

9. A method in accordance with claim 8 wherein the first sidewall defines a suction side of the respective airfoil, and the second sidewall defines a pressure side of the respective airfoil, directing cooling air into the turbine airfoil nozzle further comprises biasing airflow entering the airfoil with the insert towards the suction side of the airfoil.

10. A method in accordance with claim 8 wherein the first sidewall is convex, and the second sidewall is concave, directing cooling air into the turbine airfoil nozzle further comprises biasing airflow entering the airfoil with the insert towards the convex side of the airfoil.

11. A method in accordance with claim 6 wherein directing cooling air into the airfoil nozzle further comprises directing airflow into each respective airfoil through a pair of non-identical inserts installed within the turbine nozzle, such that the trailing airfoil is biased to receive more cooling air flow than the leading airfoil.

12. A turbine nozzle for a gas turbine engine, said nozzle comprising:

a pair of identical airfoil vanes coupled by at least one platform that is formed integrally with said airfoil vanes, each said airfoil vane comprising a first sidewall and a second sidewall connected at a leading edge and a trailing edge to define a cavity therebetween, *said airflow vane first sidewall defines an airfoil vane suction side, said airfoil vane second sidewall defines an airfoil vane pressure side*; and

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at least one inset configured to be inserted within said airfoil vane cavity and comprising a first sidewall and a second sidewall, *said insert first sidewall is adjacent said airfoil vane first sidewall*, said insert first sidewall comprising a first plurality of openings extending there-
 5 through for directing cooling air towards at least one of said airfoil vane first and second sidewalls, said insert second sidewall comprising a second plurality of open-
 10 ings extending therethrough for directing cooling air towards at least one of said airfoil vane first and second sidewalls, said first plurality of openings configured to
 15 facilitate more vane sidewall cooling than said second plurality of openings, said first plurality of cooling openings is greater than said insert second plurality of cooling openings.

[13. A nozzle in accordance with claim **12** wherein said airfoil vane first sidewall defines an airfoil vane suction side, said airfoil vane second sidewall defines an airfoil vane pres-
 20 sure side, said at least one insert further configured to be inserted within at least one airflow cavity such that said insert first sidewall is adjacent said airfoil vane first side-
 wall.]

14. A nozzle in accordance with claim **[13]** **12** wherein said airfoil vane first sidewall is convex, said airfoil vane second sidewall is concave, said insert further configured to
 25 facilitate cooling said airfoil vane first sidewall more than said airfoil vane second sidewall.

15. A nozzle in accordance with claim **[13]** **12** wherein said at least one insert further configured to be inserted such that said insert first sidewall is in flow communication and
 30 adjacent said airfoil vane first sidewall, said insert first sidewall is convex, said insert second sidewall is concave.

16. A nozzle in accordance with claim **[13]** **12** wherein said pair of airfoil vanes further comprise a leading airfoil vane and a trailing airfoil vane, said at least one insert further
 35 comprises a first insert installed within said leading airfoil vane, and a non-identical second insert installed within said trailing airfoil vane, said inserts configured to facilitate cool-
 ing said trailing airfoil vane more than said leading airfoil vane.

17. A nozzle in accordance with claim **[13]** **12** wherein said at least one insert further configured to facilitate reduc-
 40 ing thermal stresses within said nozzle.

18. *A turbine nozzle for a gas turbine engine, said nozzle comprising:*

a leading airfoil; and

a trailing airfoil; and

at least one platform that is formed integrally with said leading and trailing airfoils, and wherein each respec-

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*tive airfoil comprises a first sidewall and a second side-
 wall that extend between respective leading and trail-
 ing edges to define a cavity therein; and*

at least one insert inserted within said airfoil cavity, said turbine nozzle coupled to a cooling system configured to direct cooling air into the turbine airfoil nozzle such that a portion of said trailing airfoil is cooled more than other portions of said trailing airfoil, and such that said trailing airfoil first sidewall is cooled more than said leading airfoil first sidewall.

19. *A turbine nozzle in accordance with claim 18 wherein said turbine airfoil nozzle is further configured to receive cooling air such that a portion of the leading airfoil is cooled more than other portions of the leading airfoil.*

20. *A turbine nozzle in accordance with claim 18 wherein said turbine nozzle is further comprises:*

*a first insert configured to be inserted within one of the airfoil vanes, wherein the first insert comprises a first sidewall including a first plurality of cooling openings extending therethrough, and a second sidewall includ-
 20 ing a second plurality of cooling openings extending therethrough, and wherein the first plurality of cooling openings facilitate cooling the airfoil more than the second plurality of cooling openings, and wherein the first plurality of cooling openings is greater than the second plurality of cooling openings; and*

a second insert configured to be inserted within the remaining airfoil vane.

21. *A turbine nozzle in accordance with claim 20 wherein said first and second inserts are identical.*

22. *A turbine nozzle in accordance with claim 20 wherein said first and second inserts are non-identical.*

23. *A turbine nozzle in accordance with claim 20 wherein said first sidewall defines a pressure side of the respective airfoil, and said second sidewall defines a suction side of the respective airfoil, said insert configured to bias cooling air-
 35 flow entering the airfoil towards the suction side of the airfoil.*

24. *A turbine nozzle in accordance with claim 20 wherein said first sidewall is concave, and said second sidewall is convex, said insert configured to bias cooling airfoil enter-
 40 ing the airfoil towards the concave side of the airfoil.*

25. *A turbine nozzle in accordance with claim 18 wherein said nozzle comprises a pair of non-identical inserts config-
 45 ured to bias the cooling air directed to the trailing airfoil more than the cooling air flow directed to the leading airfoil.*

* * * * *