US011492914B1

(12) United States Patent
Quach et al.

(10) Patent No.: US 11,492,914 B1

(45) Date of Patent: Nov. 8, 2022

(54) **ENGINE WITH COOLING PASSAGE CIRCUIT FOR AIR PRIOR TO CERAMIC COMPONENT**

(71) Applicant: **Raytheon Technologies Corporation**, Farmington, CT (US)

(72) Inventors: **San Quach**, Southington, CT (US); **Adam P. Generale**, Dobbs Ferry, NY (US); **Raymond Surace**, Newington, CT (US); **Lucas Dvorozniak**, Bloomfield, CT (US)

(73) Assignee: **RAYTHEON TECHNOLOGIES CORPORATION**, Farmington, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 36 days.

(21) Appl. No.: **17/080,969**

(22) Filed: **Oct. 27, 2020**

Related U.S. Application Data

(60) Provisional application No. 62/932,534, filed on Nov. 8, 2019.

(51) **Int. Cl.**

F01D 5/18 (2006.01)
F01D 9/04 (2006.01)
F01D 11/12 (2006.01)
F01D 25/12 (2006.01)

(52) **U.S. Cl.**

CPC ***F01D 5/187*** (2013.01); ***F01D 9/041*** (2013.01); ***F01D 11/122*** (2013.01); ***F01D 25/12*** (2013.01); *F05D 2240/12* (2013.01); *F05D 2240/55* (2013.01); *F05D 2240/81* (2013.01); *F05D 2250/185* (2013.01); *F05D 2260/232* (2013.01); *F05D 2260/606* (2013.01)

(58) **Field of Classification Search**

CPC F01D 5/187; F01D 9/041; F01D 11/122; F01D 25/12; F05D 2240/12; F05D 2240/55; F05D 2240/81; F05D 2250/185; F05D 2260/232; F05D 2260/606

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,820,116	A *	4/1989	Hovan	F01D 1/32 415/115
8,979,482	B2 *	3/2015	Khanin	F01D 11/10 415/115
9,334,754	B2	5/2016	Khanin et al.	
9,988,934	B2 *	6/2018	Spangler	F01D 25/246
10,400,627	B2	9/2019	Ning et al.	
2002/0148233	A1 *	10/2002	Tiemann	F01D 5/187 60/806
2003/0035717	A1 *	2/2003	Tiemann	F02C 7/185 415/115
2012/0134781	A1 *	5/2012	Khanin	F01D 5/187 415/115
2012/0257954	A1 *	10/2012	Chanteloup	F01D 5/187 415/115
2016/0230663	A1 *	8/2016	Mizukami	F02C 7/14
2018/0135460	A1	5/2018	Barker et al.	

* cited by examiner

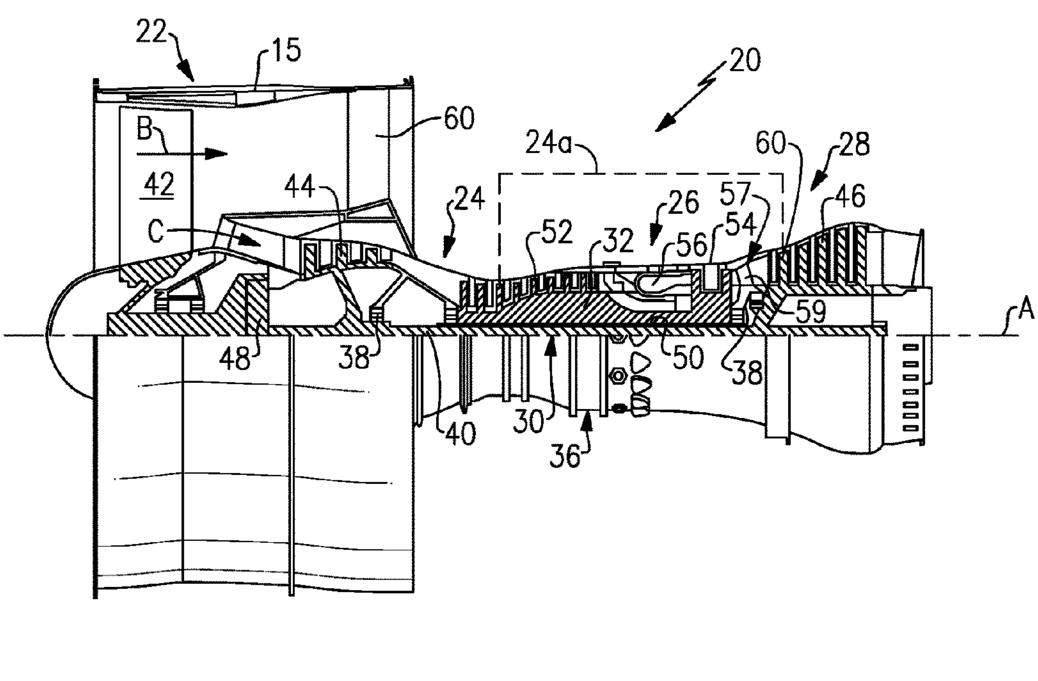
Primary Examiner — Igor Kershteyn

(74) *Attorney, Agent, or Firm* — Carlson, Gaskey & Olds, P.C.

(57) **ABSTRACT**

A gas turbine engine includes a blade outer air seal, a ceramic vane, and a cooling passage circuit that extends through a first internal passage in the blade outer air seal and a second internal passage in the ceramic vane.

18 Claims, 3 Drawing Sheets



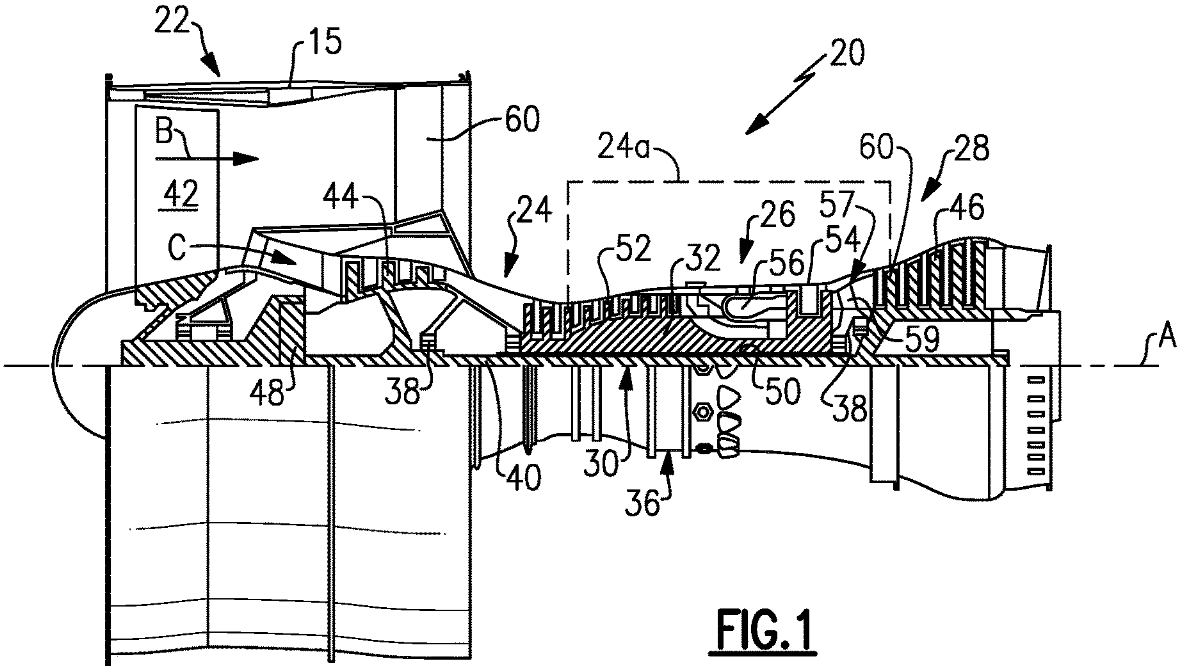

22
15
20
60
B
42
24a
60
28
44
24
26
57
46
C
52
32
56
54
59
A
48
38
50
38
40
30
36

FIG.1

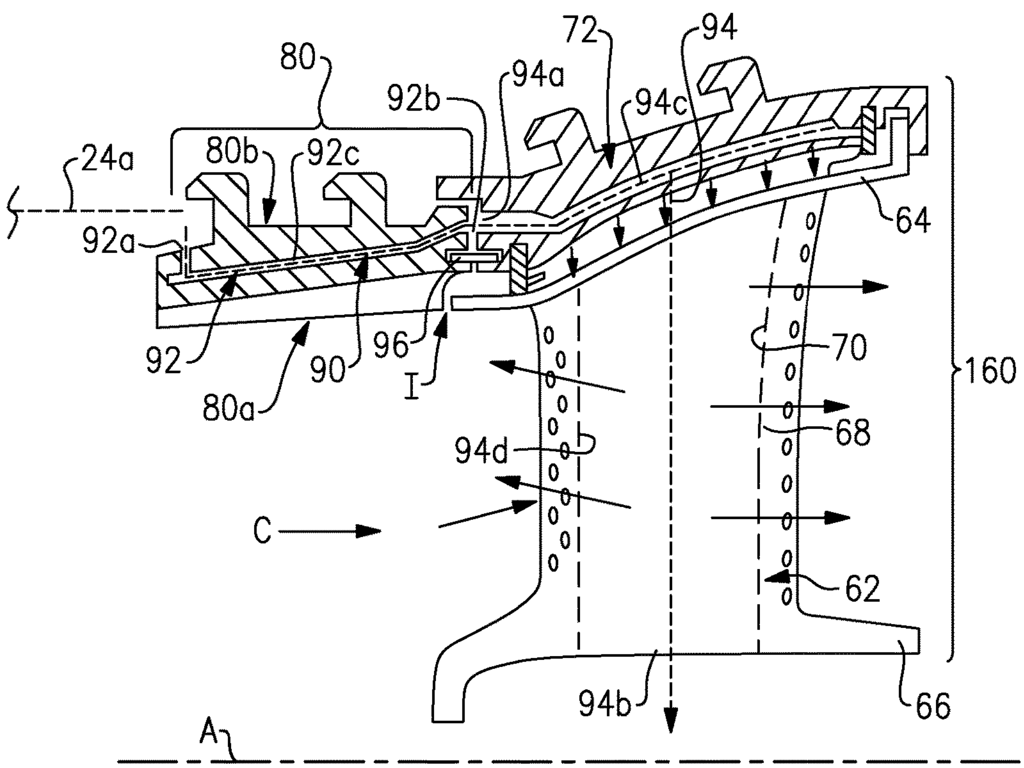

80
72
94
92b
94a
94c
24a
80b
92c
92a
64
70
160
92
90
96
I
80a
68
94d
C
62
94b
66
A

FIG.3

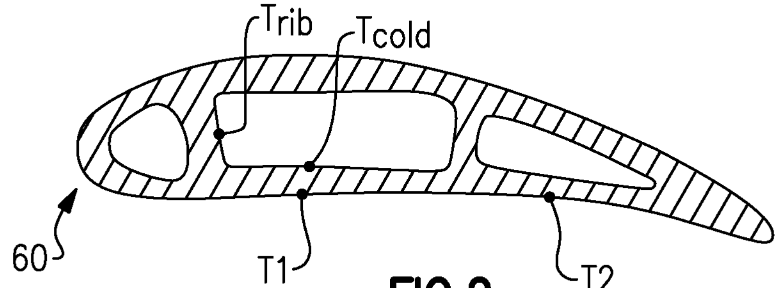

Trib
Tcold
60
T1
T2

FIG.2

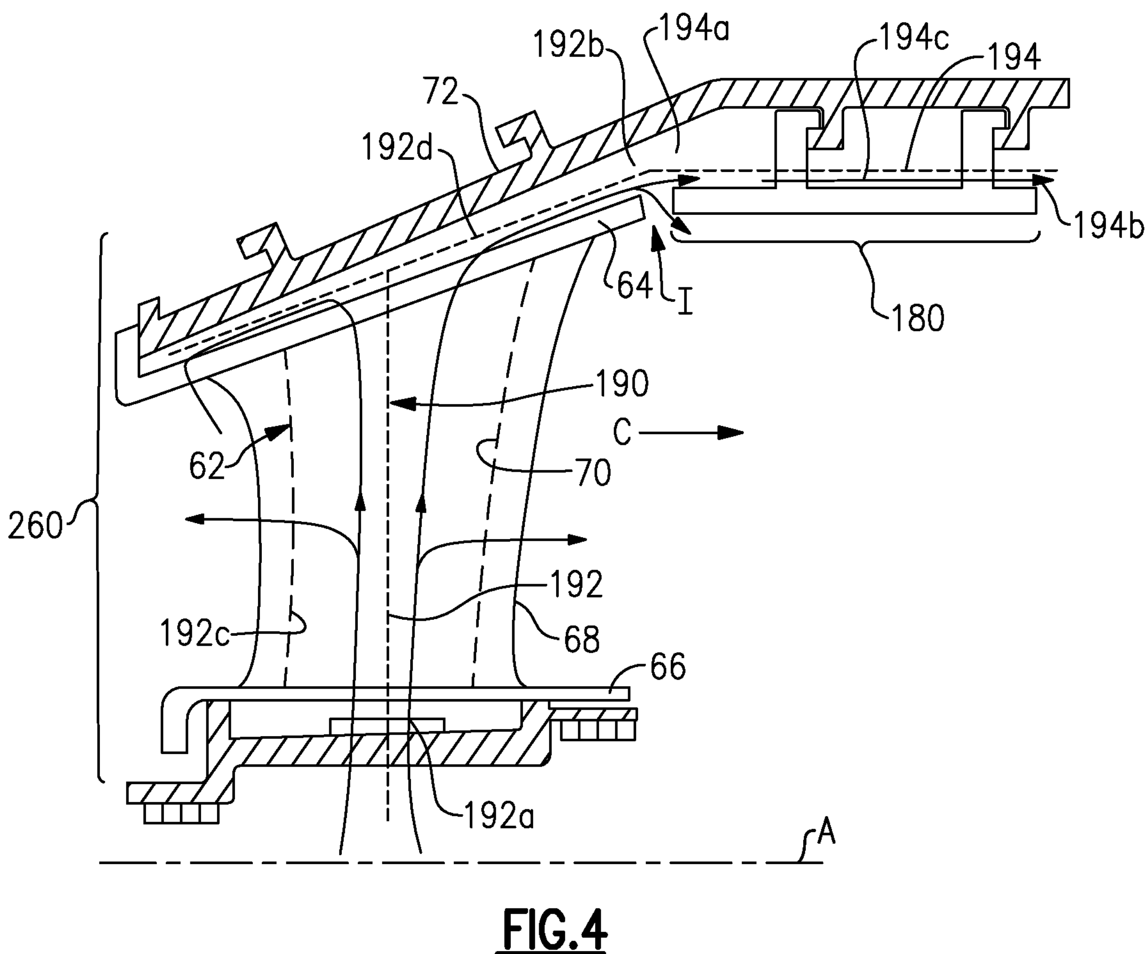

192b
194a
194c
194
72
192d
194b
64
I
180
190
C
62
70
260
192
192c
68
66
192a
A

FIG.4

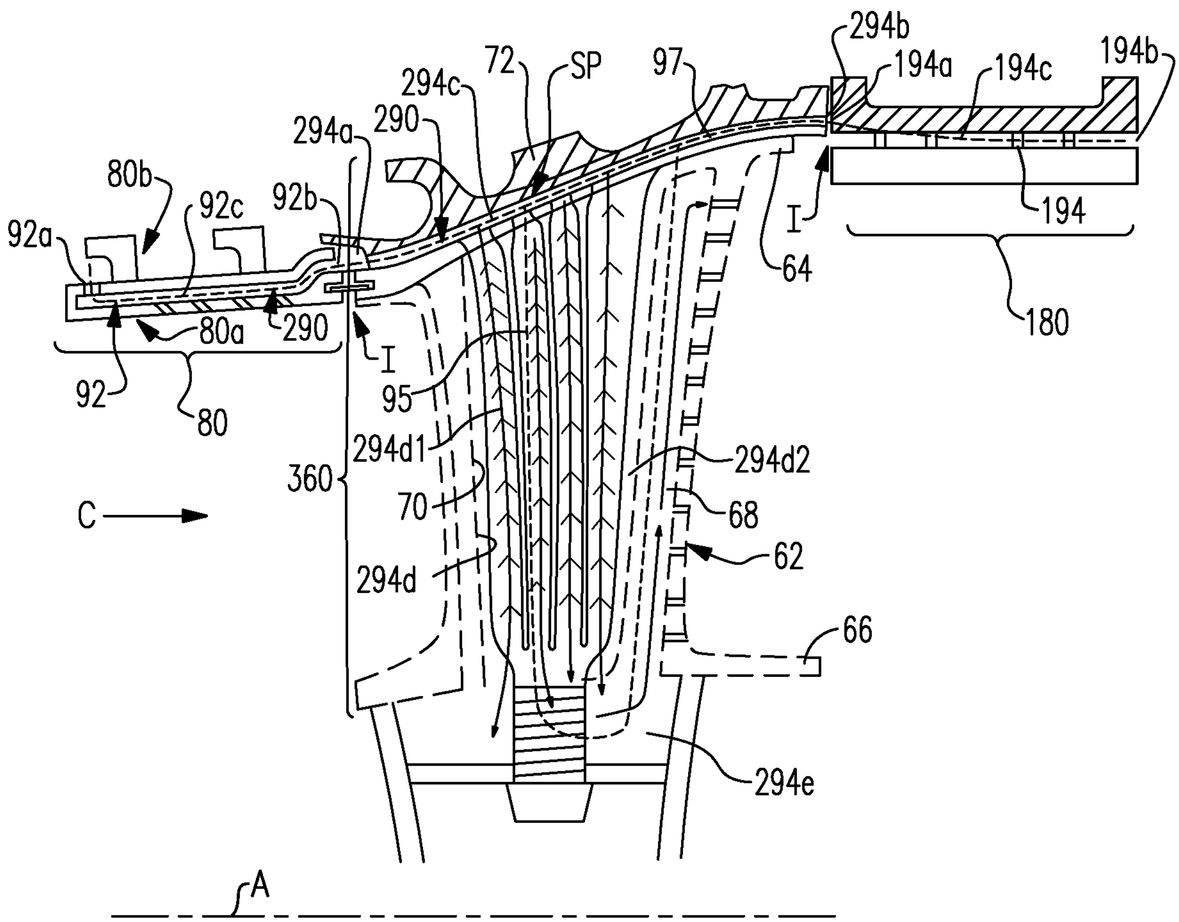

294b
194a
194c
194b
97
SP
72
294c
290
294a
80b
92c
92b
92a
80a
290
92
80
I
95
294d1
360
70
C
294d
194
180
I
64
294d2
68
62
66
294e
A

FIG.5

ENGINE WITH COOLING PASSAGE CIRCUIT FOR AIR PRIOR TO CERAMIC COMPONENT

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority to U.S. Provisional Application No. 62/932,534 filed Nov. 8, 2019.

BACKGROUND

A gas turbine engine typically includes a fan section, a compressor section, a combustor section and a turbine section. Air entering the compressor section is compressed and delivered into the combustion section where it is mixed with fuel and ignited to generate a high-speed exhaust gas flow. The high-speed exhaust gas flow expands through the turbine section to drive the compressor and the fan section. The compressor section typically includes low and high pressure compressors, and the turbine section includes low and high pressure turbines.

Components in the turbine section are typically formed of a superalloy and may include thermal barrier coatings to extend temperature resistance. Ceramic matrix composite ("CMC") materials are also being considered. CMCs have high temperature resistance. Despite this attribute however, there are unique challenges to implementing CMCs.

SUMMARY

A gas turbine engine according to an example of the present disclosure includes a blade outer air seal, a ceramic vane, and a cooling passage circuit that extends through a first passage of the blade outer air seal and through a second passage of the ceramic vane.

In a further embodiment of any of the foregoing embodiments, the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and further includes an interface seal sealing the cooling passage between the blade outer air seal and the radially outer platform.

In a further embodiment of any of the foregoing embodiments, the blade outer air seal is forward of the ceramic vane.

In a further embodiment of any of the foregoing embodiments, the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes a first leg in the blade outer air seal and a second leg in the radially outer platform, where the second leg splits into a third leg in the airfoil section and a bypass leg that bypasses the airfoil section.

In a further embodiment of any of the foregoing embodiments, the third leg is serpentine.

In a further embodiment of any of the foregoing embodiments, the bypass leg connects to an axial outlet in the radially outer platform.

A further embodiment of any of the foregoing embodiments includes an aft blade outer air seal that is aft of the ceramic vane, and the cooling passage circuit includes a fourth leg in the aft blade outer air seal that is connected with the bypass leg.

In a further embodiment of any of the foregoing embodiments, the blade outer air seal is aft of the ceramic vane.

In a further embodiment of any of the foregoing embodiments, the ceramic vane includes radially inner and outer

platforms and an airfoil section that extend there between, and the cooling passage circuit includes a radial inlet in the inner platform and an axial outlet in the outer platform.

In a further embodiment of any of the foregoing embodiments, the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes an axial inlet in the outer platform and a radial outlet in the inner platform.

A gas turbine engine according to an example of the present disclosure includes a compressor section that has a tap for providing cooling air, a combustor in fluid communication with the compressor section and a turbine section in fluid communication with the combustor. The turbine section has a first component, a second component that is formed of ceramic and that is axially aft of the first component, and a cooling passage circuit that extends through the first component and the second component. The cooling passage circuit is configured to deliver the cooling air into the first component where the cooling air is heated to provide pre-heated cooling air, and then deliver the pre-heated cooling air from the first component into the second component.

In a further embodiment of any of the foregoing embodiments, the first component is a vane and the second component is a blade outer air seal.

In a further embodiment of any of the foregoing embodiments, the first component is a blade outer air seal and the second component is a vane.

In a further embodiment of any of the foregoing embodiments, the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and further includes an interface seal sealing the cooling passage between the blade outer air seal and the radially outer platform.

In a further embodiment of any of the foregoing embodiments, the cooling passage circuit includes a bypass leg.

In a further embodiment of any of the foregoing embodiments, the cooling passage circuit includes a serpentine section.

A further embodiment of any of the foregoing embodiments includes a third component aft of the second component, and the cooling passage circuit additionally extends in the third component.

A method for cooling a ceramic vane according to an example of the present disclosure includes providing a cooling passage circuit through first and second components in a turbine section of a gas turbine engine, and routing cooling air through the cooling passage circuit in the first component. The first component heats the cooling air to provide pre-heated cooling air. The pre-heated cooling air is then routed from the first component into the cooling passage circuit in the second component. The second component is formed of ceramic.

In a further embodiment of any of the foregoing embodiments, the first component is a blade outer air seal and the second component is a vane.

In a further embodiment of any of the foregoing embodiments, the cooling passage circuit includes a bypass leg and a serpentine section.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

FIG. **1** illustrates a gas turbine engine.

FIG. **2** illustrates a section view of an example component.

FIG. **3** illustrates an example in which cooling air is pre-heated in a blade outer air seal prior to being received into a ceramic vane.

FIG. **4** illustrates an example in which cooling air is pre-heated in a vane prior to being received into a ceramic blade outer air seal.

FIG. **5** illustrates an example in which cooling air is pre-heated in a forward blade outer air seal prior to being received into a ceramic vane, and where the cooling air is further pre-heated in the vane prior to being received into an aft ceramic blade outer air seal.

DETAILED DESCRIPTION

FIG. **1** schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. The fan section **22** drives air along a bypass flow path B in a bypass duct defined within a nacelle **15**, and also drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.

The low speed spool **30** generally includes an inner shaft **40** that interconnects, a first (or low) pressure compressor **44** and a first (or low) pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive a fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a second (or high) pressure compressor **52** and a second (or high) pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. A mid-turbine frame **57** of the engine static structure **36** may be arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The mid-turbine frame **57** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

The core airflow is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **57** includes airfoils **59** which are in the core airflow path C. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of the low pressure compressor, or aft of the combustor section **26** or even aft of turbine section **28**, and fan **42** may be positioned forward or aft of the location of gear system **48**.

The engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the engine **20** bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture **48** is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine **46** has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine **20** bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **44**, and the low pressure turbine **46** has a pressure ratio that is greater than about five 5:1. Low pressure turbine **46** pressure ratio is pressure measured prior to inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1 and less than about 5:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet (10,668 meters). The flight condition of 0.8 Mach and 35,000 ft (10,668 meters), with the engine at its best fuel consumption—also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC)"—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(Tram ° R)/(518.7° R)]^0.5. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second (350.5 meters/second).

FIG. **2** illustrates an example component **60** from the turbine section **28** of the engine **20** in order to demonstrate aspects of the disclosure. In this example, the component **60** is a vane, although it is to be understood that the component **60** may alternatively be a blade outer air seal, for example. The component **60** is formed of ceramic. The ceramic may be a monolithic ceramic or a ceramic matrix composite ("CMC"). Example ceramic material may include, but is not limited to, silicon-containing ceramics. The silicon-containing ceramic may be, but is not limited to, silicon carbide (SiC) or silicon nitride (Si_3N_4). An example CMC may be a SiC/SiC CMC in which SiC fibers are disposed within a SiC matrix. As used herein, "formed of" refers to the structural self-supporting body of the component **60**, rather than a conformal body such as a coating.

In general, components that are formed of ceramic present thermal management challenges that are unlike metallic components. Metallic alloys have relatively high strength and ductility. Thus, although metallic components are often cooled, the ductility enables the metallic components to withstand high thermal gradients between exterior surfaces in the core gas path and interior surfaces that are cooled. Ceramic materials have relatively higher thermal resistance, but lower thermal conductivity and lower ductility in comparison to metallic materials. As a result, cooling a ceramic component may actually be detrimental to durability because high thermal gradients may cause thermal stresses that exceed the limits of the ceramic.

For instance, FIG. **2** shows relative temperatures T**1**, T**2**, Trib, and Tcold at different locations in the component **60** (such as during cruise). A thermal gradient between any two points can be calculated or estimated as the quotient of the temperature difference between the points divided by the distance along the wall or walls between the points. Unless indicated otherwise, the thermal gradient may be represented in units of degree Celsius per millimeter. A thermal gradient can be measured experimentally and/or estimated via computer simulation. The points T**1** and T**2** are on the exterior surface of the wall of the component **60**, directly in the core gas path C. The point Trib is in the middle portion of an internal rib in the component **60**, and the point Tcold is at the internal surface of the wall opposite of the point T**1**. For example, thermal gradients due to the temperature differences (T**1**−Trib), (T**1**−Tcold), and (T**2**−T**1**) which exceed a threshold of the ceramic may reduce durability of the component **60**. The thermal gradient may manifest in through-wall thickness, bulk temperature differences between different structures (e.g., a rib and an adjacent external wall), and/or in the plane of a wall. If relatively cool air, such as bleed air from the compressor section **24**, is used directly to cool the component **60**, the above thermal gradients may be exacerbated. For instance, the thermal gradients may be temperature differences of at least 150° C., 200° C., 300° C., or more than 400° C.

In this regard, as will be discussed below, the compressor section **24** includes a tap **24***a* (see also FIG. **1**) for providing cooling air to a cooling passage circuit that serves to pre-heat the cooling air before the cooling air is provided into the ceramic component. The pre-heated cooling air provides a cooling effect in the component but enables the component to maintain lower thermal gradients, particularly in structural locations such as ribs or support or attachment features, in comparison to non-pre-heated cooling. The non-limiting examples below demonstrate various configurations. In this disclosure, like reference numerals designate like elements where appropriate and reference numerals with the addition of one-hundred or multiples thereof designate modified elements that are understood to incorporate the same features and benefits of the corresponding elements.

FIG. **3** illustrates a component **160**. In this example, the component **160** is a vane arc segment that is situated in a circumferential row about the engine central axis A. The component **160** is comprised of an airfoil piece **62** that is formed of a ceramic as discussed above. The airfoil piece **62** includes several sections, including first and second platforms **64**/**66** and an airfoil section **68** that extends between the first and second platforms **64**/**66**. The airfoil section **68** is hollow and defines one or more internal passages or cavities **70**. In this example, the first platform **64** is a radially outer platform and the second platform **66** is a radially inner platform. The terminology "first" and "second" as used herein is to differentiate that there are two architecturally distinct components or features. It is to be further understood that the terms "first" and "second" are interchangeable in the embodiments herein in that a first component or feature could alternatively be termed as the second component or feature, and vice versa.

The component **160** further includes a structural support **72**. For example, the structural support **72** may be a spar or a case structure. The structural support **72** portion may be formed of metal, such as a nickel- or cobalt-based superalloy.

Another component **80** is situated adjacent the component **160**. In this example, the component **80** is a blade outer air seal and is located forward of the component **160**. The component **80** may be considered to be a first component, and the component **160** may be considered to be a second component. The blade outer air seal includes a gas path side **80***a* and a non-gas path side **80***b*. The non-gas path side **80***b* may include hooks or other type or attachment features for supporting the blade outer air seal.

There is a cooling passage circuit **90** that extends through the component **80** (blade outer air seal) and the component **160** (vane arc segment). The cooling passage circuit **90** is comprised of a network of interconnected passages among the components **80**/**160**. The passages and structures described in the cooling passage circuits herein are understood to route cooling air as discussed. It is thus to be understood that the description also embodies methods of routing the cooling air.

The cooling passage circuit **90** includes several circuit legs, or sections. In this example, a first leg **92** is in the component **80** and a second leg **94** is in the component **160**. For instance, the first leg **92** includes an inlet **92***a*, an outlet **92***b*, and an internal passage **92***c* in the blade outer air seal. Here, the inlet **92***a* is a radial inlet and the outlet **92***b* is an axial outlet. The inlet **92***a* is connected to a cooling air source, such as the compressor section **24**.

The second leg **94** includes an inlet **94***a*, an outlet **94***b*, a supply passage **94***c*, and an internal passage **94***d* in the airfoil section **68** (which here is the same as the internal passage **70**). The inlet **94***a* and supply passage **94***c* are formed in part or in whole by the structural support **72**. The supply passage **94***c* connects the inlet **94***a* with the internal passage **94***d* in the airfoil section **68**. The internal passage **94***d* connects the supply passage **94** with the outlet **94***b*. For instance, the outlet **94***b* may be a port in the platform **66**.

When the engine **20** is in operation, the cooling air source provides cooling air to the cooling passage circuit **90**. The cooling air is initially provided through the inlet **92***a* and into the internal passage **92***c* in the component **80**. The cooling air flows generally axially in the internal passage **92***c* and then exits the component **80** axially from the outlet **92***b*. The cooling air in the internal passage **92***c* picks up heat from the walls of the component **80**, thereby substantially increasing the temperature of the cooling air before it exits the component **80** (as pre-heated cooling air). For example, the cooling air may increase in temperature by at least 50° C., by at least 100° C., or by more than 200° C.

The inlet **94***a* receives the pre-heated cooling air from the outlet **92***b* and feeds the pre-heated cooling air to the supply passage **94***c*. The pre-heated cooling air may pick up additional heat in the supply passage **94***c*, and thereby further increase in temperature. The supply passage **94***c* feeds the pre-heated cooling air into the internal passage **94***d* to cool the airfoil section **68**. The airfoil section **68** may discharge a portion of the pre-heated cooling air for film cooling. The remaining pre-heated cooling air exits through the outlet **94***b*.

By first flowing through the component **80** to be pre-heated, the cooling air received into the component **160** is warmer than it otherwise would have been if received directly from the cooling air source. The relatively warmer pre-heated cooling air maintains at least a portion of the component **160** at a desired thermal gradient. For instance, if cooling air were used directly from the cooling air source, the internal surfaces of the component would be cooled to a greater degree, thereby creating relatively large thermal gradients as discussed above. As an example, thermal gradients in the component **160** may be maintained at a temperature differential of 400° C. or less, 300° C. or less, or 150° C. or less.

The outlet **92***b* and the inlet **94***a* are at an interface (I) between the components **80**/**160**. The cooling passage circuit **90** may also include one or more interface seals **96** in the interface (I) to seal the cooling passage circuit **90** and limit escape of the cooling air into the core gas path C. For example, the interface seal **96** may be, but is not limited to, a feather seal.

FIG. **4** illustrates another example, in which component **180** is aft of component **260**. In this example, the component **180** is a blade out air seal and the component **260** is a vane arc segment. At least the component **180** is formed of a ceramic as discussed above, but the airfoil piece **62** may also be formed of a ceramic as discussed above. There is a cooling passage circuit **190** that extends through the component **260** (vane arc segment) and the component **180** (blade outer air seal). In this example, the component **260** may be considered to be a first component, and the component **180** may be considered to be a second component.

The cooling passage circuit **190** includes several circuit legs, or sections. In this example, a first leg **192** is in the component **260** and a second leg **194** is in the component **180**. For instance, the first leg **192** includes an inlet **192***a*, an outlet **192***b*, an internal passage **192***c* (which in this example is the internal passage **70**), and a supply passage **192***d*. Here, the inlet **192***a* is a radial inlet or port in the platform **66** and the outlet **192***b* is an axial outlet. The inlet **192***a* is connected to a cooling air source, such as the compressor section **24**. The internal passage **192***c* connects the inlet **192***a* with the supply passage **192***d*. The supply passage **192***d* connects the passage **192***c* with the outlet **192***b*. For instance, the supply passage **192***d* and the outlet **192***b* are formed in part or in whole by the structural support **72**.

The second leg **194** includes an inlet **194***a*, an outlet **194***b*, and a passage **194***c*. The inlet **194***a*, outlet **194***b*, and passage **194***c* are formed in part or in whole by the blade outer air seal.

When the engine **20** is in operation, the cooling air source provides cooling air to the cooling passage circuit **190**. The cooling air is initially provided through the inlet **192***a* and into the internal passage **192***c* in the component **260**. The cooling air flows generally radially in the internal passage **192***c* and then into the supply passage **192***d*. The cooling air then exits the component **260** axially from the outlet **192***b*. The cooling air in the internal passage **192***c* and the supply passage **192***d* picks up heat from the walls of the component **260**, thereby substantially increasing the temperature of the cooling air before it exits the component **260** (as pre-heated cooling air). For example, the cooling air may increase in temperature by at least 50° C., by at least 100° C., or by more than 200° C.

The inlet **194***a* receives the pre-heated cooling air from the outlet **192***b* and feeds the pre-heated cooling air to the passage **194***c* to cool the component **180**. The pre-heated cooling air is then discharged from the component **180** through the outlet **194***b*. In this example, there is no interface seal in the interface (I) and a portion of the pre-heated cooling air may escape through the interface (I). The escape of the cooling air here may serve to purge the interface (I).

By first flowing through the component **260** to be pre-heated, the cooling air received into the component **180** is warmer than it otherwise would have been if received directly from the cooling air source. The relatively warmer pre-heated cooling air maintains at least a portion of the component **180** at a desired thermal gradient, similar to as discussed above.

FIG. **5** illustrates a further example that is a modified combination of the prior examples. Here, components **80** and **180** are substantially as described above unless otherwise modified below. However, component **360** is configured to both receive the pre-heated cooling air from the component **80** and also deliver the further pre-heated cooling air to the component **180**. In this example, at least the airfoil piece **62** is formed of a ceramic as discussed above, and the component **180** may also be formed of a ceramic as discussed above.

There is a cooling passage circuit **290** that extends through the component **80** (forward blade outer air seal), the component **360** (vane arc segment), and component **180** (aft blade outer air seal). The cooling passage circuit **290** includes several circuit legs, or sections. In this example, the first leg **92** is in the component **80** as discussed above. A second leg **294** extends in the radially outer platform **64** of the component **360**. The second leg **294** splits, as represented at split (SP), into a third leg **95** in the airfoil section **68** and a bypass leg **97** that bypasses the airfoil section **62**.

In this example, component **360** includes an inlet **294***a*, an outlet **294***b*, a supply passage **294***c*, an internal passage **294***d* (which in this example is the internal passage **70**), and a turn section **294***e*. The second leg **294** includes the inlet **294***a* and a portion of the supply passage **294***c*. The supply passage **294***c* splits into the internal passage **294***d*. The remaining portion of the supply passage **294***c* continues past the split and serves as the structure for the bypass leg **97**. The bypass leg **97** portion of the supply passage **294***c* connects to the outlet **294***b*.

The third leg **95** includes the internal passage **294***d* and the turn section **294***e*. The internal passage **294***d* includes at least one feed sub-passage **294***d***1** and at least one return sub-passage **294***d***2**. The feed sub-passage **294***d***1** is connected to the supply passage **294***c* and the turn section **294***e*. The return sub-passage **294***d***2** is connected to the turn section **294***e* and the bypass leg **97** portion of the supply passage **294***c*. The feed sub-passage **294***d***1**, the turn section **294***e*, and the return sub-passage **294***d***2** together form a serpentine as the third leg **95** of the cooling passage circuit **290**.

The component **180** is substantially as described above, except that **194** represents a fourth leg of the cooling passage circuit **290**.

The cooling air is pre-heated in the component **80** as described above and then fed to the inlet **294***a*. The pre-heated cooling air flows through the supply passage **294***c*. A portion of the cooling air splits off into the feed sub-passage **294***d***1** and a remaining portion of the cooling air continues to flow past the split into the bypass leg **97** portion of the supply passage **294***c*. The cooling air in the feed sub-passage **294***d***1** cools the airfoil section **68** and flows radially inwards toward the platform **66** and then into the turn section **294***e*. The turn section **294***e* redirects the cooling air, which then flows into the return sub-passage **294***d***2** to further cool the airfoil section **68**. The return sub-passage **294***d***2** feeds the cooling air to the bypass leg **97** of the supply passage **294***c*, which then feeds the cooling air to the outlet **294***b*. The further pre-heated cooling air then flows into the component **180** as described above. The cooling air is thus twice pre-heated prior to being received into the component **180**—a first pre-heating in the component **80** and a second pre-heating in the component **360**.

Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

What is claimed is:

1. A gas turbine engine comprising:
a blade outer air seal;
a ceramic vane including radially inner and outer platforms and an airfoil section that extends there between;
a cooling passage circuit extending through a first passage of the blade outer air seal and through a second passage of the ceramic vane, the cooling passage circuit including a first leg in the blade outer air seal and a second leg in the radially outer platform, the second leg splitting into a third leg in the airfoil section and a bypass leg that bypasses the airfoil section.

2. The gas turbine engine as recited in claim **1**, wherein the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and further comprising an interface seal sealing the cooling passage between the blade outer air seal and the radially outer platform.

3. The gas turbine engine as recited in claim **1**, wherein the blade outer air seal is forward of the ceramic vane.

4. The gas turbine engine as recited in claim **1**, wherein the third leg is serpentine.

5. The gas turbine engine as recited in claim **4**, wherein the bypass leg connects to an axial outlet in the radially outer platform.

6. The gas turbine engine as recited in claim **5**, further comprising an aft blade outer air seal that is aft of the ceramic vane, and the cooling passage circuit includes a fourth leg in the aft blade outer air seal that is connected with the bypass leg.

7. The gas turbine engine as recited in claim **1**, wherein the blade outer air seal is aft of the ceramic vane.

8. The gas turbine engine as recited in claim **1**, wherein the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes a radial inlet in the inner platform and an axial outlet in the outer platform.

9. The gas turbine engine as recited in claim **1**, wherein the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes an axial inlet in the outer platform and a radial outlet in the inner platform.

10. A gas turbine engine comprising:
a compressor section having tap for providing cooling air;
a combustor in fluid communication with the compressor section; and
a turbine section in fluid communication with the combustor, the turbine section including
a blade outer air seal,
a ceramic vane including radially inner and outer platforms and an airfoil section that extends there between, and
a cooling passage circuit extending through the blade outer air seal and the ceramic vane, the cooling passage circuit configured to deliver the cooling air into one of the blade outer air seal or the ceramic vane where the cooling air is heated to provide pre-heated cooling air, and then deliver the pre-heated cooling air from the one of the blade outer air seal or the ceramic vane into the other of the blade outer air seal or the ceramic vane, and
an interface seal sealing the cooling passage between the blade outer air seal and the radially outer platform.

11. The gas turbine engine as recited in claim **10**, wherein the cooling passage circuit includes a bypass leg.

12. The gas turbine engine as recited in claim **11**, wherein the cooling passage circuit includes a serpentine section.

13. The gas turbine engine as recited in claim **10**, further comprising a component aft of the ceramic vane, and the cooling passage circuit additionally extends in the component.

14. A gas turbine engine comprising:
a blade outer air seal;
a ceramic vane;
a cooling passage circuit extending through a first passage of the blade outer air seal and through a second passage of the ceramic vane.

15. The gas turbine engine as recited in claim **14**, wherein the ceramic vane is a ceramic matrix composite and includes radially inner and outer platforms and an airfoil section that extend there between, and further comprising an interface seal sealing the cooling passage between the blade outer air seal and the radially outer platform.

16. The gas turbine engine as recited in claim **15**, wherein the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes a first leg in the blade outer air seal and a second leg in the radially outer platform, where the second leg splits into a third leg in the airfoil section and a bypass leg that bypasses the airfoil section.

17. The gas turbine engine as recited in claim **16**, wherein the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes a radial inlet in the inner platform and an axial outlet in the outer platform.

18. The gas turbine engine as recited in claim **16**, wherein the ceramic vane includes radially inner and outer platforms and an airfoil section that extend there between, and the cooling passage circuit includes an axial inlet in the outer platform and a radial outlet in the inner platform.

* * * * *