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(54) **COMPRESSOR ROTOR COOLING APPARATUS**

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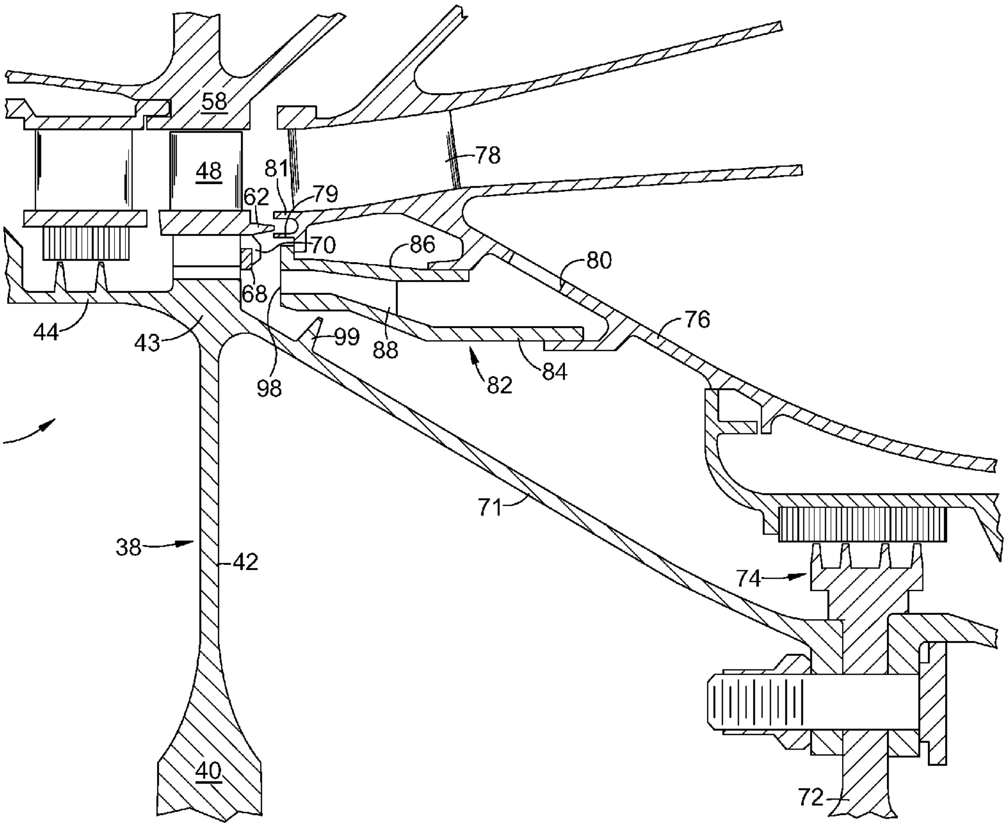
(57) **ABSTRACT**

A compressor cooling apparatus includes: a blade row mounted for rotation about a centerline axis; a stationary diffuser located downstream of, and in flow communication with, the blade row; an inducer disposed between the diffuser and the blade row, the inducer having an inlet in flow communication with the diffuser, and having an outlet oriented to direct flow towards the blade row.



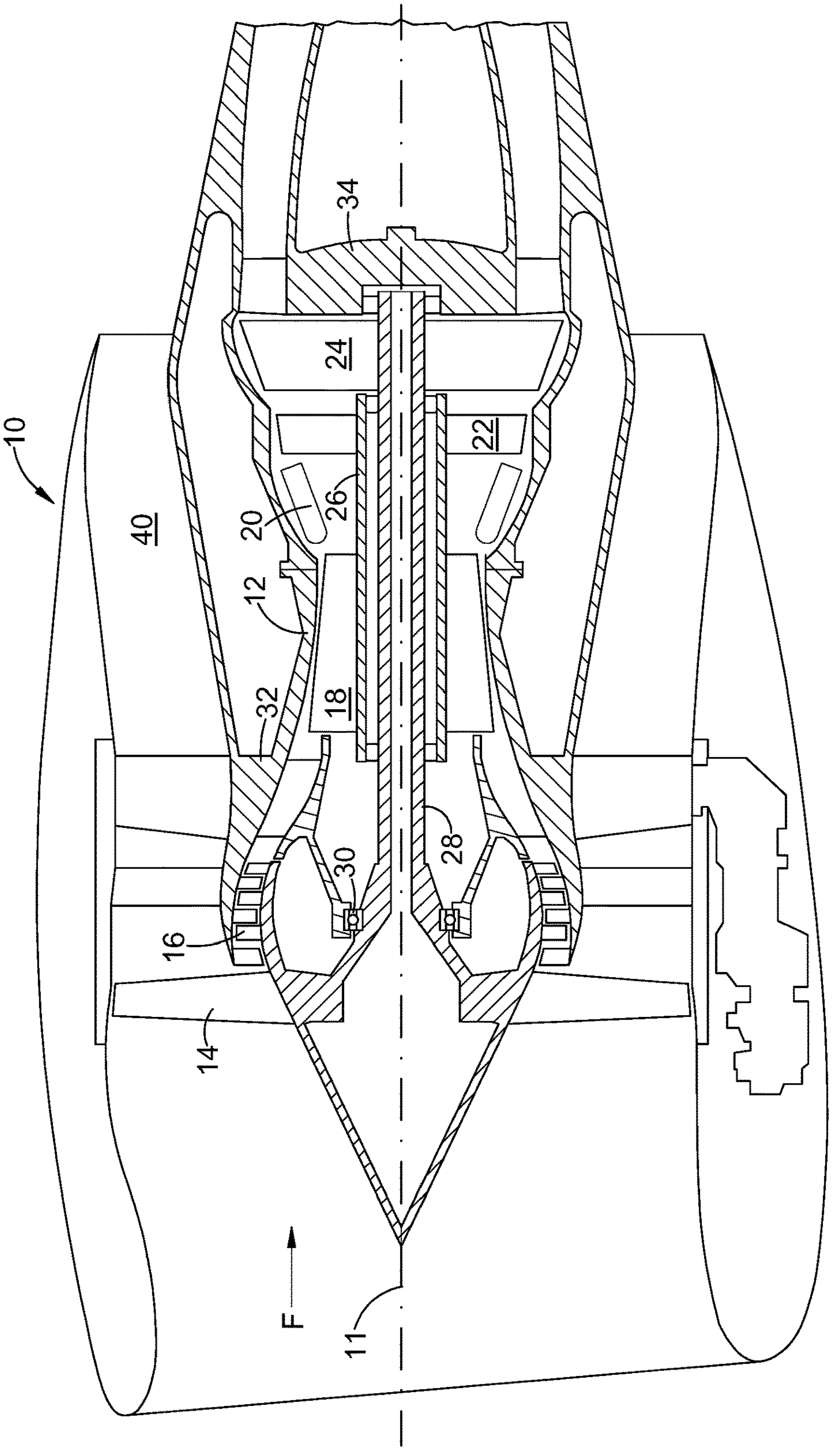


FIG. 1

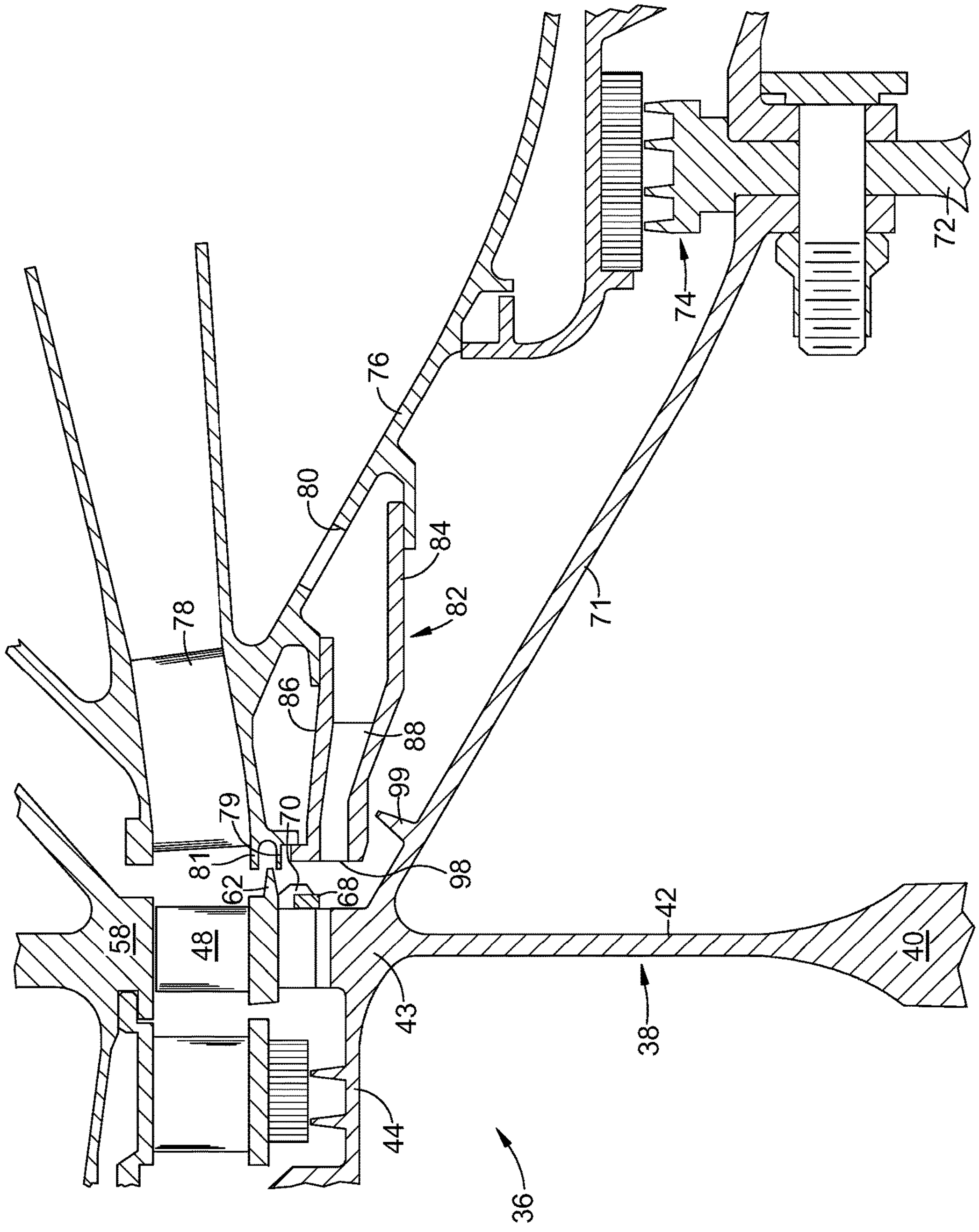

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FIG. 2

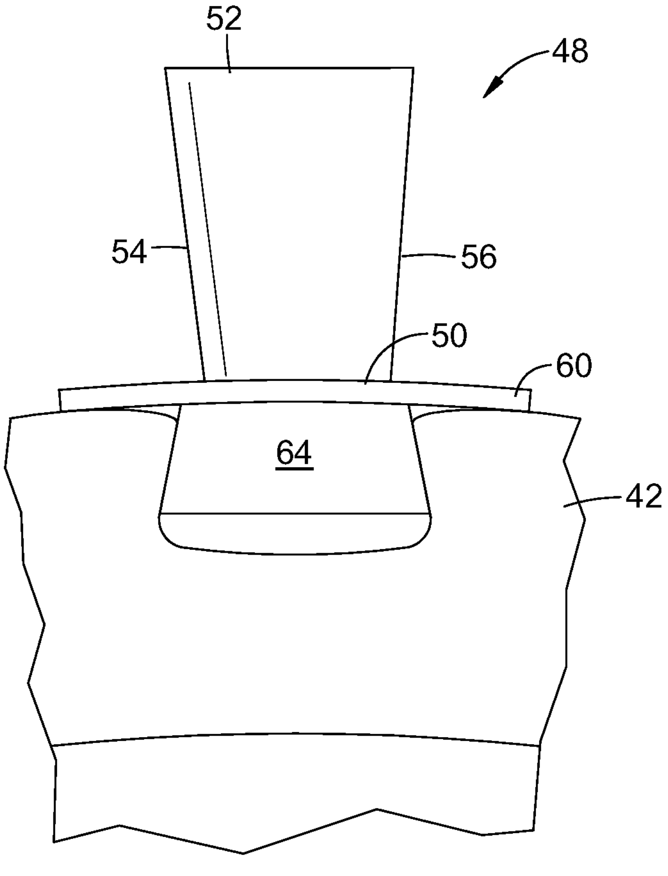

FIG. 3

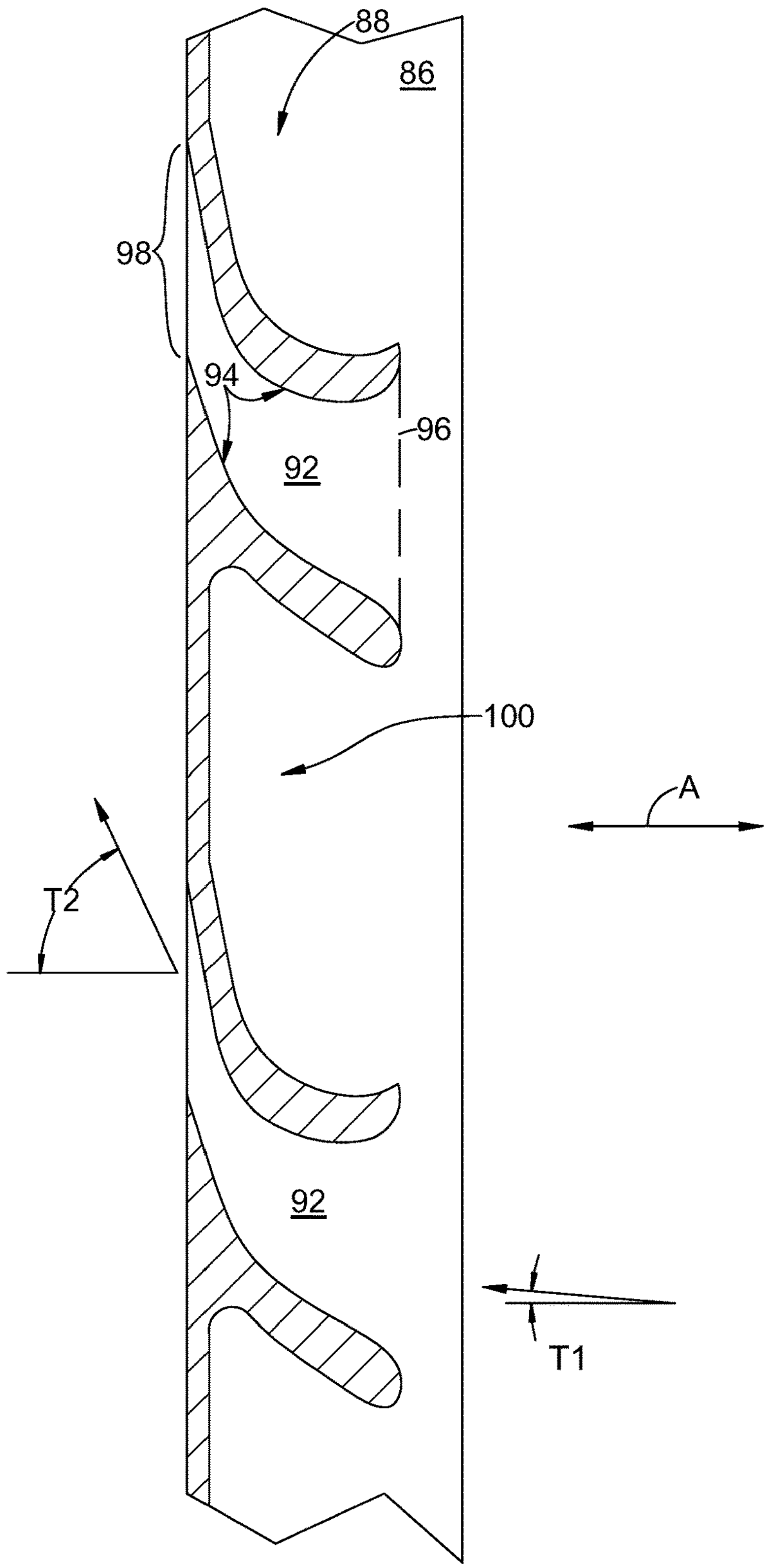

FIG. 4

COMPRESSOR ROTOR COOLING APPARATUS

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to compressors in gas turbine engines, and more particularly relates to cooling in such compressors.

[0002] A gas turbine engine includes, in serial flow communication, a compressor, a combustor, and turbine. The turbine is mechanically coupled to the compressor and the three components define a turbomachinery core. The core is operable in a known manner to generate a flow of hot, pressurized combustion gases to operate the engine as well as perform useful work such as providing propulsive thrust or mechanical work.

[0003] Modern aviation gas turbines are running at higher and higher overall pressure ratios ("OPR"), providing improvement in specific fuel consumption ("SFC").

[0004] One problem with higher OPRs is that they result in higher compressor discharge temperatures (T**3**). High T**3** temperatures are challenging the creep and fatigue capability of the aft stages of modern compressors.

BRIEF DESCRIPTION OF THE INVENTION

[0005] This problem is addressed by a compressor cooling apparatus which is configured to channel cooling air from a downstream diffuser to a final stage of the compressor.

[0006] According to one aspect of the technology described herein, a compressor cooling apparatus includes: a blade row mounted for rotation about a centerline axis; a stationary diffuser located downstream of, and in flow communication with, the blade row; an inducer disposed between the diffuser and the blade row, the inducer having an inlet in flow communication with the diffuser, and having an outlet oriented to direct flow towards the blade row.

[0007] According to another aspect of the technology described herein, a gas turbine engine apparatus includes: an compressor, a combustor, and a turbine arranged in a serial flow relationship, wherein the compressor includes: an annular compressor casing; a blade row mounted for rotation about a centerline axis inside the compressor casing; a stationary diffuser located downstream of, and in flow communication with, the blade row; an inducer disposed between the diffuser and the compressor, the inducer having an inlet in flow communication with the diffuser, and having an outlet oriented to direct flow towards the blade row.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The invention may be best understood by reference to the following description taken in conjunction with the accompanying drawing figures in which:

[0009] FIG. **1** is a cross-sectional, schematic view of a gas turbine engine that incorporates a compressor cooling apparatus;

[0010] FIG. **2** is a schematic, half-sectional view of a portion of a compressor of the engine of FIG. **1**;

[0011] FIG. **3** is front elevation view of a portion of a rotor and a compressor blade; and

[0012] FIG. **4** is a schematic sectional plan view of a portion of an inducer shown in FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Referring to the drawings wherein identical reference numerals denote the same elements throughout the various views, FIG. **1** depicts an exemplary gas turbine engine **10** incorporating a compressor rotor cooling apparatus. While the illustrated example is a high-bypass turbofan engine, the principles of the present invention are also applicable to other types of engines, such as low-bypass turbofans, turbojets, stationary gas turbines, etc. Several of the components of the engine **10** are illustrated in schematic block diagram form. The engine **10** has a longitudinal centerline axis **11** and an outer stationary annular casing **12** disposed concentrically about and coaxially along the centerline axis **11**. The engine **10** has a fan **14**, booster **16**, high-pressure compressor ("HPC") **18**, combustor **20**, high-pressure turbine ("HPT") **22**, and low-pressure turbine ("LPT") **24** arranged in serial flow relationship. In operation, pressurized air from the high-pressure compressor **18** is mixed with fuel in the combustor **20** and ignited, thereby generating combustion gases. Some work is extracted from these gases by the high-pressure turbine **22** which drives the compressor **18** via an outer shaft **26**. The combustion gases then flow into the low-pressure turbine **24**, which drives the fan **14** and booster **16** via an inner shaft **28**. The inner and outer shafts **28** and **26** are rotatably mounted in bearings **30** which are themselves mounted in a fan frame **32** and a turbine rear frame **34**.

[0014] It is noted that, as used herein, the terms "axial" and "longitudinal" both refer to a direction parallel to the centerline axis **11**, while "radial" refers to a direction perpendicular to the axial direction, and "tangential" or "circumferential" refers to a direction mutually perpendicular to the axial and radial directions. As used herein, the terms "forward" or "front" refer to a location relatively upstream in an air flow passing through or around a component, and the terms "aft" or "rear" refer to a location relatively downstream in an air flow passing through or around a component. The direction of this flow is shown by the arrow "F" in FIG. **1**. These directional terms are used merely for convenience in description and do not require a particular orientation of the structures described thereby.

[0015] Illustrated in FIG. **2** is a schematic representation of a portion of a rotor assembly **36** of the HPC **18**. It will be understood that the compressor includes a number of stages of axial-flow blading; for example, a typical compressor could include 6-14 stages. In operation, the static air pressure is incrementally increased by each subsequent compressor stage, with the final stage discharging air at the intended compressor discharge pressure ("CDP") for subsequent flow into a diffuser and thence into a combustor. The concepts described herein relate to the configuration at the aft end (exit) of the compressor **18**.

[0016] The rotor assembly **36** includes a final stage rotor disk **38** with a hub **40**, a web **42**, and a rim **43**. The rim **43** is integral with a generally cylindrical compressor spool **44**, as are the rotor disks of other stages of the compressor **18** (not shown).

[0017] The rim **43** includes a plurality of axial dovetail slots **46** (see FIG. **3**) carrying a row of compressor blades **48**. Each compressor blade **48** includes an airfoil body having opposed pressure and suction sides extending in span between a root **50** and a tip **52** and in chord between a leading edge **54** and a trailing edge **56**. The tips **52** of the compressor blades **48** run in close proximity to a surrounding annular compressor casing **58** (FIG. **2**).

[0018] Each compressor blade **48** includes a platform **60** which extends laterally outwards to define a flowpath surface and extends axially aft to form an arcuate sealing element **62** referred so as an "angel wing" (see FIG. **2**).

[0019] Each compressor blade **48** has a dovetail **64** formed at its base, inboard of the platform **60**. The dovetails **64** are received in complementary dovetail slots **66** formed in the rim **43**. The blades may be retained axially by a split ring **68** engaging hooks **70** in the rim **43**.

[0020] A generally conical aft arm **71** extends axially rearward and radially inward from the rim **18** and is joined to a CDP seal rotor **72** which carries one-half of a rotating CDP seal **74**. The other half of the CDP seal **74** is mounted to an annular wall **76** of a stationary diffuser **78**.

[0021] Feed holes **80** are provided in the diffuser wall **76** which pass CDP air into the space between the diffuser wall **76** and the aft arm **71**.

[0022] The forward end of the diffuser **78** incorporates an arcuate inner sealing element **79** positioned radially inboard of the angel wing **62** and overlapping the angel wing **62** in the axial direction. The forward end of the diffuser **78** incorporates an arcuate outer sealing element **81** positioned radially outboard of the angel wing **62** and overlapping the angel wing **62** in the axial direction. Collectively, the angel wing **62** and the inner and outer sealing elements **79**, **81** form a double-overlapping rotating seal.

[0023] An inducer **82** is mounted to the wall **76** of the diffuser **78**, using appropriate fasteners, mechanical joints, or a combination thereof. The inducer **82** comprises an annular inner wall **84** spaced apart from an annular outer wall **86**. The inner and outer walls **84**, **86** are interconnected by a central wall structure **88**.

[0024] The central wall structure **88** is shown in more detail in FIG. **4**. it defines an array of channels **92** disposed around the circumference of the inducer **82**. Each channel is bounded at its lateral extents by sidewalls **94**, and extends between an inlet **96**, which is in flow communication with the feed holes **80**, and an outlet **98**. The outlets **98** are positioned just downstream (e.g. axially aft) of the rim **43**, and at approximately the same radius as the rim **43**.

[0025] The channels **92** are configured to turn and/or accelerate the flow passing through them in a tangential direction to change a tangential velocity (or tangential velocity component) of the flow. This may be done for the purpose of matching the tangential velocity of the rotor disk **38**. In one example the input tangential angle "T**1**" of the flow is about 0° relative to axial direction "A", and the output tangential angle "T**2**" of the flow is about 70° to about 80°.

[0026] The configuration of the channels **92**, including characteristics such as their number, sectional shape, length dimension, radial dimension, convergence angle, and orientation may be selected using appropriate design tools to provide a desired degree of flow turning with the least amount of pressure loss for a specific application and range of operational conditions.

[0027] In the illustrated example, the central wall structure **88** incorporates "cut-outs" **100** between the channels **92**, which are areas where material is removed for the purposes of saving weight.

[0028] During engine operation a portion of the compressed air from the diffuser **78** passes through the feed holes **80** and into the inducer **82**. The air is turned and accelerated to match its velocity to the tangential velocity of the rim **43**. The air is then discharged towards the rim **43** where it is effective to cool the rim and/or the compressor blades **48**. The double-overlap sealing arrangement described above prevents the cooling air flow from leaking back into the primary flowpath.

[0029] Additionally, the aft arm **71** may be provided with a rotating seal **99** such as the illustrated annular seal tooth which extends radially outwards, terminating in close proximity to the inducer **82**. This is effective to inhibit cooling air discharged from the inducer **82** from leaking into the secondary flowpath away from the rim **43**. The spent cooling air can flow through the axial dovetail slots **66** to exit to a lower pressure sink.

[0030] Optionally, the compressor blades **48** could be provided with one or more internal passages open to the dovetail slots **66** in order to channel the cooling flow into the compressor blades and thus provide cooling.

[0031] The compressor cooling apparatus described herein has advantages over the prior art. Analysis has shown it can significantly reduce transient peak temperatures compared to the prior art. This cooling configuration will allow the aft rim of the compressor to meet creep and cyclic life requirements while also enabling high OPR that improves SFC.

[0032] The foregoing has described a compressor cooling apparatus. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0033] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0034] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

What is claimed is:

1. A compressor cooling apparatus, comprising:

a blade row mounted for rotation about a centerline axis;

a stationary diffuser located downstream of, and in flow communication with, the blade row;

an inducer disposed between the diffuser and the blade row, the inducer having an inlet in flow communication with the diffuser, and having an outlet oriented to direct flow towards the blade row.

2. The apparatus of claim **1** wherein the blade row comprises a rotatable disk having a hub, a web, and a rim, wherein a plurality of compressor blades extend from the rim.

3. The apparatus wherein the inducer defines a circumferential array of channels, the channels configured to change a tangential velocity of airflow through the inducer.

4. The apparatus of claim **1** wherein the diffuser includes an annular, generally conical inner arm.

5. The apparatus of claim **1** wherein the inner arm of the diffuser includes a feed hole formed therein.

6. The apparatus of claim **1** wherein the inducer comprises annular inner and outer walls interconnected by a central wall structure.

7. The apparatus of claim **1** wherein the blade row comprises:

a rotatable disk having a rim defining an array of axial dovetail slots; and

a plurality of compressor blades each having an axial dovetail received in one of the dovetail slots of the disk.

8. The apparatus of claim **1** further comprising a retaining ring securing the compressor blades in the dovetail slots.

9. The apparatus of claim **1** wherein each of the compressor blades is an airfoil-shaped body including opposed concave and convex side walls extending between a leading edge and a trailing edge.

10. The apparatus of claim **1** wherein the blade row is mounted for rotation inside an annular compressor casing;

11. A gas turbine engine apparatus, comprising:

a compressor, a combustor, and a turbine arranged in a serial flow relationship, wherein the compressor includes:

an annular compressor casing;

a blade row mounted for rotation about a centerline axis inside the compressor casing;

a stationary diffuser located downstream of, and in flow communication with, the blade row;

an inducer disposed between the diffuser and the compressor, the inducer having an inlet in flow communication with the diffuser, and having an outlet oriented to direct flow towards the blade row.

12. The apparatus of claim **11** wherein the blade row comprises a rotatable disk having a hub, a web, and a rim, wherein a plurality of compressor blades extend from the rim.

13. The apparatus of claim **11** wherein the inducer defines a circumferential array of channels, the channels configured to change a tangential velocity of airflow through the inducer.

14. The apparatus of claim **11** wherein the diffuser includes an annular, generally conical inner arm.

15. The apparatus of claim **14** wherein the inner arm of the diffuser includes a feed hole formed therein.

16. The apparatus of claim **11** wherein the inducer comprises annular inner and outer walls interconnected by a central wall structure.

17. The apparatus of claim **11** wherein the blade row comprises:

a rotatable disk having a rim defining an array of axial dovetail slots; and

a plurality of compressor blades each having an axial dovetail received in one of the dovetail slots of the disk.

18. The apparatus of claim **17** further comprising a retaining ring securing the compressor blades in the dovetail slots.

19. The apparatus of claim **11** wherein each of the compressor blades is an airfoil-shaped body including opposed concave and convex side walls extending between a leading edge and a trailing edge.

20. The apparatus of claim **11** wherein:

the blade row includes an annular sealing element; and

the diffuser includes one or more annular sealing elements which overlap the annular sealing element of the blade row in the axial direction.

* * * * *