US009624784B2

(12) **United States Patent**
Hafner

(10) **Patent No.: US 9,624,784 B2**
(45) **Date of Patent: *Apr. 18, 2017**

(54) **TURBINE SEAL SYSTEM AND METHOD**

(71) Applicant: **General Electric Company**, Schenectady, NY (US)

(72) Inventor: **Matthew Troy Hafner**, Greenville, SC (US)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 845 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/937,109**

(22) Filed: **Jul. 8, 2013**

(65) **Prior Publication Data**

US 2015/0010393 A1 Jan. 8, 2015

(51) **Int. Cl.**
F01D 11/00 (2006.01)
F01D 5/30 (2006.01)

(52) **U.S. Cl.**
CPC ***F01D 11/001*** (2013.01); ***F01D 5/3015*** (2013.01); ***F01D 11/003*** (2013.01); ***F01D 11/005*** (2013.01); ***F01D 11/006*** (2013.01); ***F01D 11/008*** (2013.01); *Y10T 29/49245* (2015.01)

(58) **Field of Classification Search**
CPC F01D 11/001; F01D 11/003; F01D 11/005; F01D 11/006; F01D 11/008; F01D 5/3015; F05D 2240/55; Y10T 29/49245
USPC 415/173.7
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,295,825	A *	1/1967	Hall, Jr.	F01D 5/06 415/173.7
3,814,539	A	6/1974	Klompas	
4,088,422	A *	5/1978	Martin	F01D 5/06 415/173.7
4,582,467	A *	4/1986	Kisling	F01D 5/3015 415/115
4,869,640	A *	9/1989	Schwarz	F01D 11/001 415/173.7
4,884,950	A	12/1989	Brodell et al.	
6,398,488	B1 *	6/2002	Solda	F01D 5/081 415/173.7
7,220,099	B2	5/2007	Bekrenev et al.	

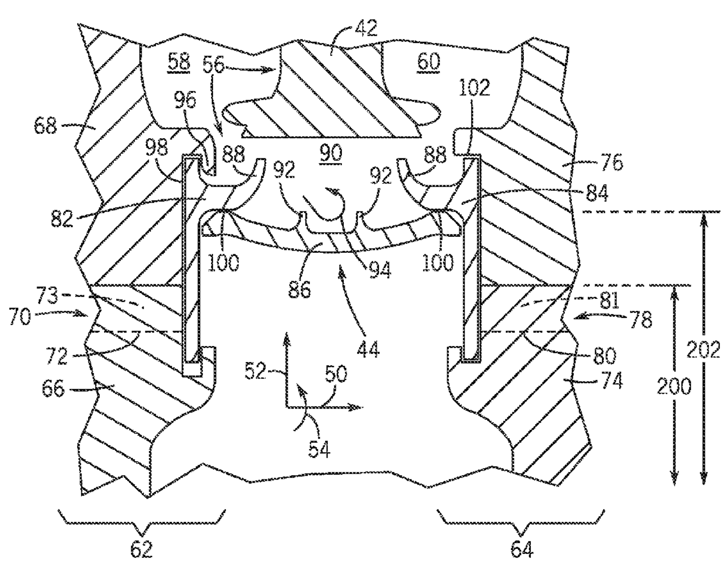
(Continued)

Primary Examiner — Craig Kim
Assistant Examiner — Brian P Wolcott
(74) *Attorney, Agent, or Firm* — Fletcher Yoder, P.C.

(57) **ABSTRACT**

A system includes a multi-stage turbine that includes a first turbine stage having a first wheel having a plurality of first blade segments spaced circumferentially about the first wheel. The turbine also includes a second turbine stage having a second wheel having a plurality of second blade segments spaced circumferentially about the second wheel. The turbine also includes a seal assembly extending axially between the first and second turbine stages. The seal assembly includes a first coverplate coupled to the first turbine stage. The first coverplate includes a first air director. The seal assembly also includes a second coverplate coupled to the second turbine stage. The second coverplate comprises a second air director. The seal assembly also includes an interstage seal. The first coverplate, the second coverplate, or both are configured to support the interstage seal.

20 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

8,845,284	B2	9/2014	Farrell et al.	
2010/0074732	A1*	3/2010	Marra	F01D 5/025 415/173.4

* cited by examiner

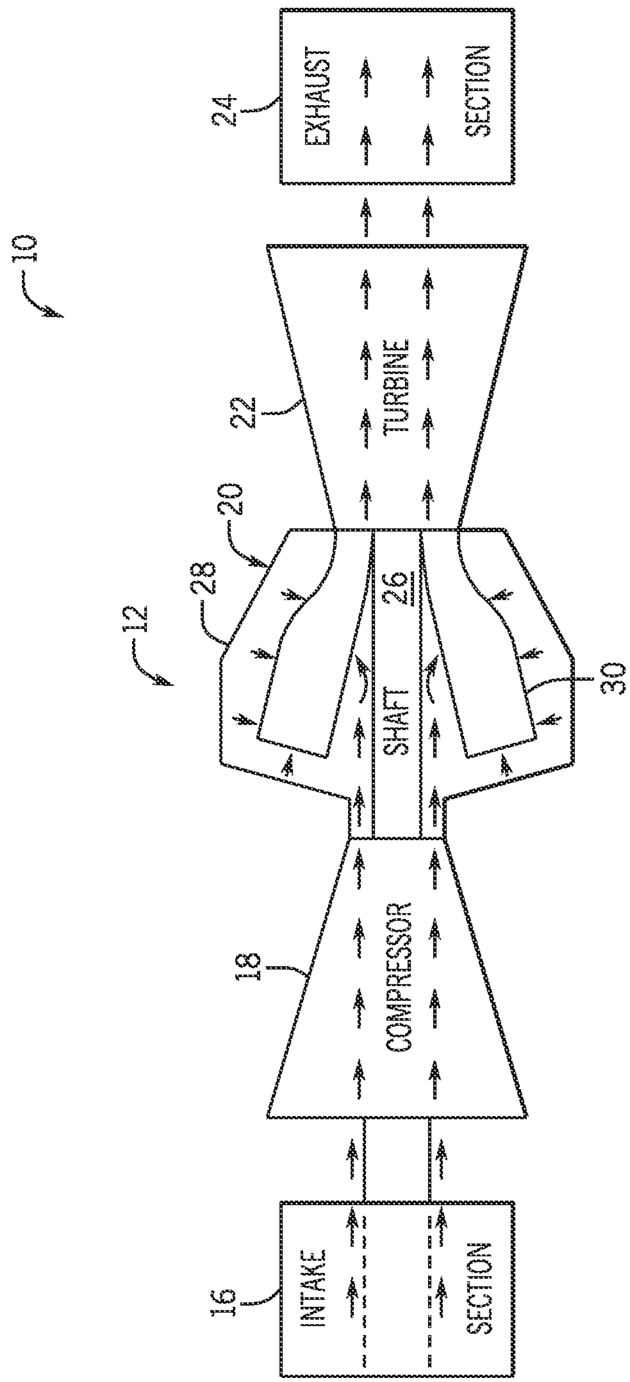

10
12
16
INTAKE
SECTION
18
COMPRESSOR
20
22
TURBINE
24
EXHAUST
SECTION
26
SHAFT
28
30

FIG. 1

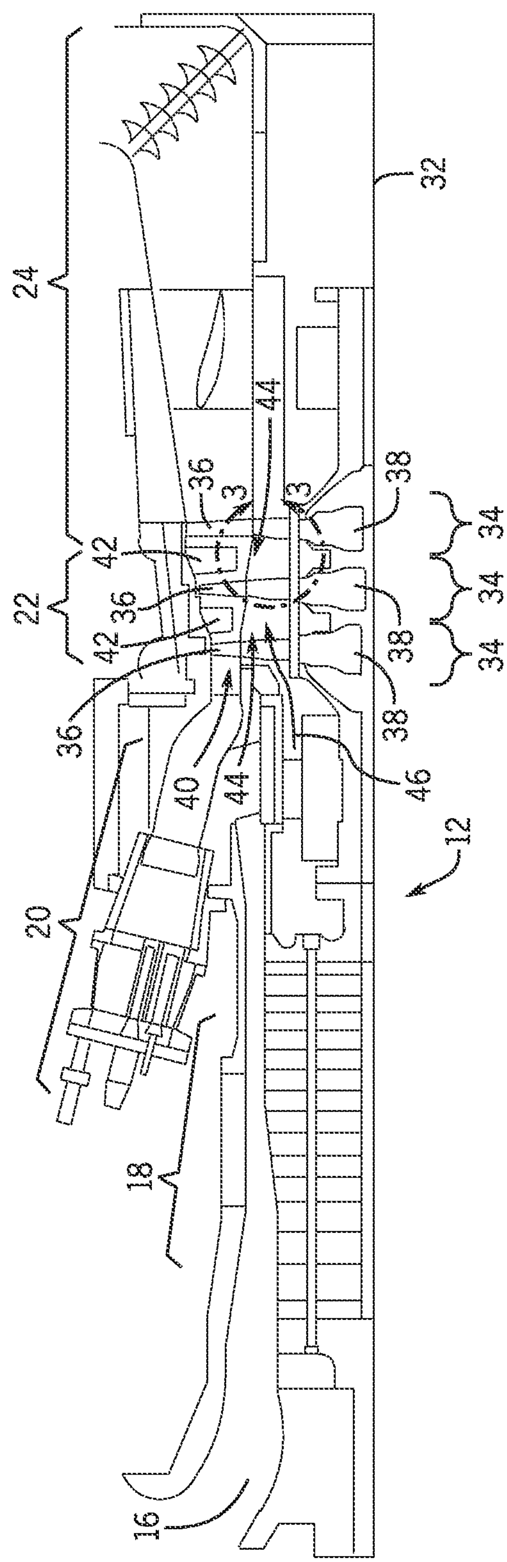


FIG. 2

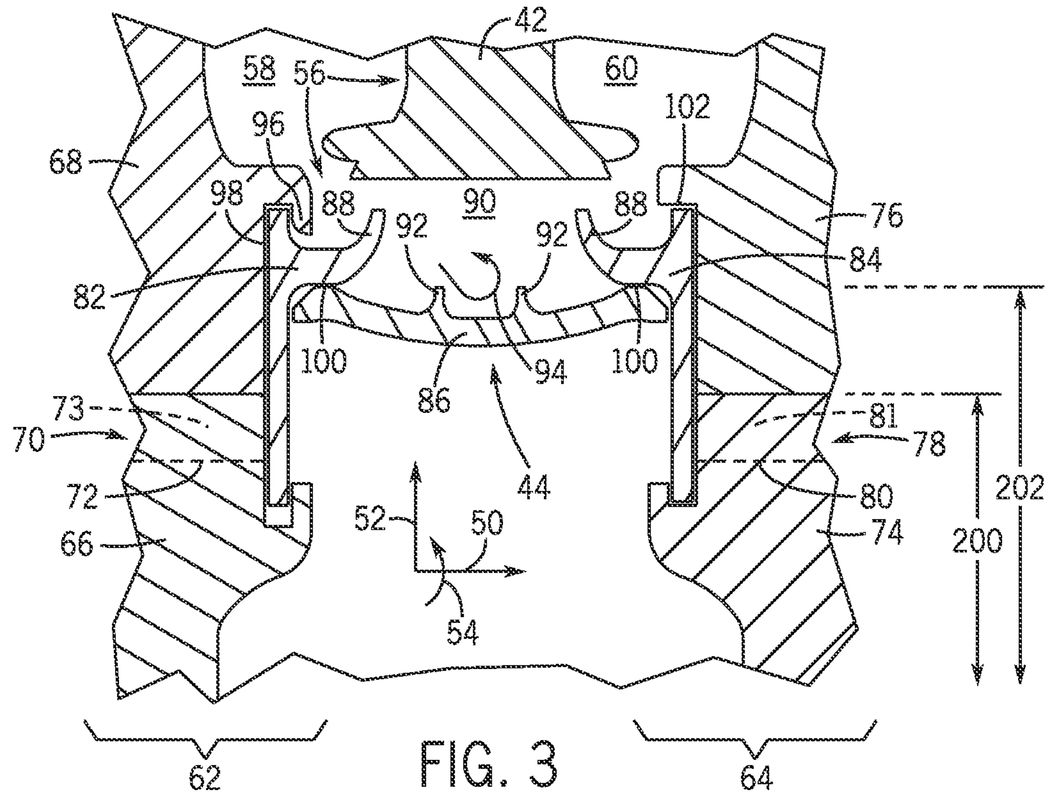

42
58
56
60
102
96
68
98
88
90
92
88
76
84
82
100
86
94
100
73
70
81
78
72
80
202
44
52
50
66
74
200
54
62
64

FIG. 3

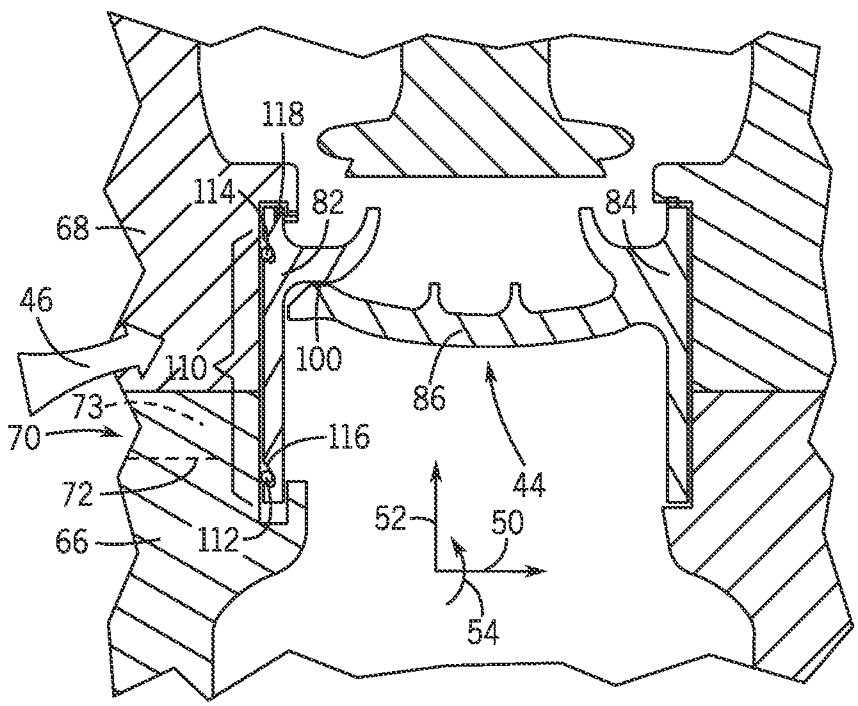

118
114
82
84
68
46
110
100
86
73
70
116
44
72
52
50
66
112
54

FIG. 4

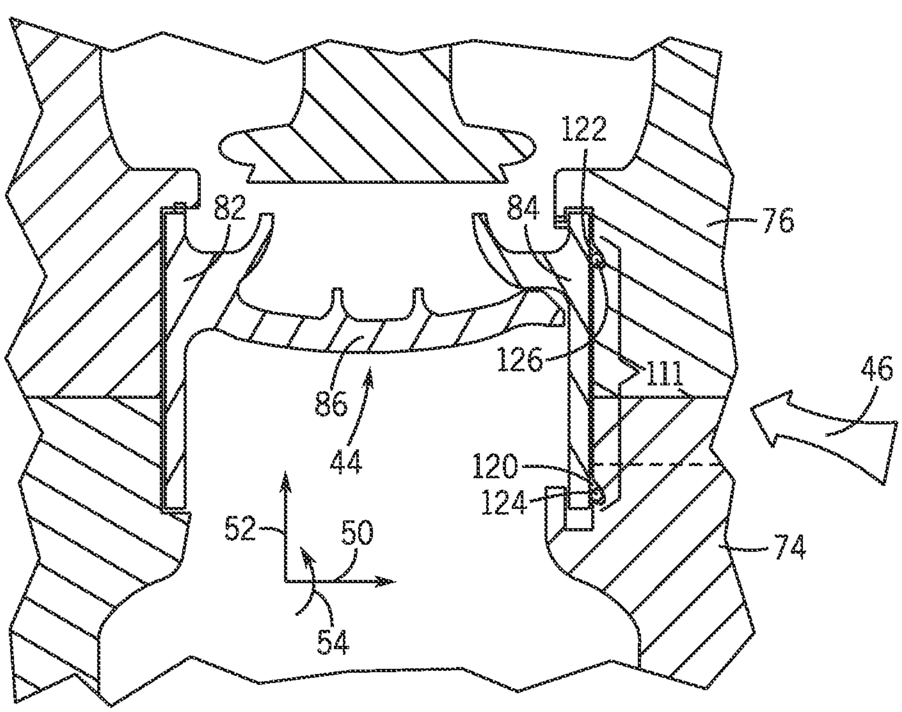


FIG. 5

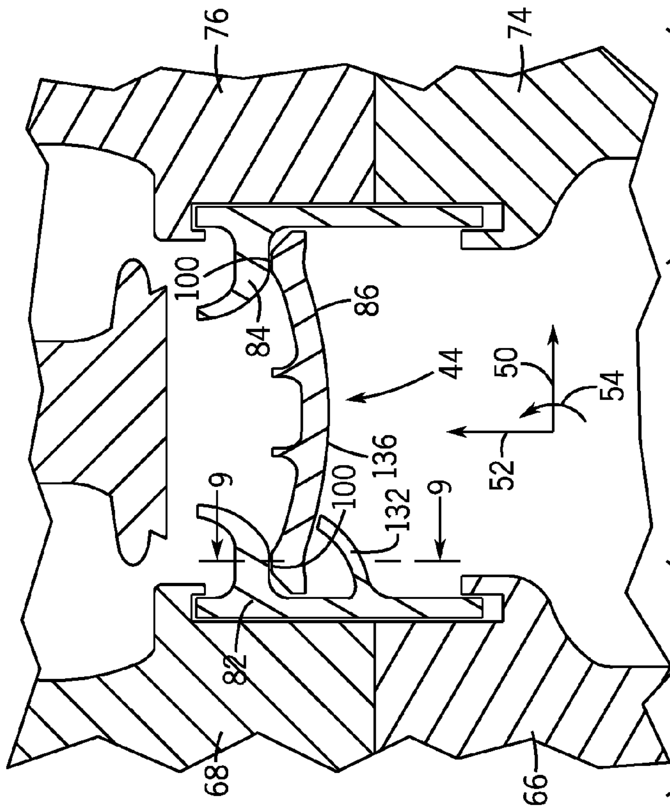


FIG. 8

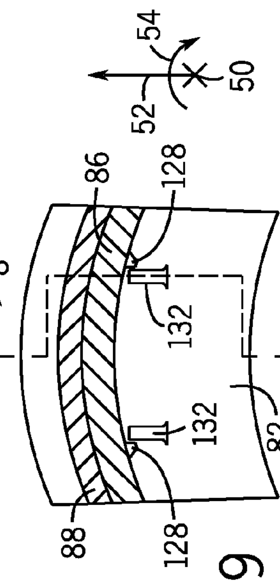


FIG. 9

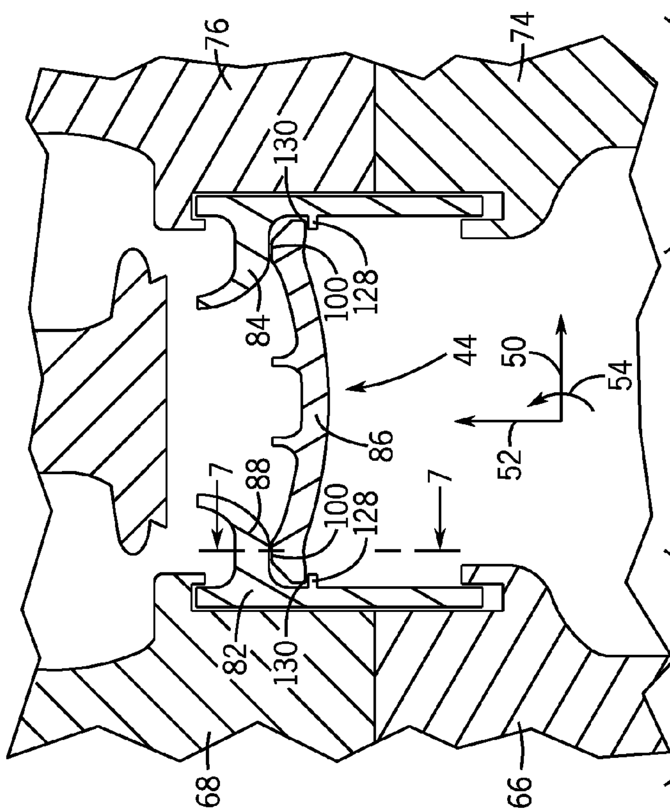


FIG. 6

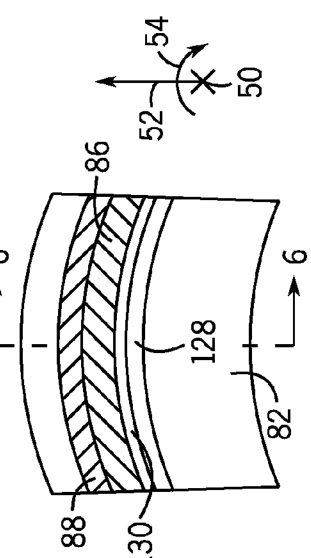


FIG. 7

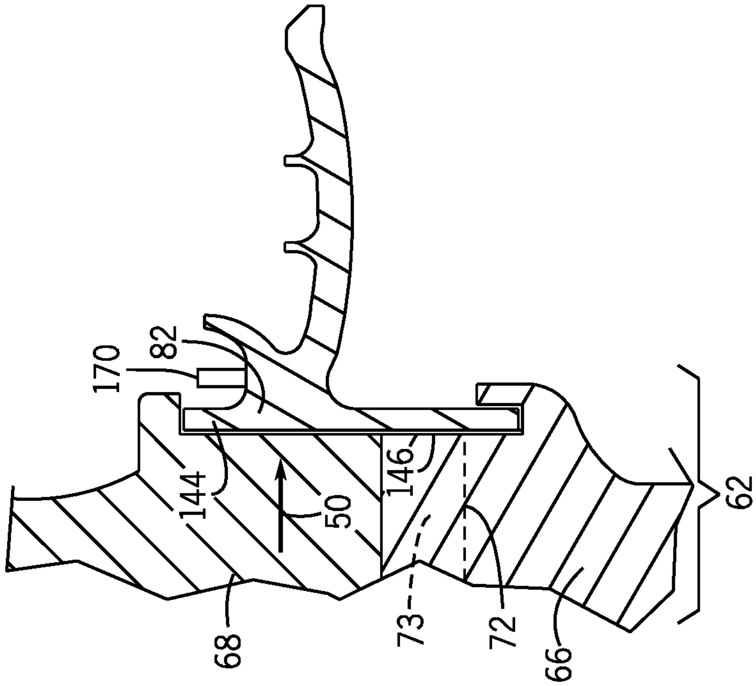


FIG. 11

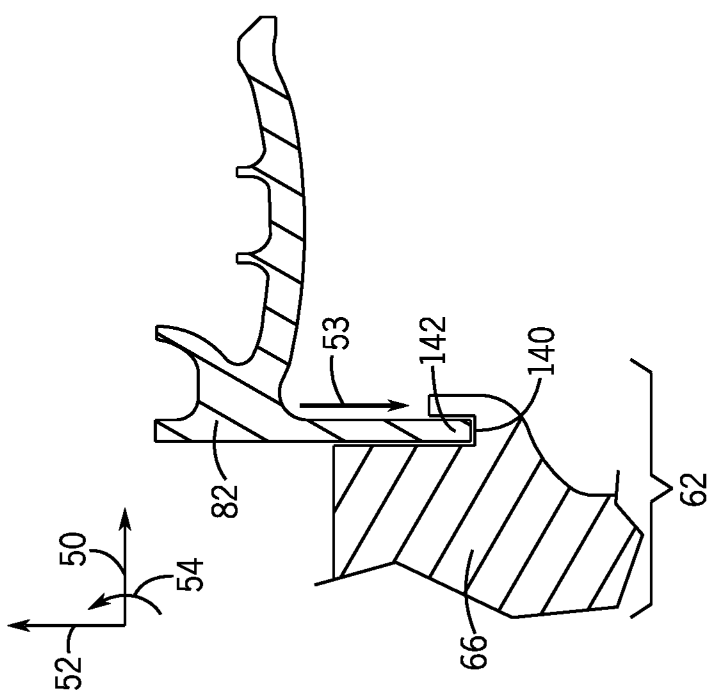


FIG. 10

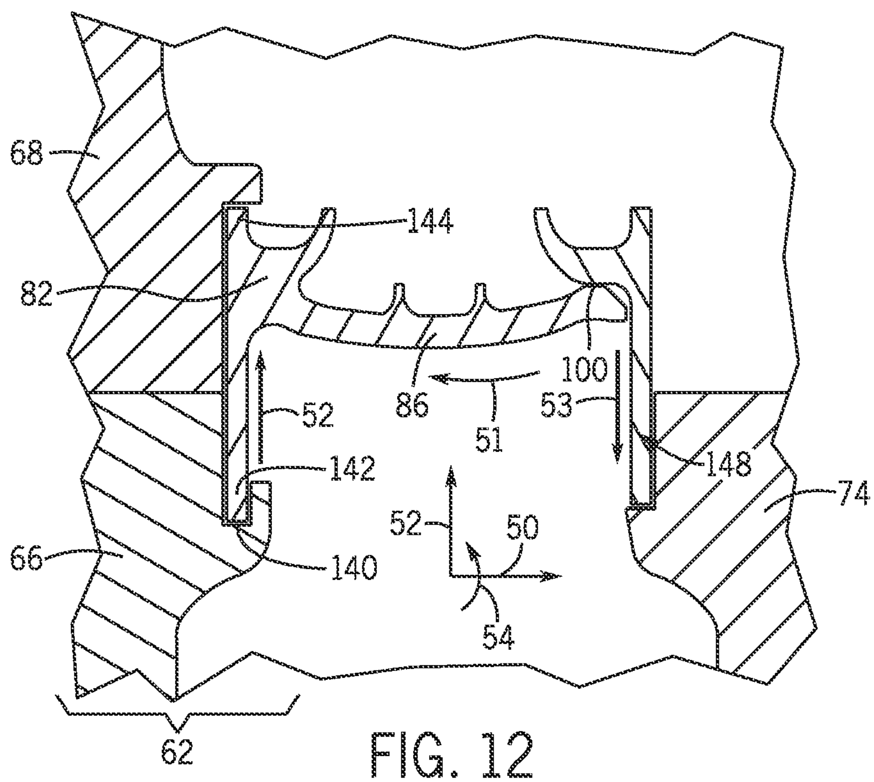
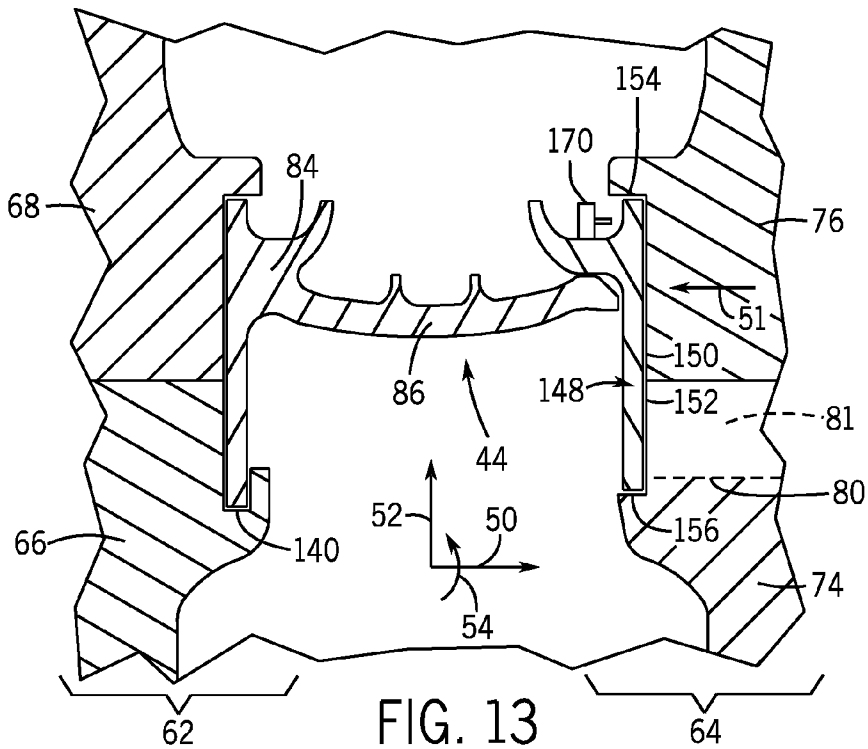
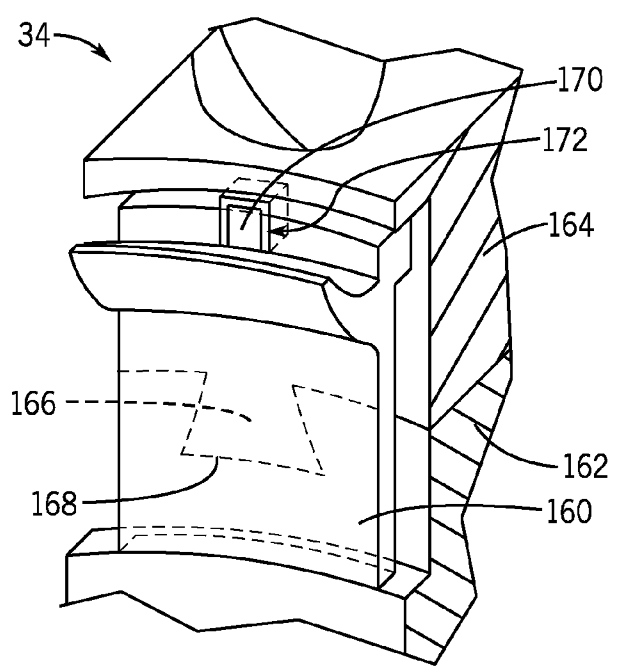


FIG. 12



154
170
84
68
76
51
150
148
152
86
81
44
80
52
50
156
66
140
74
54
62
64

FIG. 13



34
170
172
164
166
162
168
160

FIG. 14

TURBINE SEAL SYSTEM AND METHOD

BACKGROUND

The subject matter disclosed herein relates to gas turbines, and more specifically, to seals within turbines.

In general, gas turbine engines combust a mixture of compressed air and fuel to produce hot combustion gases. The combustion gases may flow through one or more turbine stages to generate power for a load and/or compressor. The combination of hot gases and high pressures can cause stress and wear of components in the turbine. To reduce the stress and wear, cooling gases flow through parts of the turbine, such as the sections between wheels, or the interior of turbine blades. Between each stage, a pressure drop may allow some leakage of the combustion gases to sections designated for cooling gases, or the cooling gases may leak into sections designated for combustion gases. Fluid leakage can reduce the efficiency of the turbine, reduce uniformity between turbines (which can cause uncertainty in a service schedule), or can allow wear of the turbine components, among other problems. Seal assemblies may be disposed between the stages to reduce fluid leakage between stages. Unfortunately, the seals may be subject to stresses, such as thermal stresses, which may bias the seals in axial and/or radial directions, thereby reducing effectiveness of the seals. To reduce the stresses on the seal assemblies, the assemblies may be placed away from the path of the combustion gases. This arrangement, however, may cause additional leakage between the seal assembly and a nozzle that is used to direct the combustion gases. Furthermore, the seal assemblies may extend the distance between turbine stages, which can cause an increase in the overall cost of the turbine.

BRIEF DESCRIPTION

Certain embodiments commensurate in scope with the originally claimed invention are summarized below. These embodiments are not intended to limit the scope of the claimed invention, but rather these embodiments are intended only to provide a brief summary of possible forms of the invention. Indeed, the invention may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

In a first embodiment, a system includes a multi-stage turbine that includes a first turbine stage having a first wheel having a plurality of first blade segments spaced circumferentially about the first wheel. The turbine also includes a second turbine stage having a second wheel having a plurality of second blade segments spaced circumferentially about the second wheel. The turbine also includes a seal assembly extending axially between the first and second turbine stages. The seal assembly includes a first coverplate coupled to the first turbine stage. The first coverplate includes a first air director. The seal assembly also includes a second coverplate coupled to the second turbine stage. The second coverplate comprises a second air director. The seal assembly also includes an interstage seal. The first coverplate, the second coverplate, or both are configured to support the interstage seal.

In a second embodiment, a method of installing a seal assembly between a first turbine stage and a second turbine stage of a multi-stage turbine includes installing a first coverplate into a first wheel of the first turbine stage and installing a first blade segment around a first circumferential rim of the first wheel. The first blade segment is configured to secure the first coverplate. The method also includes

installing a second coverplate into a second wheel of the second turbine stage and installing an interstage seal between the first coverplate and the second coverplate. The first coverplate and the second coverplate are configured to secure the interstage seal. The method also includes installing a second blade segment around a second circumferential rim of the second wheel.

In a third embodiment, a seal assembly for use in a multi-stage turbine includes a first coverplate configured to be coupled to a first turbine stage of a multi-stage turbine. The first coverplate includes a first seal. The seal assembly also includes a second coverplate configured to be coupled to a second turbine stage of the multi-stage turbine. The second coverplate includes a second seal. The seal assembly also includes an interstage seal. The first coverplate, the second coverplate, or both are configured to support the interstage seal.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. **1** is a schematic flow diagram of an embodiment of a gas turbine engine that may employ turbine seals;

FIG. **2** is a cross-sectional side view of an embodiment of the gas turbine engine of FIG. **1** taken along the longitudinal axis;

FIG. **3** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly between turbine stages;

FIG. **4** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly between adjacent stages;

FIG. **5** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly between adjacent stages;

FIG. **6** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly between turbine stages;

FIG. **7** is a partial cross-sectional front view illustrating an embodiment of a coverplate of FIG. **6**, taken along line **7-7** of FIG. **6**.

FIG. **8** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly between turbine stages;

FIG. **9** is a partial cross-sectional front view illustrating an embodiment of a coverplate of FIG. **8**, taken along line **9-9** of FIG. **8**.

FIG. **10** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly being installed between adjacent stages;

FIG. **11** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly being installed between adjacent stages;

FIG. **12** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly being installed between adjacent stages;

FIG. **13** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of a seal assembly being installed between adjacent stages;

FIG. **14** is a perspective view of an embodiment of an anti-rotation tab installed in a coverplate of the gas turbine engine of FIG. **2**.

DETAILED DESCRIPTION

One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

The present disclosure is directed to gas turbine engines that include interstage seal assemblies, wherein each interstage seal assembly includes seals that are separated from a blade segment of a turbine stage. The separation of the seal from the blade segments may enable the turbine stages to fit closer together in the gas turbine engine. Thus, gas turbine engines that include such interstage seal assemblies may have a shorter overall length and thus, be less costly than engines using other blade segments or seal assemblies. For example, the gas turbine engine may include a first turbine stage that includes a first wheel that has a plurality of first blade segments spaced circumferentially about the first wheel, and a second turbine stage that includes a second wheel having a plurality of second blade segments spaced circumferentially about the second wheel. The interstage seal assembly may extend axially between the first and second turbine stages to seal an interstage gap between the first and second stages. In addition, embodiments of the interstage seal may be installed and removed without disassembling a rotor of the gas turbine engine. For example, the interstage seal assembly may be configured to be installed or removed while the first and second wheels remain in place in the respective first and second turbine stages. Thus, if only the interstage seal assembly is replaced, the rotor of the gas turbine engine is not disturbed, thereby potentially reducing maintenance time, complexity, and/or cost. In some embodiments, the interstage seal assembly may include one or more coverplates configured to enable the interstage seal assembly to be installed in multiple steps or stages. The coverplate may include a seal (different from the interstage seal), such as an angel wing or curved wing, which directs combustion gases, or other fluids, in a desired direction. In contrast to positioning the seal on the blade segment, the disclosed embodiments separate the seal from the blade segment and move the seal to the coverplate to enable the seal to be placed under the blade segment, which in turn enables the turbine stages to be closer together, shortening the overall length of the gas turbine. Additionally, the coverplate may include a sealing element, different from the seal or the interstage seal, which blocks cooling gases from escaping the cooling paths within the gas turbine

FIG. **1** is a block diagram of an exemplary system **10** including a gas turbine engine **12** that may employ interstage seal assemblies configured to be installed or removed without rotor disassembly, as described in detail below. In certain embodiments, the system **10** may include an aircraft, a watercraft, a locomotive, a power generation system, or combinations thereof. The illustrated gas turbine engine **12** includes an air intake section **16**, a compressor **18**, a combustor section **20**, a turbine **22**, and an exhaust section **24**. The turbine **22** is coupled to the compressor **18** via a shaft **26**.

As indicated by the arrows, air may enter the gas turbine engine **12** through the intake section **16** and flow into the compressor **18**, which compresses the air prior to entry into the combustor section **20**. The illustrated combustor section **20** includes a combustor housing **28** disposed concentrically or annularly about the shaft **26** between the compressor **18** and the turbine **22**. The compressed air from the compressor **18** enters combustors **30**, where the compressed air may mix and combust with fuel within the combustors **30** to drive the turbine **22**.

From the combustor section **20**, the hot combustion gases flow through the turbine **22**, driving the compressor **18** via the shaft **26**. For example, the combustion gases may apply motive forces to turbine rotor blades within the turbine **22** to rotate the shaft **26**. After flowing through the turbine **22**, the hot combustion gases may exit the gas turbine engine **12** through the exhaust section **24**. As discussed below, the turbine **22** may include a plurality of interstage seal assemblies, which may be installed or removed while rotary components of the turbine **22**, such as wheels, remain in place. Thus, maintenance affecting the interstage seal assemblies may be performed without complete disassembly of the turbine **22**.

FIG. **2** is a cross-sectional side view of an embodiment of the gas turbine engine **12** of FIG. **1** taken along the longitudinal axis **32**. As depicted, the gas turbine **22** includes three separate stages **34**. Each stage **34** includes a set of blades **36** coupled to a rotor wheel **38** that may be rotatably attached to the shaft **26** (FIG. **1**). The blades **36** extend radially outward from the rotor wheels **38** and are partially disposed within the path of the hot combustion gases **40**. The combustion gases **40** also flow through stationary nozzles **42** (e.g., stationary blades) that direct the combustion gases **40** against the blades **36**, so that the blades **36** may drive the rotor **26** more effectively. Seal assemblies **44** extend between adjacent rotor wheels **38**. As discussed below, the seal assemblies **44** may include coverplates that fit about adjacent wheels **38** for support. The coverplates may be configured to block the flow of a cooling fluid **46** that flows along a path on the radially inner side (i.e., closer to the longitudinal axis **32**) of the seal assemblies **44**. The cooling fluid **46**, in some embodiments, may also flow through cooling paths within the blades **36**. The interstage seal assemblies **44** may be installed or removed, with the coverplates, while the rotor wheels **38** remain in place in the gas turbine engine **12**. Although the gas turbine **22** is illustrated as a three-stage turbine, the seal assemblies **44** described herein may be employed in any suitable type of turbine with a multiple number of stages and shafts. For example, the seal assemblies **44** may be included in a two stage gas turbine, in a dual turbine system that includes a low-pressure turbine and a high-pressure turbine, or in a steam turbine. Further, the seal assemblies **44** described herein may also be employed in an axial compressor, such as the compressor **18**. The seal assemblies **44** may be made from various high-temperature alloys, such as, but not limited to, nickel based alloys.

As described above with respect to FIG. **1**, air enters through the air intake section **16** and is compressed by the compressor **18**. The compressed air from the compressor **18** is then directed into the combustor section **20** where the compressed air is mixed with fuel. The mixture of compressed air and fuel is generally burned within the combustor section **20** to generate high-temperature, high-pressure combustion gases, which are used to generate torque within the turbine **22**. Specifically, the combustion gases apply motive forces to the blades **36** to rotate the wheels **38**. In certain embodiments, a pressure drop may occur at each stage **34** of the turbine **22**, which may allow gas leakage flow through unintended paths. For example, the hot combustion gases **40** may leak into the interstage volume between turbine wheels **38**, normally reserved for the cooling fluid **46**. This type of leakage may place thermal stresses on the turbine components. Furthermore, flow of hot combustion gases **40** into the interstage volume may abate the cooling effects of the cooling fluid **46**. Accordingly, the seal assemblies **44** may be disposed between adjacent wheels **38** to seal and enclose the interstage volume from the hot combustion gases **40**.

FIG. **3** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** between turbine stages **34**. In the following discussion, reference may be made to an axial direction or axis **50**, a radial direction or axis **52**, and a circumferential direction or axis **54**, relative to the longitudinal axis **32** of the gas turbine engine **12**. Hot fluids, such as hot combustion gases **40** or steam, with a flow path **56** (illustrated generally by arrows) enters at an upstream side **58** and exits at a downstream side **60**. For illustrative purposes, only a portion of the stages **34** are illustrated in FIG. **3**. Specifically, a first turbine stage **62** is shown near the upstream side **58** and a second turbine stage **64** is shown near the downstream side **60**. The first turbine stage **62** includes a first wheel **66** with a plurality of first blade segments **68** extending radially outward **52** from a first wheel post portion **70** of the first wheel **66**. The first wheel post portion **70** is disposed along the circumference of the first wheel **66** and includes slots **72** (e.g., axial dovetail slots) for retaining lower segments (e.g., axial dovetail tabs **73**) of the first blade segments **68**. Similarly, the second turbine stage **64** includes a second wheel **74** with a plurality of second blade segments **76** extending radially outward **52** from a second wheel post portion **78** of the second wheel **74**. The second wheel post portion **78** is disposed along the circumference of the second wheel **74** and includes slots **80** (e.g., axial dovetail slots) for retaining lower segments (e.g., axial dovetail tabs **81**) of the plurality of second blade segments **76**. In certain embodiments, approximately 50 to 150 first and second blade segments **68** and **76** may be mounted and spaced circumferentially **54** around the first and second wheels **66** and **74** and a corresponding axis of rotation (extending generally in the direction indicated by arrow **50**). In further embodiments, methods other than the slots and tabs described above may be used to couple the first and second blade segments **68** and **76** to the first and second wheels **66** and **74**.

The interstage seal assembly **44** includes a first coverplate **82** and a second coverplate **84**. The first coverplate **82** is secured within the first turbine stage **62** while the second coverplate **84** is secured within the second turbine stage **64**. An interstage seal **86** is positioned between the first coverplate **82** and the second coverplate **84**. The interstage seal **86** may be supported by or attached to the first and/or second coverplates **82** and **84**, as described in detail below. The seal assembly **44** may include a plurality of coverplates **82**, **84** and interstage seals **86**, such as 2 to 100 disposed circumferentially **54** adjacent to one another to form a complete 360-degree ring about the longitudinal axis **32** of the gas turbine engine **12**. The seal assembly **44** may include equal numbers of coverplates **82**, **84** or may include different numbers of first coverplates **82** and second coverplates **84**. Similarly, the interstage seal assembly **44** may include a different number of interstage seals **86** than either first coverplates **82** or second coverplates **84**. Each of the components (**82**, **84**, **86**) of the interstage seal assembly **44** is arcuate in the circumferential direction **54**.

As illustrated, the first coverplate **82** and the second coverplate **84** include a seal **88** that directs the combustion gases **56** away from a gap **90** between the interstage seal **86** and the nozzle **42**. During operation of the turbine engine **12**, the stages **34** rotate in the circumferential direction **54** while the nozzles **42** remain stationary. Thus, the interstage seal **86** and the nozzle **42** are not connected to one another, thereby creating the gap **90**. Combustion gases **56** may flow through the gap **90**, and the flow of combustion gases **56** is greater when the gap **90** is wider. Reducing the size of the gap **90**, however, may take precise calibration which can be labor and time intensive. Thus, it is desirable to minimize the flow of combustion gases **56** through the gap **90** in other ways. Seals **88**, such as angel wings or curved wings, may be used to direct combustion gases **56** away from the gap **90**, reducing the flow therethrough. As discussed below, the disclosed embodiments attach the seal **88** to the coverplates **82** and **84**, rather than placing the seal (e.g., an angel wing) on a component that includes the blade (e.g., blade segments **68**, **76**). Thereby helping to reduce the distance between turbine stages **34** and decrease overall length of the turbine engine **12**. Attaching the seal **88** to the coverplates **82** and **84** can reduce the length of the turbine engine **12** due to the shorter distance that the bucket uses to slide out of the wheel during removal. The interstage seal **86** may also include seal teeth **92** directed at the gap **90** and the nozzle **42**. The seal teeth **92** reduce the flow speed of combustion gases **56** through the gap **90**. The seal teeth **92** create a flow path **94** that breaks up any straight-line path that the combustion gases **56** may otherwise travel. In other words, the seal teeth **92** may create a tortuous path for the combustion gases **56**.

As described in detail below, the first blade segment **68** may include a hook **96** that is configured to couple the first coverplate **82** to an inner edge **98** of the first blade segment **68**. The hook **96** holds the first coverplate **82** in place during operation of the turbine engine **12** and during installation of the interstage seal assembly **44**. The first coverplate **82** and the second coverplate **84** may also hold the interstage seal **86** in place. During operation of the turbine engine **12**, the seal assembly **44** rotates in the circumferential direction **54**, which causes radial **52** forces on the interstage seal **86** which in turn forces the interstage seal **86** to engage the coverplates **82**, **84** tightly at engagement points **100**. The interstage seal **86** may also attach to the coverplates **82**, **84** at the engagement points **100**. The attachment may be through physical, mechanical, chemical, or other means including examples described below. This configuration enables the interstage seal **86** to engage the coverplates **82**, **84** at a greater radial **52** distance than would otherwise be practical. For example, rather than engaging the coverplates **82**, **84** at a radial **52** distance that is less than the radius **200** of the turbine wheel **66**, **74**, the interstage seal **86** may engage at the engagement points **100** which are positioned at attachment radius **202**. In the illustrated embodiment, the engagement points **100**, are radially **52** outside the point where the first wheel **66** meets the first blade segment **68** and outside the point where the second wheel **74** meets the second blade segment **76**. This enables a more efficient flow of combustion gases **56** and also blocks the cooling fluid **46** from entering the path of the combustion gases **56**.

In some embodiments, the attachment may not be a rigid attachment such that the interstage seal **86** may freely respond to growth that occurs due to thermal expansion. The engagement causes the coverplates **82**, **84** to load into the blade segments **68**, **76** such that the seal assembly **44** remains secure as it rotates with the turbine engine **12**. The seal assembly **44**, in some embodiments, may use the hook **96** only on one side of the assembly. In other words, it is possible that the second blade segment **76** does not include a hook on the outer edge **102** where it meets the second coverplate **84**, as shown in FIG. **3**. Instead, engagement with the interstage seal **86** may be used to hold the second coverplate **84** in place.

FIG. **4** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** between turbine stages **34**. The seal assembly **44** illustrated includes an interstage seal **86** that is integrally formed with the second coverplate **84**. Whereas the seal assembly **44** of FIG. **3** included three separate components engaged at engagement points **100**, the seal assembly **44** of FIG. **4** includes two components: the first coverplate **82** and the second coverplate **84**/interstage seal **86** combination. This configuration may be easier to install within the system **10** as the number of components to install is reduced. Also, manufacturing two components may be cheaper and/or easier, thus saving cost overall of the system **10**. The interstage seal **86** may engage with the first coverplate **82** at the engagement point **100** as described with regard to FIG. **3**.

FIG. **4** also illustrates an embodiment of a forward sealing element **110** that may be included with the first coverplate **82**. FIG. **4** shows the first coverplate **82** installed within the first stage **62** described above. It will be appreciated that the sealing element **110** may be segmented (e.g., multiple segments in the circumferential **54** direction) like the other components of the seal assembly **44**. Multiple components may form the sealing element **110**, so that it encompasses 360 degrees of the turbine stage (e.g., turbine stage **34**). The coverplate **82** includes a radially **52** inner seal structure **112** and a radially **52** outer seal structure **114**. Collectively, the inner seal structure **112** and the outer seal structure **114** form the sealing element **110**. The sealing element **110** may be installed on either coverplate **82**, **84** of the seal assembly **44**. If installed on the first coverplate **82**, the sealing element **110** may be the forward sealing element. If installed on the second coverplate **84**, the sealing element **110** may be the aft sealing element. The inner seal structure **112** may be disposed radially **52** closer to the longitudinal axis **32** than the outer seal structure **114**. In certain embodiments, the inner seal structure **112** may be disposed within an inner notch **116** while the outer seal structure **114** is disposed within an outer notch **118**, either or both of which may be an indentation or other recessed portion within the coverplate **82**. Each of the inner seal structure **112** or the outer seal structure **114** may be a metal wire coated in ceramic thermal insulation, a metal wire without ceramic insulation, or some other thermally insulating seal that is configured to fit within the notch **116**, **118** on the coverplate **112**.

The sealing element **110** may be configured to block the flow of cooling fluid **46** as it flows through the blade segment **68** and around the wheel **66**. As explained above with regard to FIG. **2**, cooling fluid **46** may flow through the turbine engine **12** to lower the temperature of certain components. The efficiency and/or durability of the turbine components may be adversely affected if the cooling fluid **46** escapes designated paths. For example, the cooling fluid **46** may flow around the dovetail tabs **73** that are fitted within the slots **72**. To block this flow, inner seal structure **112** and/or outer seal structure **114** form a barrier around the area from which the cooling fluid **46** may flow. For example, the inner seal structure **112** may be configured to block the flow of cooling fluid **46** between the first coverplate **82** and the first wheel **66**. The outer seal structure **114** may be configured to block the flow of cooling fluid **46** between the first coverplate **82** and the first blade segment **68**. Installation of the sealing element **110** may occur concurrent with the installation of the first coverplate **82**, or it may be installed within the coverplate notches **112**, **114** before the first coverplate **82** is installed.

FIG. **5** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** between turbine stages **34**. The illustrated seal assembly **44** includes an interstage seal **86** that is integrally formed with the first coverplate **82**. The seal assembly **44** of FIG. **5** includes two components: the second coverplate **84** and the first coverplate **82**/interstage seal **86** combination. Again, a configuration with only two components may be easier to install within the gas turbine engine **12** as there are fewer parts. The interstage seal assembly **44** may be segmented for ease of installation and replacement. Also, this configuration may be more cost efficient as the combination **82**/**86** may be manufactured together. The interstage seal **86** may engage with the second coverplate **84** at the engagement points **100** as described with regard to FIG. **3**.

FIG. **5** also illustrates an embodiment of an aft sealing element **111** installed with the second coverplate **84**. The second coverplate **84** with the sealing element **111** may be installed within any turbine stage **34** as part of the seal assembly **44**. The second coverplate **84** may also form a barrier around the area from which the cooling fluid **46** may flow. The second coverplate **84** in FIG. **5** illustrates that an inner notch **120** and an outer notch **122** may be formed in the second wheel **74** and the second blade segment **76**, respectively. The inner seal structure **124** and/or outer seal structure **126** may, as described in regards to FIG. **4**, form a barrier around the area from which the cooling fluid **46** may flow. With the notches **120**, **122** formed in the wheel **74** and blades segment **76**, respectively, the inner seal structure **124** the outer seal structure **126** may form a continuous circular structure even when the second coverplate **84** is segmented. This may reduce the time it takes to install the seal assembly **44** by eliminating the time otherwise needed to install each individual seal structure **124**, **126** into each individual coverplate **84**. In other embodiments, the seal structures **124**, **126** may be segmented. For example, the seal structures **124**, **126** may be segmented to correspond to the segmentation of the second coverplate **84**. The embodiments illustrated in FIG. **4** and FIG. **5** may also be used in combination. That is, the second wheel **74** may have one notch (e.g., notch **124**) while the coverplate has another notch (e.g., notch **114**). Also, the second blade segment **76** may have one notch (e.g., notch **126**) while the second coverplate **84** has another notch (e.g., **116**). Furthermore, as stated above, the seal assembly **44** may include the forward sealing element **110** and the aft sealing element **111**.

FIG. **6** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** between turbine stages **34**. As illustrated, the seal assembly **44** is installed between the first stage **62** and the second stage **64**. As described above, the first stage

62 includes the first coverplate **82**, the first wheel **66**, and the first blade segment **68**. The second stage **64** includes the second coverplate **84**, the second wheel **74**, and the second blade segment **76**. The seal assembly **44** also includes the interstage seal **86** engaged with the first coverplate **82** and second coverplate **84** at the engagement points **100**. The first coverplate **82** and the second coverplate **84** include a lip **128** that supports the interstage seal **86** across the bottom edge **130**. The lip **128** may extend along the circumferential length of the interstage seal **86** as shown in FIG. **7**, which represents a partial cross-sectional front view of the first coverplate **82** taken along the line labeled **7-7** of FIG. **6**. Correspondingly, the partial cross-sectional side view of FIG. **6** is indicated along the line labeled **6-6** in FIG. **7**. The lip **128** in other embodiments may extend only partially or intermittently (e.g., see FIG. **9**) across the circumferential length of the interstage seal **86**. In other words, the lip **128** may include two, three, four, or more lips along an edge **130** of the interstage seal **86**. Furthermore, some embodiments may have the lip **128** only on the first coverplate **82** or only on the second coverplate **84**. The lip **128** as shown in FIG. **6** may improve the speed of installation and/or may decrease the cost of the seal assembly **44**. For example, the interstage seal **86** may wear out differently than the first coverplate **82** or the second coverplate **84**. In the embodiment shown in FIG. **6**, each component **82**, **84**, **86** of the seal assembly **44** may be replaced independently of the others, thereby saving time and costs associated with servicing and parts replacement.

FIG. **8** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** between turbine stages **34**. As illustrated, the seal assembly **44** is installed between the first stage **62** and the second stage **64**. As described above, the first stage **62** includes the first coverplate **82**, the first wheel **66**, and the first blade segment **68**. The second stage **64** includes the second coverplate **84**, the second wheel **74**, and the second blade segment **76**. The seal assembly **44** also includes the interstage seal **86** engaged with the first coverplate **82** and second coverplate **84** at the engagement points **100**. As illustrated, the first coverplate **82** includes support arms **132** that support the interstage seal **86** across the bottom side **136**. The support arms **132** may extend outward from the first coverplate **82** from multiple locations as shown in FIG. **9**, which represents a partial cross-sectional front view of the first coverplate **82** taken along the line labeled **9-9** of FIG. **8**. Correspondingly, the partial cross-sectional side view of FIG. **8** is indicated along the line labeled **8-8** in FIG. **9**. FIG. **9** shows two support arms **132**, but in other embodiments the first coverplate **82** may include one, three, or more support arms **132**. The support arms **132** may provide more substantial support for the interstage seal **86**; this may be useful over other embodiments if the interstage seal **86** is manufactured from a heavy material, or if the lip **128** from FIG. **6** does not support the thermal expansion and contraction of the interstage seal **86** during operation of the gas turbine engine **12**.

FIG. **10** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** being installed between adjacent stages **62**. As illustrated, the first stage **62** includes the first wheel **66** without the first blade segment **68**. It will be appreciated that the installation process may begin with either the first stage **62** (as illustrated) or the second stage **64**. Each blade segment **68**, **76** may be removed from the first stage **62** and the second stage **64** as part of a servicing or other procedure. The first wheel **66** includes a slot at a circumferential rim **140**, which is empty following the service procedure and before the installation process starts. In other embodiments, the first wheel **66** may lack a slot at the circumferential rim **140**. As illustrated in FIG. **10**, the first coverplate **82** is installed into the slot at the circumferential rim **140** in the direction **53** opposite the radial direction **52**. As illustrated, the interstage seal **86** and the first coverplate **82** may be integrally connected (e.g., one-piece structure). A lower end **142** of the first coverplate **82** fits relatively securely into the slot at the circumferential rim **140**, which may hold the first coverplate **82** in place without additional support. As shown, the lower end **142** is inserted completely into the bottom of the slot at the circumferential rim **140**. Thus, FIG. **8** may represent a first step in the assembly of the seal assembly **44** in the gas turbine engine **12**.

FIG. **11** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** being installed between adjacent stages **62**. Specifically, FIG. **11** may represent a second step in the assembly of the seal assembly **44** in the gas turbine engine **12**. It may be understood that the assembly of the seal assembly **44** may start with the installation of the second coverplate **84** in the second stage **64**; no limitation is intended as to the order of the assembly. As shown, after the first coverplate **82** is installed in the slot at the circumferential rim **140**, as shown in FIG. **11**, the first blade segment **68** slides in the axial direction **50** into place around the outside of the first wheel **66**. An inner edge **144** of the first blade segment **68** is even with (e.g., adjacent to) an inner edge **146** of the first wheel **66**. As explained in detail above with regard to FIGS. **4** and **5**, the first coverplate **82** is configured to block cooling fluid **46** from seeping through the slot **72** around the tab **73**. The hook **96** on the edge of the blade segment **68** is configured to slide over or past the top of the first coverplate **82** while the first coverplate **82** is inserted into the bottom of the slot at the circumferential rim **140**. In other embodiments, the blade segment **68** lacks a hook **96** such that it may circumferentially attach the coverplate **82** by sliding over the top of the coverplate **82** without any extra space in the radial **52** direction.

FIG. **12** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** being installed between adjacent stages **62**. Specifically, FIG. **12** may represent a third step in the assembly of the seal assembly **44** in the gas turbine engine **12**. After the first blade segment **68** is secured into place above the first wheel **66**, the second coverplate **84** is installed. The interstage seal **86** may hold the second coverplate **84** outward in the radial direction **52** at the engagement point **100**. The second coverplate **84** is installed into a recess **148** of the second wheel **74**. As illustrated, the recess **148** does not include the slot at the circumferential rim **140** shown in the first stage **62**. The recess **148** may include a slot if required to constrain the seal plate during operation.

FIG. **13** is a partial cross-sectional side view of the gas turbine engine of FIG. **2** illustrating an embodiment of the seal assembly **44** being installed between adjacent stages **62**. The final step in installing the interstage assembly **44** is to install the second blade segment **76** around the circumferential rim **156** of the second wheel **74**. The second blade segment **76** may be installed in the direction **51** that is opposite the axial direction **50** and the dovetail tab **81** is secured within the slot **80**. The second blade segment may also be installed using a circumferential attachment. An inside edge **150** of the second blade segment **76** is even with an inside edge **152** of the second wheel **74**, and the second coverplate **84** is flush against the inside edges **150**, **152**. The second coverplate **84** may fit into the recess **148** without extra space on the top and bottom of the coverplate **84**. In other words, the second blade segment **76** and the second wheel **74** may help block excessive relative radial **52** movement of the second coverplate **84**. As illustrated in FIG. **13**, the second coverplate **84** may be secured and supported in the recess **148** by the interstage seal **86**. To clarify, the outer edge **154** of the recess **148** may not have the hook **96** shown in the first stage **62**, and the circumferential rim **156** may not have the slot at the circumferential rim **140** shown in the first stage **62**. This arrangement may enable faster assembly and/or reduced cost of the turbine engine **12**. In other embodiments, the second stage **64** may include the slot at the circumferential rim **140** and the hook **96**. In still further embodiments, the first stage **62** and the second stage **64** may both lack the slot at the circumferential rim **140** and the hook **96** as illustrated by the second stage **64** in FIG. **13**. The foregoing steps may be modified to accommodate the other embodiments disclosed herein. For example, for embodiments that include three separate components (e.g., first coverplate **82**, second coverplate **84**, and a separate interstage seal **86**) the interstage seal **86** may be installed during the third step illustrated by FIG. **12**.

FIG. **14** is a perspective view of an embodiment of an anti-rotation tab installed in a coverplate (e.g., first or second coverplate **82**, **84**) of the gas turbine engine of FIG. **2**. A coverplate **160** in FIG. **14** represents either the first coverplate **82** or the second coverplate **84** and may be installed in any turbine stage **34** as part of a seal assembly **44**. The turbine stage **34** includes wheel **162** and blade segment **164** that are connected by the dovetail tab **166** fitted within the slot **168**. The seal assembly **44** may include an anti-rotation tab **170**. The anti-rotation tab **170** may be integrally formed with the coverplate **160** or may be integrally formed with the blade segment **164**, or may be a separate component. As illustrated, the anti-rotation tab **170** is integrally formed with the coverplate **160** and disposed within an anti-rotation slot **172** through the front of the blade segment **164**. The anti-rotation slot **172** in some embodiments may extend only partially through the blade segment **164**.

The anti-rotation tab **170** is configured to block circumferential **54** movement of the coverplate **160** with respect to the wheel **162** and the blade segment **164**. It will be understood that all pieces of the seal assembly **44** (wheel **162**, blade segment **164**, coverplate **160**, and anti-rotation tab **170**) rotate in the circumferential direction **54** (or in the opposite direction), but the anti-rotation tab **170** is configured such that the seal assembly **44** rotates together. The anti-rotation tab **170** may be installed with the blade segment **164** as illustrated in FIG. **11** or FIG. **13**, or may be installed at any time during the installation of the seal assembly **44**.

The disclosed embodiments may be beneficial in that they may be used to increase cooling efficiency by reducing leakage of cooling fluid **46** from cooling passages within gas turbines **10** while also reducing overall costs of gas turbines **10**. For example, the interstage seal assembly **44** may include coverplates **82**, **84**, **170** that may be employed to improve separation of the cooling fluid **46** from the combustion gases **56**. The interstage seal **86** may also direct the combustion gases **56** through the turbine blades **36** and the nozzles **42**, which decreases extraneous flow and thus increases efficiency of the gas turbine engine **12**. Furthermore, the disclosed embodiments include seals **88** that are attached to the coverplates **82**, **84**, **170** instead of the blade segments **68**, **76**, which may enable a decrease in the distance between stages **34** in the turbine engine **12**. This decrease in distance translates into an overall shortening of the gas turbine engine **12** and corresponding decrease in cost.

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 have 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 language of the claims.

The invention claimed is:

1. A system, comprising:

a multi-stage turbine, comprising:

- a first turbine stage comprising a first wheel having a plurality of first blade segments spaced circumferentially about the first wheel;
- a second turbine stage comprising a second wheel having a plurality of second blade segments spaced circumferentially about the second wheel; and
- a seal assembly extending axially between the first and second turbine stages, comprising:
  - a first coverplate coupled to the first turbine stage, wherein the first coverplate comprises a first seal;
  - a second coverplate coupled to the second turbine stage, wherein the second coverplate comprises a second seal; and
  - an interstage seal comprising a radially outermost surface, wherein the interstage seal is supported by the first coverplate, the second coverplate, or both at the radially outermost surface of the interstage seal, wherein the first coverplate comprises a first seal wing and/or the second coverplate comprises a second seal wing, and the radially outermost surface of the interstage seal contacts the first seal wing and/or the second seal wing.

2. The system of claim **1**, wherein the interstage seal comprises one or more seal teeth protruding from the radially outermost surface of the interstage seal and configured to block interstage axial leakage between the first turbine stage and the second turbine stage.

3. The system of claim **1**, comprising a forward sealing element, an aft sealing element, or both, wherein the forward sealing element is configured to block a flow of gases between the first coverplate and at least one of the first blade segments, the first wheel, or any combination thereof, and the aft sealing element is configured to block the flow of gases between the second coverplate and at least one of the second blade segments, the second wheel, or any combination thereof.

4. The system of claim **3**, wherein the forward sealing element, the aft sealing element, or a combination thereof, is disposed in at least one notch formed in at least one of the first coverplate, the first blade segments, or the first wheel, or any combination thereof.

5. The system of claim **1**, wherein the first coverplate comprises a first lip and the second coverplate comprises a second lip, wherein the first lip and second lip are configured to support the interstage seal.

6. The system of claim **1**, wherein the interstage seal is integrally formed with the first coverplate or the second coverplate.

7. The system of claim 1, wherein the interstage seal assembly comprises an anti-rotation tab configured to restrict circumferential movement of at least one of the first coverplate with respect to the first turbine stage, the second coverplate with respect to the second turbine stage, or any combination thereof.

8. The system of claim 1, wherein the first seal is disposed at a first radial seal distance that is greater than an outermost radial wheel distance of the interstage seal, and the second seal is disposed at a second radial seal distance that is greater than the outermost radial wheel distance of the interstage seal.

9. The system of claim 1, comprising a nozzle disposed between the first turbine stage and the second turbine stage.

10. The system of claim 1, wherein the interstage seal is configured to engage with the first coverplate and the second coverplate at a radial engagement distance that is greater than a radius of the first wheel, the second wheel, or any combination thereof.

11. The system of claim 1, comprising cooling passages configured to direct a cooling fluid through the first turbine stage, the second turbine stage, or any combination thereof, wherein the first coverplate, the second coverplate, or any combination thereof, are configured to block the cooling fluid from escaping the cooling passages.

12. The system of claim 1, wherein the seal assembly comprises a plurality of seal assemblies arranged circumferentially about the first turbine stage and the second turbine stage.

13. A method of installing a seal assembly between a first turbine stage and a second turbine stage of a multi-stage turbine, comprising:

installing a first coverplate comprising a first seal wing into a first wheel of the first turbine stage, wherein the first seal wing extends axially away from the first coverplate;

installing a first blade segment around a first circumferential rim of the first wheel, wherein the first blade segment is configured to secure the first coverplate;

installing a second coverplate comprising a second seal wing into a second wheel of the second turbine stage, wherein the second seal wing extends axially away from the second coverplate; and

installing an interstage seal between the first coverplate and the second coverplate, wherein the interstage seal comprises a radially outermost surface, the interstage seal is supported by the first seal wing with the radial outermost surface at a first radial engagement or the second seal wing with the radial outermost surface at a second radial engagement, and the interstage seal is secured between the first coverplate and the second coverplate; and

installing a second blade segment around a second circumferential rim of the second wheel.

14. The method of claim 13, comprising integrally forming the interstage seal with the first coverplate or the second coverplate before installing the interstage seal.

15. The method of claim 13, comprising installing at least one anti-rotation tab configured to restrict circumferential movement of at least one of the first coverplate with respect to the first turbine stage, the second coverplate with respect to the second turbine stage, or any combination thereof.

16. The method of claim 13, wherein installing the first coverplate comprises installing the first coverplate into a recess in the first wheel.

17. A seal assembly for use in a multi-stage turbine, comprising:

a first coverplate configured to be coupled to a first turbine stage of the multi-stage turbine, wherein the first coverplate comprises a first seal;

a second coverplate configured to be coupled to a second turbine stage of the multi-stage turbine, wherein the second coverplate comprises a second seal;

an interstage seal comprising a radially outermost surface having a curved shape along an axial direction, wherein the first coverplate, the second coverplate, or both are configured to support the interstage seal at the radially outermost surface of the interstage seal; and one or more seal wings attached to the first coverplate or the second coverplate, wherein the one or more seal wings extend axially away from the coverplate and are configured to support the interstage seal at a first or a second radial engagement at the radially outermost surface of the interstage seal.

18. The seal assembly of claim 17, wherein the interstage seal is integrally formed with one of the first coverplate or the second coverplate.

19. The system of claim 1, wherein the interstage seal comprises a curved shape from a first end of the interstage seal to a second end of the interstage seal in an axial direction.

20. The system of claim 1, wherein the first coverplate and/or the second coverplate comprises one or more support arms that are cantilever mounted from the coverplate and extends axially away from the coverplate.

* * * * *