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Zheng et al.

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(54) **STEAM TURBINE AND METHODS OF ASSEMBLING THE SAME**

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(51) **Int. Cl.**

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F01D 25/12	(2006.01)
F01D 9/06	(2006.01)
F01D 11/00	(2006.01)
F01D 25/24	(2006.01)

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

CPC ***F01D 9/045*** (2013.01); ***F01D 5/08*** (2013.01); ***F01D 9/06*** (2013.01); ***F01D 9/065*** (2013.01); ***F01D 11/003*** (2013.01); ***F01D 11/005*** (2013.01); ***F01D 11/02*** (2013.01); ***F01D 25/12*** (2013.01); ***F01D 25/24*** (2013.01); *F05D 2240/55* (2013.01); *Y10T 29/49316* (2015.01)

(58) **Field of Classification Search**

CPC F01D 11/02; F01D 25/12; F01D 5/08; F01D 11/001; F05D 2240/55

See application file for complete search history.

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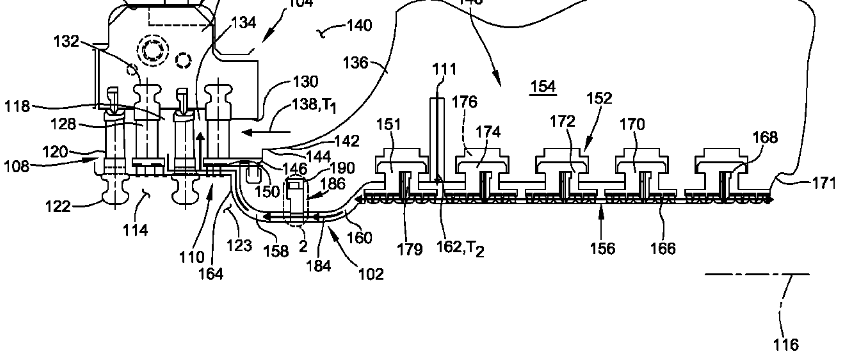
(57) **ABSTRACT**

A steam turbine is provided. The steam turbine includes a housing and a steam inlet configured to discharge a primary steam flow within the housing. A stator is coupled to the housing and a rotor is coupled to the housing and located within the stator. The rotor and the stator are configured to define a primary flow path there between and in flow communication with the primary steam flow. The steam turbine includes a seal assembly coupled to the housing. The seal assembly includes a packing head and a plurality of seals. The packing head is configured to define a cooling flow path in flow communication with the rotor and configured to discharge a cooling steam flow toward the rotor. An anti-swirl device is coupled to the seal assembly and located between the rotor and the packing head.

20 Claims, 8 Drawing Sheets



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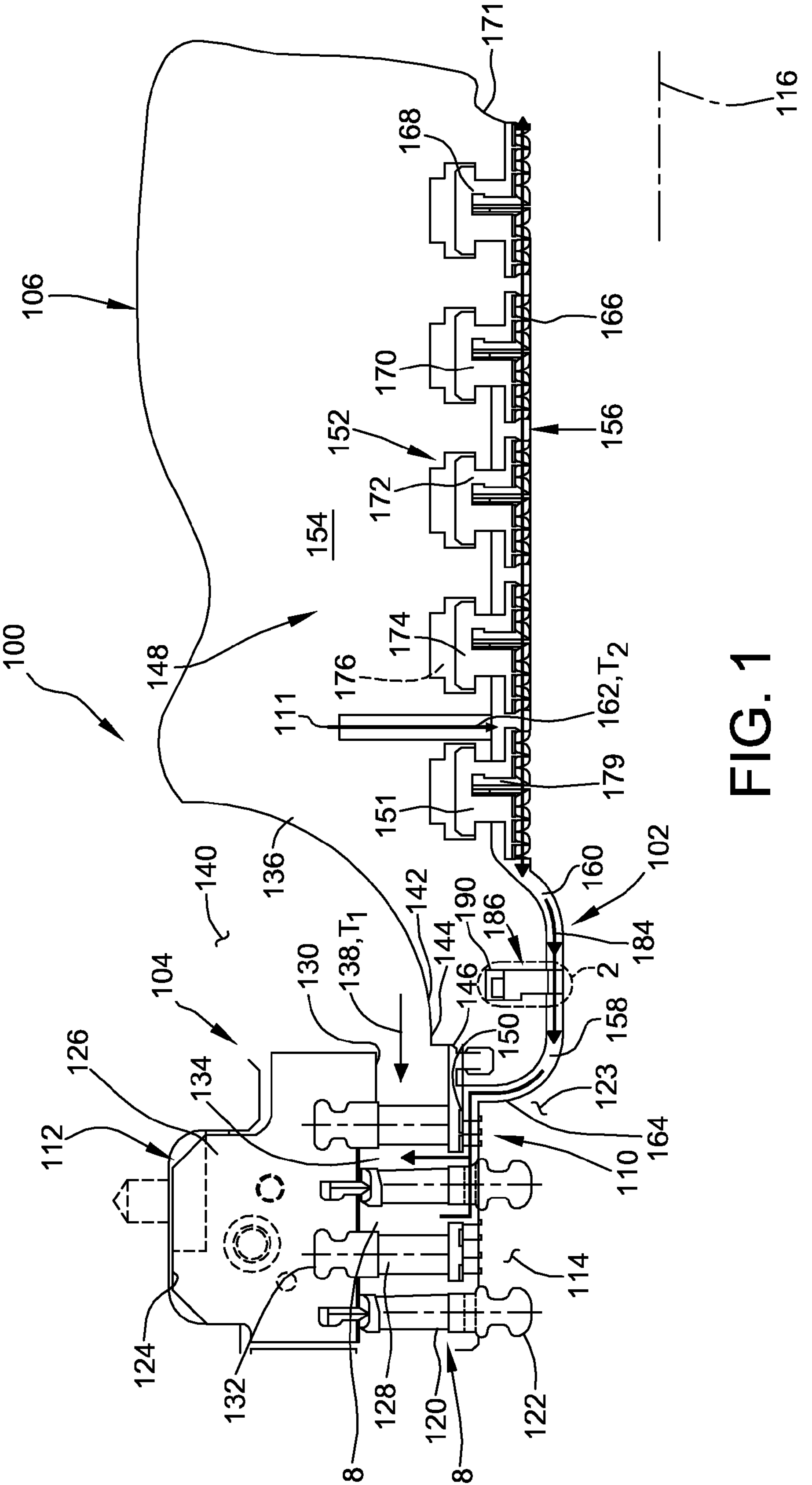
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162,T2
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142
190
186
184
2
138,T1
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104
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164
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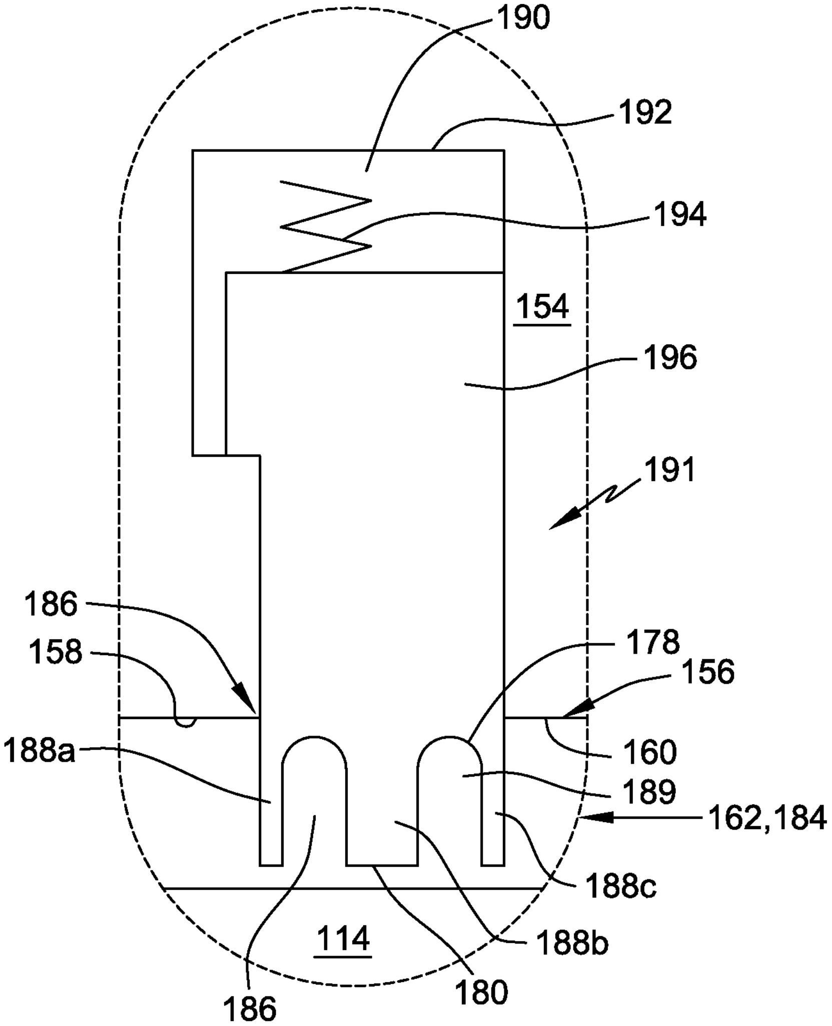
122

FIG. 1


190
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188a
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162,184
188c
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188b
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FIG. 2

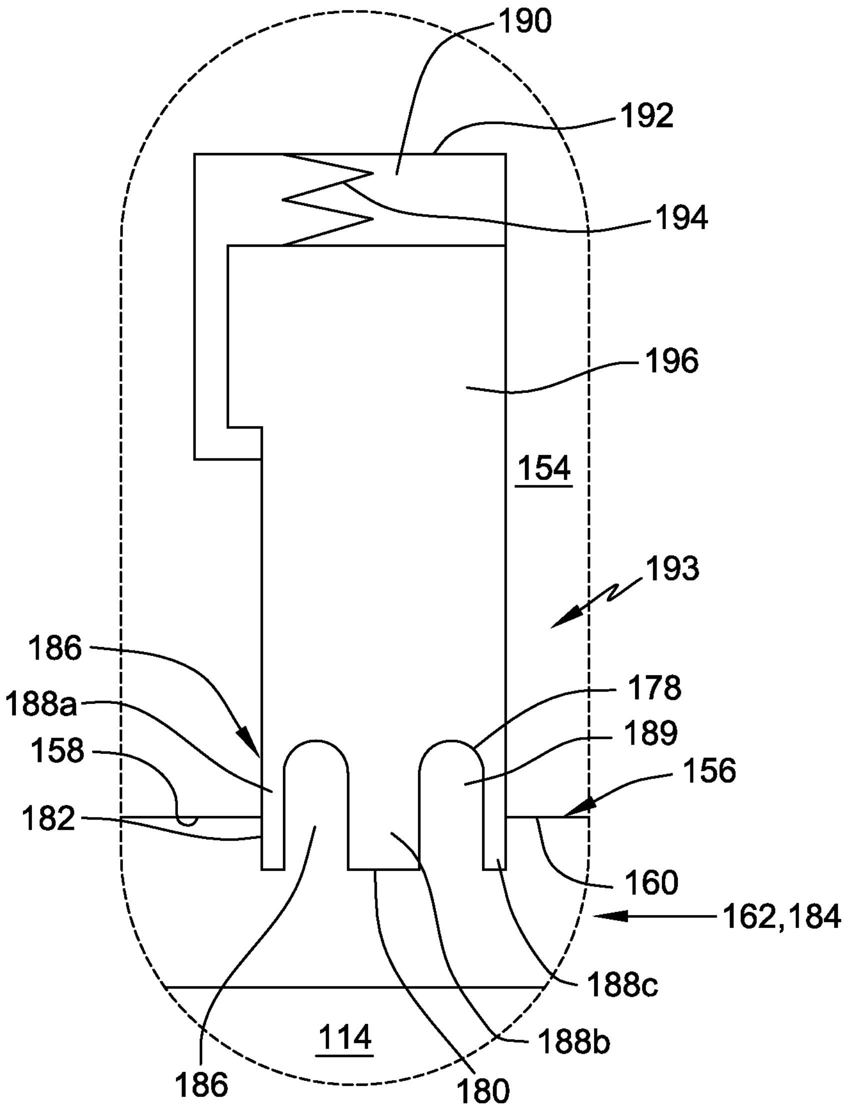
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FIG. 3

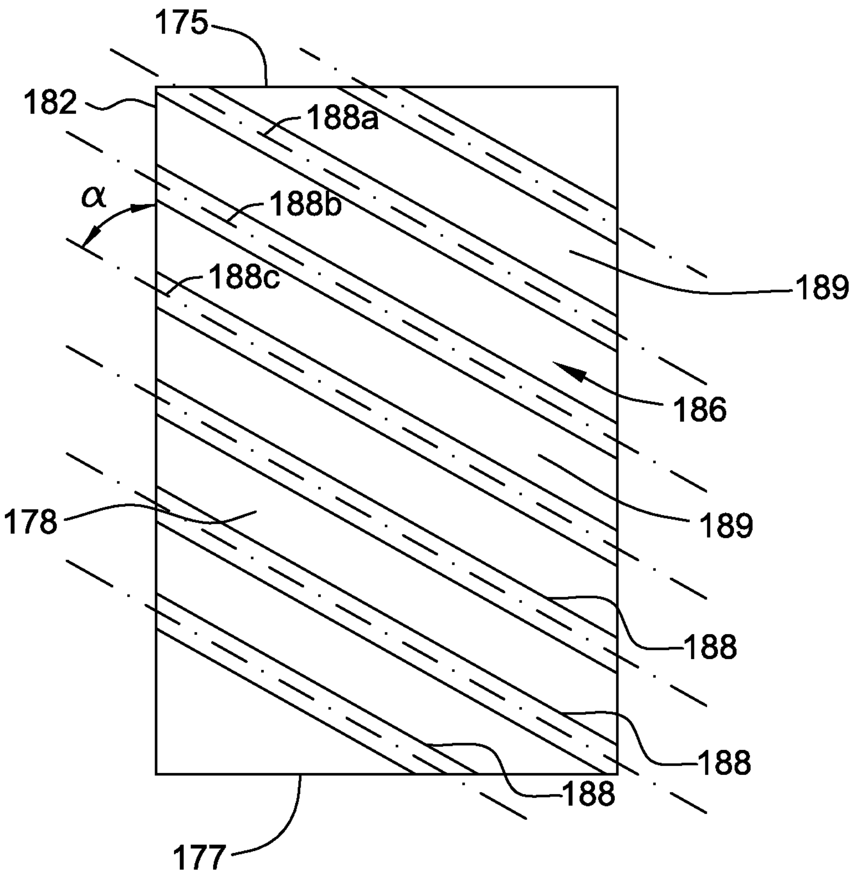
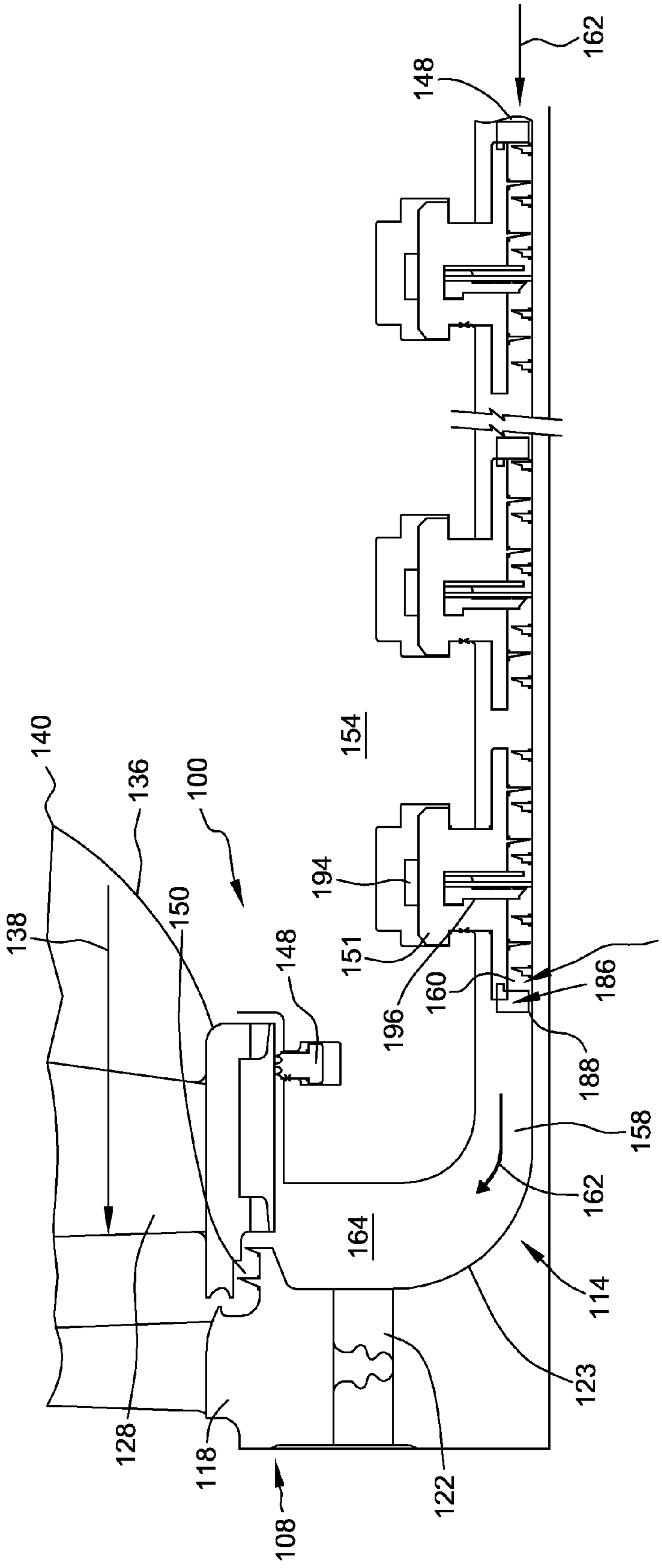


FIG. 4


162
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154
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136
100
138
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186
184
188
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114
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128
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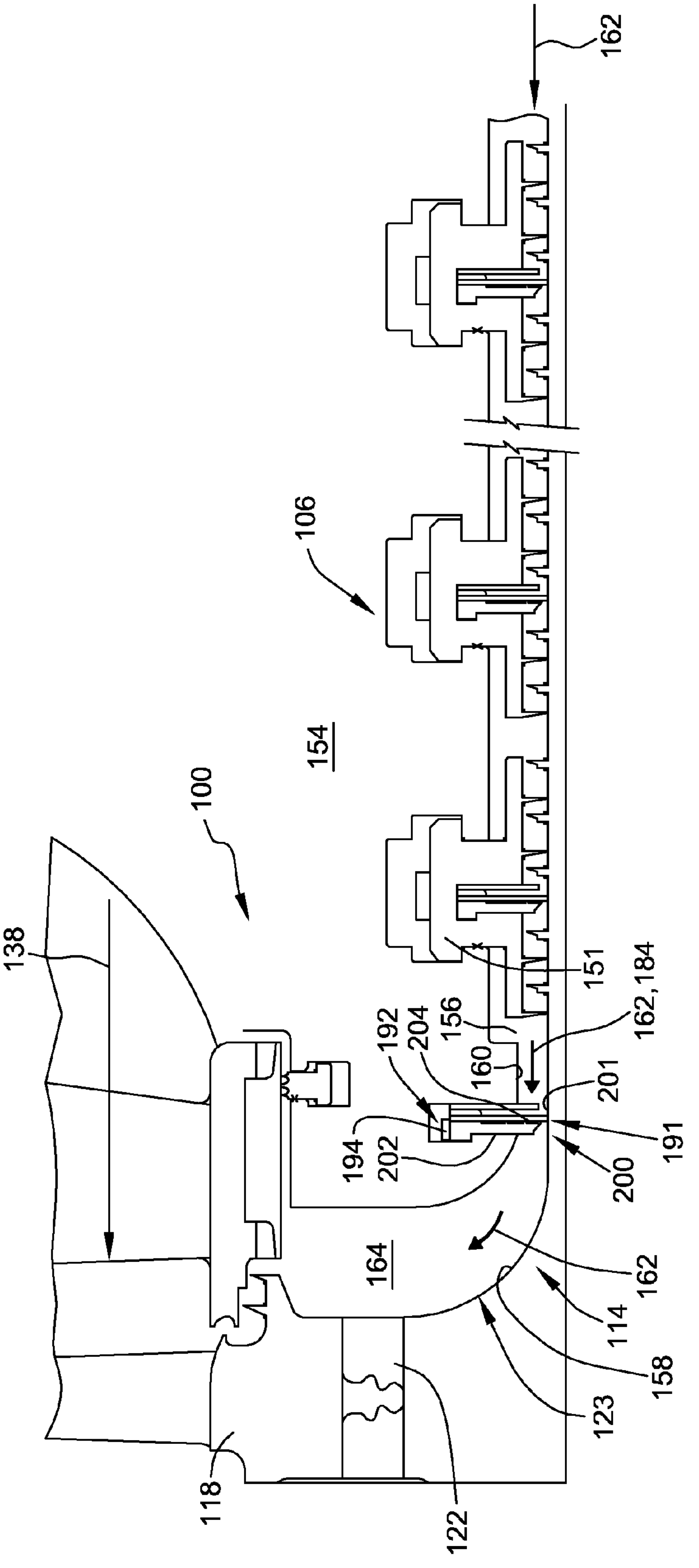
122
108

FIG. 5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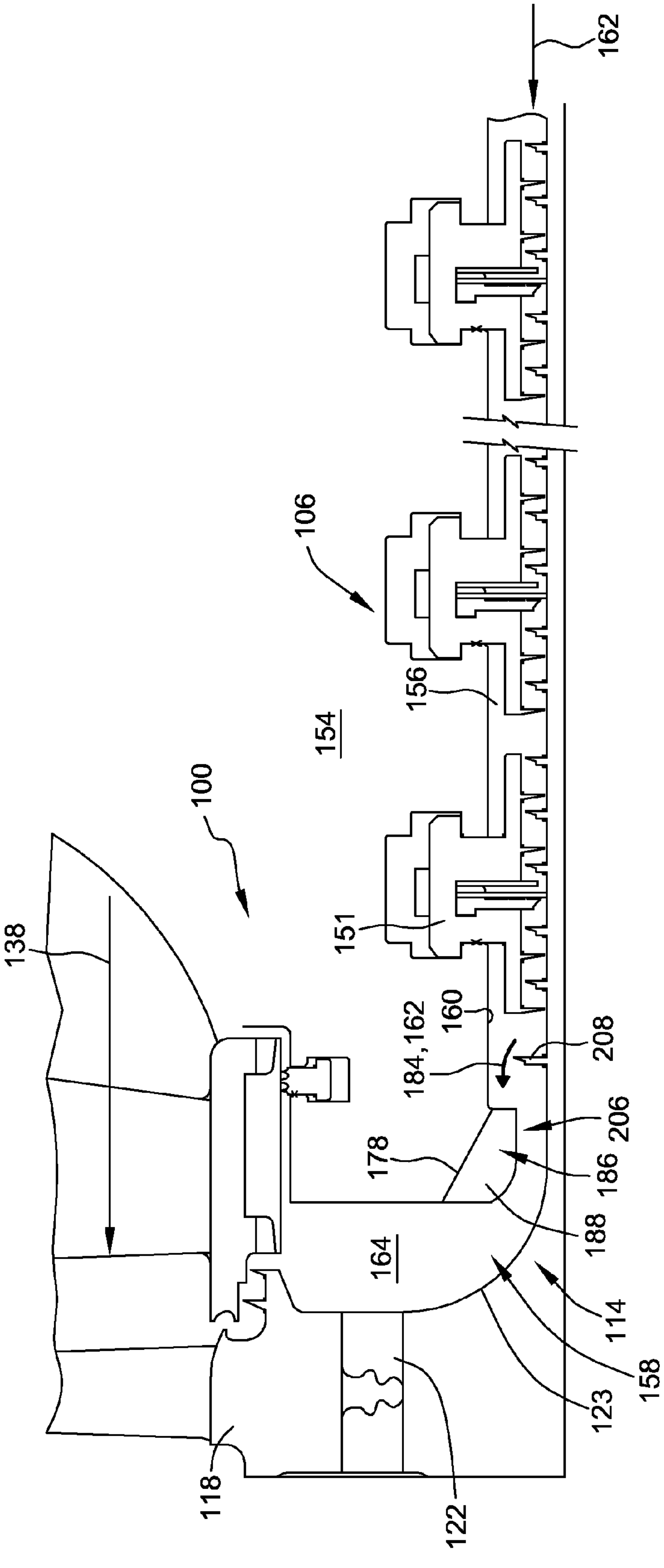
122

FIG. 6


162
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184,162
208
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186
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164
114
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123
118
122

FIG. 7

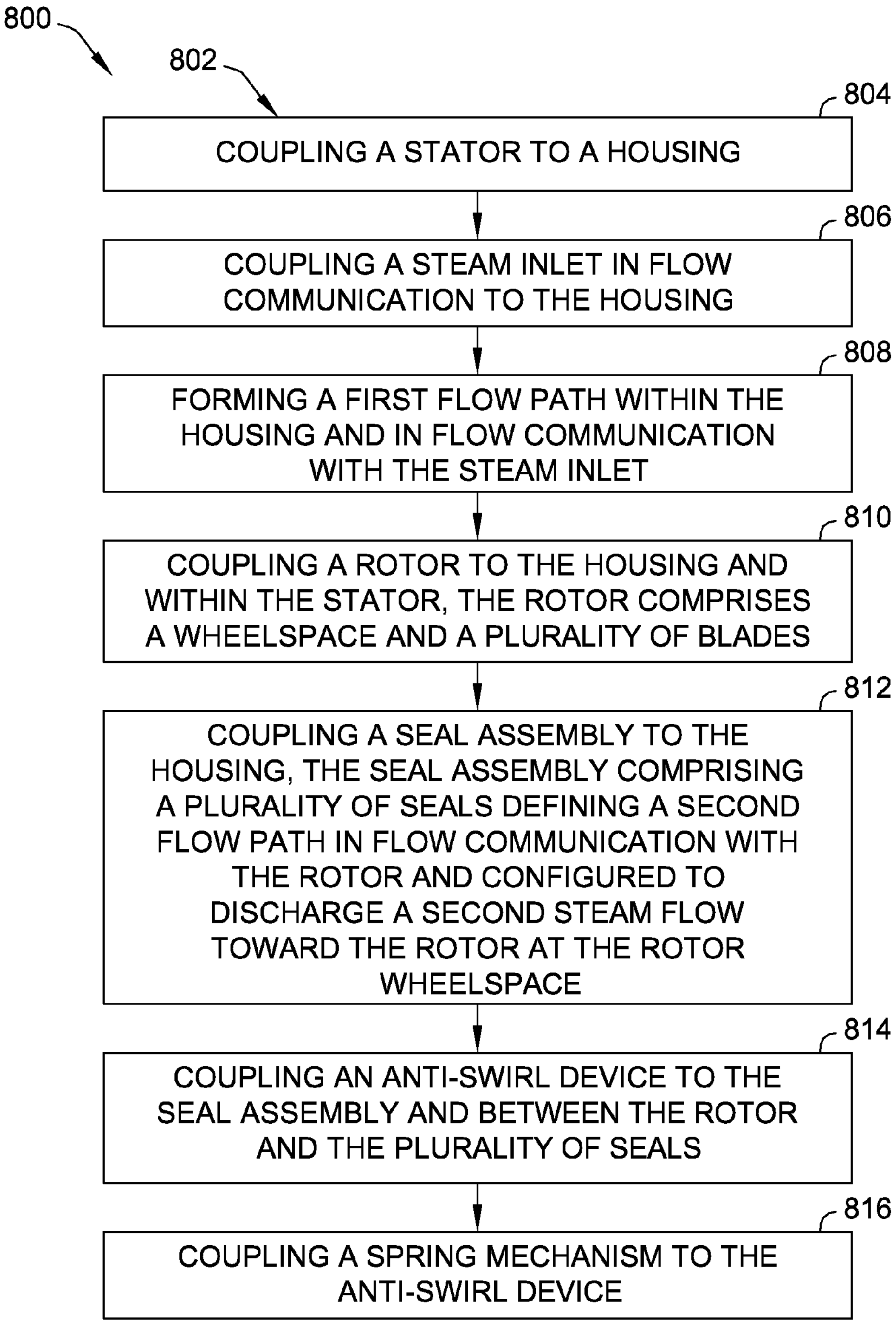
800
802
804
COUPLING A STATOR TO A HOUSING
806
COUPLING A STEAM INLET IN FLOW COMMUNICATION TO THE HOUSING
808
FORMING A FIRST FLOW PATH WITHIN THE HOUSING AND IN FLOW COMMUNICATION WITH THE STEAM INLET
810
COUPLING A ROTOR TO THE HOUSING AND WITHIN THE STATOR, THE ROTOR COMPRISES A WHEELSPACE AND A PLURALITY OF BLADES
812
COUPLING A SEAL ASSEMBLY TO THE HOUSING, THE SEAL ASSEMBLY COMPRISING A PLURALITY OF SEALS DEFINING A SECOND FLOW PATH IN FLOW COMMUNICATION WITH THE ROTOR AND CONFIGURED TO DISCHARGE A SECOND STEAM FLOW TOWARD THE ROTOR AT THE ROTOR WHEELSPACE
814
COUPLING AN ANTI-SWIRL DEVICE TO THE SEAL ASSEMBLY AND BETWEEN THE ROTOR AND THE PLURALITY OF SEALS
816
COUPLING A SPRING MECHANISM TO THE ANTI-SWIRL DEVICE

FIG. 8

STEAM TURBINE AND METHODS OF ASSEMBLING THE SAME

BACKGROUND OF THE INVENTION

The embodiments described herein relate generally to steam turbines, and more particularly, to methods and systems for reducing a swirl effect of a cooling flow for a rotor of the steam turbine.

As steam turbines rely on higher steam temperatures to increase efficiency, steam turbines are fabricated to withstand the higher steam temperatures so as not to compromise the useful life of the turbine. During a typical turbine operation, steam flows from a steam source through a housing inlet and substantially parallel to an axis of rotation along an annular hot steam path. Typically, turbine stages are positioned within the steam path such that the steam flows through vanes and blades of subsequent turbine stages. The turbine blades may be secured to a plurality of turbine wheels, where each turbine wheel is coupled to, or is formed, integral with the rotor shaft for rotation therewith. Alternatively, the turbine blades may be secured to a drum type turbine rotor rather than individual wheels, wherein the drum is formed integrally with the shaft.

At least some turbine blades include an airfoil that extends radially outward from a substantially planar platform, and a root portion that extends radially inwardly from the platform. The root portion may include a dovetail or other means to secure the blade to the turbine wheel of the turbine rotor. In general, during operation, steam flows over and around the turbine blade, which are subject to high thermal stresses. These high thermal stresses may limit the service life of the turbine blades, the wheel, and/or the rotor. More particularly, as steam temperatures increase, the rotor materials may experience creep and rupture. Conventional steam turbines may use materials that are more temperature resistant to increase the operating life and performance of the rotor. However, these materials may increase the cost of fabrication of the turbine rotor. Some steam turbines may inject cooling steam from an intermediate pressure stage towards the rotor. Typical cooling steam, however, may have a swirl effect that may affect the heat transfer from the rotor and/or negatively affect rotor operation.

BRIEF DESCRIPTION OF THE INVENTION

In one aspect, a steam turbine is provided. The steam turbine includes a housing and a steam inlet configured to discharge a first steam flow within the housing. A stator is coupled to the housing and a rotor is coupled to the housing and located within the stator. The rotor and the stator define a first flow path there between in flow communication with the first steam flow. The rotor includes a rotor wheelspace. The steam turbine includes a seal assembly coupled to the housing. The seal assembly includes a packing head and a plurality of seals. The packing head defines a second flow path that is in flow communication with the rotor at a rotor wheelspace and is configured to discharge a second steam flow toward the rotor wheelspace. An anti-swirl device is coupled to the seal assembly and between the rotor wheelspace and the packing head.

In another aspect, a rotor assembly is provided. The rotor assembly is coupled to a housing and located within a primary flow path of a steam turbine. The rotor assembly includes a rotor coupled to the housing. The rotor includes a rotor wheelspace. The rotor assembly further includes a seal assembly coupled to the housing. The seal assembly includes a plurality of seals that define a second flow path that is in flow communication with the rotor wheelspace and discharges a second steam flow toward the rotor wheelspace. An anti-swirl device is coupled to the seal assembly and between the rotor wheelspace and the plurality of seals. The anti-swirl device is configured to reduce a swirl of the cooling steam flow.

In yet another aspect, a method of assembling a steam turbine is provided. The method includes coupling a stator to a housing and coupling a steam inlet in flow communication to the housing. A first flow path is formed within the housing and in flow communication with the steam inlet. The method includes coupling a rotor to the housing and within the stator. The rotor includes a rotor wheelspace and a plurality of blades. A seal assembly is coupled to the housing and includes a plurality of seals that define a second flow path that is in flow communication with the rotor at the rotor wheelspace. The second flow path is configured to discharge a second steam flow toward the rotor wheelspace. The method further includes coupling an anti-swirl device to the seal assembly and between the rotor wheelspace and the plurality of seals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view of a steam turbine, a rotor assembly and an exemplary anti-swirl device coupled to the steam turbine.

FIG. **2** is a side elevational view of the anti-swirl device shown in FIG. **1** in a first position.

FIG. **3** is a side elevational view of the anti-swirl device shown in FIG. **1** in a second position.

FIG. **4** is a bottom view of the anti-swirl device shown in FIGS. **2** and **3**.

FIG. **5** is another side view of the steam turbine shown in FIG. **1** and the anti-swirl device coupled to the steam turbine.

FIG. **6** is a side elevational view of the steam turbine shown in FIG. **1** and including an alternative anti-swirl device.

FIG. **7** is a side view of the steam turbine shown in FIG. **1** and including yet another alternative anti-swirl device.

FIG. **8** is a flowchart illustrating an exemplary method of manufacturing a steam turbine.

DETAILED DESCRIPTION OF THE INVENTION

The embodiments described herein relate generally to steam turbines. More particularly, the embodiments relate to methods and systems for use in reducing and/or eliminating a swirl effect of cooling steam flowing within the steam turbine. It should be understood that the embodiments described herein for component cooling are not limited to turbine rotors, and further understood that the description and figures that utilize a steam turbine and rotors are for exemplary purposes only. Moreover, while the embodiments illustrate steam turbines and rotors, the embodiments described herein may be included in other suitable turbine components. Additionally, it should be understood that the embodiments described herein relating to flow paths need not be limited to turbine components. It should also be understood that the terms “primary flow path” and “first flow path” are used interchangeably; the terms “primary steam flow” and “first steam flow” are used interchangeably; the terms “cooling flow path” and “second flow path” are used interchangeably; and, the terms “cooling steam flow” and "second steam flow" are used interchangeably. Specifically, the embodiments may generally be used in any suitable article through which a medium, such as water, steam, air, fuel and/or any other suitable fluid, is directed towards a surface of the article for cooling of the article.

FIG. **1** illustrates a side elevational view of a steam turbine **100**, a rotor assembly **102**, and an anti-swirl device **186** coupled to steam turbine **100**. FIG. **2** is a side elevational view of anti-swirl device **186** shown in a first position **191**. FIG. **3** is a side elevational view of anti-swirl device **186** shown in a second position **193**. FIG. **4** is a bottom view of anti-swirl device **186**. In the exemplary embodiment, steam turbine **100** includes a turbine section **104** and a turbine end region **106**. Alternatively, steam turbine **100** may include any number of turbine sections, regions, and/or configurations that enable steam turbine **100** to function as described herein. In the exemplary embodiment, turbine section **104** includes a plurality of stages **108** in a spaced relationship with respect to each other. Each stage **108** includes a rotating assembly **110** and a stationary assembly **112**. Rotating assembly **110** includes a rotor **114** that rotates about an axis of rotation **116** of steam turbine **100**. A plurality of blades **118** are coupled to a plurality of platforms **120**, such that each blade **118** extends radially outward from platforms **120** towards stationary assembly **112**. A plurality of blade roots **122** are coupled to platforms **120** and extend radially outward from platform **120** and couple to rotor **114**. Roots **122** couple blades **118** to a rotor body **123** of rotor **114**. Moreover, adjacent blades **118** define a root area **134** located there between. Rotor body **123** includes a rotor wheelspace **164** which experiences high temperatures and high stresses during turbine operation.

Stationary assembly **112** includes a housing **124**, a stator **126** and a plurality of stationary vanes **128**. Vanes **128** are coupled in dovetails **132** defined in stator **126** and are spaced circumferentially between stages of blades **118**. Housing **124** encloses at least one of rotor **114**, blades **118**, stator **126** and vanes **128**. In the exemplary embodiment, rotor **114** and stator **126** are in a spaced relationship that defines a first flow path **130** or primary flow path there between within housing **124**. Stationary assembly **112** also includes a steam inlet **136** coupled in flow communication with primary flow path **130**. Steam inlet **136** channels a primary steam flow **138** or first steam flow at a first temperature T_1 towards primary flow path **130** and in flow communication with the plurality of blades **118**. In the exemplary embodiment, steam inlet **136** is located within housing **124** and is in flow communication with a steam source **140** such as, for example, a boiler or heat recovery steam generator. Steam inlet **136** also includes a bowl area **142** having a bowl insert **144** and a leakage flow path **146**.

Turbine end region **106** includes a seal assembly **148** coupled to rotor **114**. Seal assembly **148** includes a first seal member **150**, a second seal member **151** and a third seal member **152**. In the exemplary embodiment, seal assembly **148** includes a packing head **154** that is coupled to rotor **114** at an upstream position from steam inlet **136**. First seal member **150** reduces leakage of primary steam flow **138** into a rotor wheelspace **164** and facilitates increasing pressure in wheelspace **164** to prevent or limit hot steam ingestion. Rotor wheelspace **164** requires cooling since rotor wheelspace **164** is subjected to high temperatures within the primary flow path **130** and to high stresses experienced by holding rotating blades **118**.

Packing head **154** defines a second flow path **156** or cooling flow path having a first section **158** that is in flow communication with primary flow path **130** and a second section **160** that is in flow communication with first section **158**. In the exemplary embodiment, a cooling flow source **111** is coupled in flow communication to second flow path **156**. Cooling flow source **111** is configured to discharge a second steam flow **162** or cooling steam flow into second flow path **156**. In the exemplary embodiment, second steam flow **162** has a second temperature T_2 that is different than first temperature T_1 of primary steam flow **138**. More particularly, second temperature T_2 is less than first temperature T_1. Alternatively, second temperature T_2 may be approximately the same as, or greater than, first temperature T_1. Second temperature T_2 may have any temperature value that enables cooling of rotor body **123** in rotor wheelspace **164**.

Packing head **154** directs and/or discharges second steam flow **162** through second section **160** and first section **158** to facilitate cooling rotor body **123** at rotor wheelspace **164**. Third seal member **152** includes one or more seal rings **168**, **170**, **172** and **174**. Seal member **152** is configured to limit cooling flow from leaking out towards a rotor end **171** and/or limit a leaking flow (not shown) from a high-pressure section (not shown) from entering second flow path **156** at rotor end **171**.

A plurality of seals **166** are located within flow path **156** to reduce flow leakage of second steam flow **162**. Seals **166** may couple to seal rings **168**, **170**, **172** and **174** and against counterpart portions of rotor **114**. Turbine **100** may include any number of seals **166** that enables turbine end region **106** to function as described herein. A spring mechanism **176** biases each seal ring **168**, **170**, **172**, and **174** to a closed position and/or biases each seal ring **168**, **170**, **172**, and **174** to an open position. Seals **166** may include configurations such as, but not limited to, flexible members such as brush seals, honeycomb seals, interlocking and, and/or hydrodynamic face seals. In the exemplary embodiment, second seal member **151** is located between cooling flow source **111** and anti-swirl device **186**. In the exemplary embodiment, second seal member **151** includes a brush seal **179**. Alternatively, second seal member **151** can include any type of seal to enable turbine end region **106** to function as described herein.

Anti-swirl device **186** is coupled to packing head **154** and is located at least partially within second flow path **156**. More particularly, anti-swirl device **186** is located between first section **158** and second section **160**. Anti-swirl device **186** includes a first end **178**, a second end **180**, and a plurality of vanes **188** that are configured to define voids **189** between first end **178** and second end **180**. Vanes **188** start from end **178** and terminate at second end **180**. Anti-swirl device **186** can be segmented with circumferential end **175** and an opposite end **177**. In the exemplary embodiment, vanes **188** also extend between ends **175** and **177**. Vanes **188** such as, for example vanes **188***a*, **188***b*, and **188***c*, are angled with respect to side surface **182**. More particularly, vanes **188** include an angle α having a range between about 10° and about 90°. More particularly, angle α is about 45°. Alternatively, vanes **188** may include any angle with respect to at least one of circumferential end **175** and circumferential end **177** or can be substantially parallel to axis **116** (shown in FIG. **1**).

In the exemplary embodiment, packing head **154** includes a recess **190** that is in flow communication with second section **160**. A spring **194** is located between a recess end **192** and anti-swirl device **186**. An arm **196** is coupled to spring **194** to move anti-swirl device **186** between first position **191** (FIG. **2**) and a second position **193** (FIG. **3**) within second section **160**. In first position **191**, second end **180** is at a close position with respect to rotor **114**; and in second position **193**, second end **180** is further away from rotor **114**. Spring **194** is configured to bias vane **188** into first position **191** to facilitate positioning anti-swirl device **186** in an operation position, while allowing anti-swirl device **186** to move toward second position **193** upon any contact with rotor **114** to facilitate minimum rubbing contact between rotor **114** and anti-swirl device **186** due to rotor vibration and/or misalignment during transient conditions.

Anti-swirl device **186** is located downstream of second seal member **151** and upstream of rotor wheelspace **164** with respect to second steam flow **162**. Second steam flow **162** has steam swirl **184** that occurs when second steam flow **162** moves through second flow path **156** and gains a tangential velocity component from rotation of rotor **114**. Steam swirl **184** negatively affects heat transfer from rotor wheelspace **164** and/or operation of rotor **114** as second steam flow **162** contacts rotor wheelspace **164**. Anti-swirl device **186** reduces and/or eliminates steam swirl **184** present within second steam flow **162**. Alternatively, anti-swirl device **186** reverses steam swirl **184** present within second steam flow **162** to increase relative velocity to enhance the heat exchange from rotor **114** and into second steam flow **162** to facilitate cooling rotor wheelspace **164**. Heat transfer rate may be correlated to a heat transfer coefficient and a temperature difference. Increasing the relative velocity will increase the heat transfer coefficient and outpace the decrease of temperature difference.

Anti-swirl device **186** reduces and/or eliminates effects of steam swirl **184** present in second steam flow **162** to enhance heat transfer due to the higher relative rotational speed between rotor **114** and second steam flow **162**. More particularly, the location of anti-swirl device **186** and the angle α of vane **188** is configured to alter the flow direction of second steam flow **162** to reduce positive steam swirl **184**. Alternatively, vane **188** is sized and shaped to reverse steam swirl **184** present in second steam flow **162** by setting the angel α of vane **188** against rotor rotating direction to achieve a negative swirl (not shown). Second steam flow **162** passes anti-swirl device **186** and contacts rotor wheelspace **164** at high relative velocity to facilitate heat transfer from rotor **114** and into second steam flow **162**. More particularly, during operation, second steam flow **162** is directed past anti-swirl device **186** and contacts at least one of rotor body **123**, roots **122**, blades **118**, and rotor wheelspace **164** to facilitate heat transfer therefrom. Second steam flow **162** continues to flow and mix with primary steam flow **138**.

FIG. **5** is another side elevational view of steam turbine **100** and anti-swirl device **186**. In the exemplary embodiment, anti-swirl device **186** is coupled to second seal member **151**. More particularly, anti-swirl device **186** is integrally coupled to second seal member **151**. Alternatively, anti-swirl device **186** can be removable coupled to second seal member **151**. Anti-swirl device **186** is coupled to a downstream side of second seal member **151** and upstream of rotor wheelspace **164** with respect to second steam flow **162** to facilitate reducing and/or eliminating and/or reversing steam swirl **184** present within second steam flow **162**.

During operation, primary steam flow **138**, at high pressures and high temperatures, is directed from steam source **140**, through steam inlet **136** and towards primary flow path **130**. More particularly, primary steam flow **138** is directed towards blades **118** and vanes **128**. As primary steam flow **138** contacts blades **118**, primary steam flow **138** rotates blades **118** and rotor **114**. Primary steam flow **138** passes through stages **108** in a downstream direction and flows through successive stages (not shown) in a similar manner.

Steam flow that does not perform work by flowing through the plurality of blades **118** and rotating rotor **114** is considered a leakage flow. Leakage flow that does not perform work in a steam turbine **100** results in a loss output. First seal member **150** is configured to reduce leakage of primary steam flow **138** into wheelspace **164**. Meanwhile, second steam flow **162**, which is directed from cooling flow source **111**, flows through second seal member **151** and anti-swirl device **186**. More particularly, second steam flow **162** flows through vanes **188** of anti-swirl device **186**.

During operation, second steam flow **162**, at lower temperatures and higher pressures than primary steam flow **138** after vane **128**, is directed through packing head **154**. In the exemplary operation, second steam flow **162** is directed through cooling flow path **156**. As second steam flow **162** travels through seal **151**, and second flow path **156**, second steam flow **162** gains a rotating speed from rotor **114** which generates swirl **184** within second steam flow **162**. Second steam flow **162** continues to flow past second seal member **151** and in contact with anti-swirl device **186**. Vanes **188** capture or channel second steam flow **162** and reduce tangential velocity of and/or reverse the direction of second steam flow **162**. Therefore, the relative speed between rotor **114** and second steam flow **162** will approach the rotating speed of rotor **114**, which increases the heat transfer between rotor **114** and second steam flow **162** in rotor wheelspace **164** to facilitate cooling rotor body **123**.

Anti-swirl device **186** reduces and/or eliminates effects of steam swirl **184** present in second steam flow **162** to enhance heat transfer due to the higher relative rotational speed between rotor **114** and second steam flow **162**. More particularly, the angle α of vane **188** is configured to alter the flow direction of second steam flow **162** to reduce positive steam swirl **184**. Alternatively, vane **188** is sized and shaped to reverse steam swirl **184** present in second steam flow **162** by setting the angel α of vane **188** against rotor rotating direction to achieve a negative swirl (not shown). Second steam flow **162** passes anti-swirl device **186** and contacts rotor wheelspace **164** at high relative velocity to facilitate heat transfer from rotor **114** and into second steam flow **162**. More particularly, during operation, second steam flow **162** is directed past anti-swirl device **186** and contacts at least one of rotor body **123**, roots **122**, blades **118**, and rotor wheelspace **164** to facilitate heat transfer therefrom.

Moreover, during operation, spring **194** via arm **196** biases anti-swirl device **186** into first position **191** (shown in FIG. **2**) with a small clearance with rotor **114**. Second steam flow **162** proceeds through channels within vane **188** which redirects second steam flow **162** into axial and/or reversed rotating flow direction. Upon exiting vanes **188**, second steam flow **162** facilitates cooling rotor wheelspace **164**. If there are large rotor excursions during transient times, such as startup and shutdown, rotor **114** could contact second end **180**. Should rotor **114** contact second end **180**, rotor **114** moves anti-swirl device **186** against spring **194** and outward to second position **193** (shown in FIG. **3**) so as to avoid hard-rub damage to rotor **114**.

FIG. **6** is a side elevational view of steam turbine **100** and an alternative anti-swirl device **200** coupled to steam turbine **100**. In FIG. **6**, similar components of FIGS. **1-5** are labeled with the same element numbers. In the exemplary embodiment, anti-swirl device **200** is between seal **151** and wheelspace **164**. Anti-swirl device **200** is coupled to packing head **154** and extends toward rotor **114**. Anti-swirl device **200** includes a brush seal **202** that is located between first section **158** and second section **160** and spaced away from seal member **151**. Brush seal **202** includes tightly-packed, generally cylindrical bristles **204** having porous media configured to filter out swirl **184** in the second steam flow **162**. Brush seal **202** can be any porous media type of device that has high resistance to circumferential flow. In the exemplary embodiment, bristles **204** have a low radial stiffness that enables movement during turbine operation while maintaining a tight clearance during steady state operations. Spring loaded device **192** moves bristles **204** between first position **191** and second position **193** (shown in FIG. **2** and respectfully **3**) within second section **160**. In first position **191**, a bristle end **201** is near rotor **114**; and in second position **193**, bristle end **201** is away from rotor **114**.

During an operation, second steam flow **162**, at lower temperatures than primary steam flow **138**, is directed through end region **106** via packing head **154**. In the exemplary operation, second steam flow **162** is directed through cooling flow path **156**. As second steam flow **162** travels through the small gap between seal **151** and rotor **114**, second steam flow **162** gains a rotating speed from rotor **114** which generates swirl **184** within second steam flow **162**. More particularly, second steam flow **162** is directed through second section **160** and across seal **151**. Second section **160** directs second steam flow **162** from seals **151** and toward anti-swirl device **200**.

Anti-swirl device **200** reduces and/or eliminates effects of swirl **184** present in second steam flow **162** to facilitate increasing relative velocity of second steam flow **162** to rotor **114**. Second steam flow **162** passes anti-swirl device **200** and contacts rotor **114** to facilitate heat transfer from rotor **114** into second steam flow **162**. More particularly, during operation, second steam flow **162** is directed past anti-swirl device **200** and contacts at least one of rotor body **123**, roots **122**, blades **118** and wheelspace **164** to facilitate heat transfer therefrom. Second steam flow **162** continues to flow and mixes with primary steam flow **138**.

Alternatively, anti-swirl device **200** may include hydrodynamic face seals (not shown) to facilitate reducing leakage of a pressurized fluid through packing head **154**. Hydrodynamic face seals include a mating (rotating) ring (not shown) and a seal (stationary) ring (not shown). Generally, shallow hydrodynamic grooves (not shown) are formed or etched on mating ring face. During operation, hydrodynamic grooves in the rotating ring generate a hydrodynamic force that causes stationary ring to lift or separate from the rotating ring such that a small gap is created between the two rings. A sealing gas flows via the gap between the rotating and stationary rings.

FIG. **7** is a side elevational view of steam turbine **100** and an alternative anti-swirl device **206** coupled to steam turbine **100**. In the exemplary embodiment, anti-swirl device **206** is integrally formed with packing head **154**. Anti-swirl device **206** includes a flow deflector **208** within second section **160** and spaced away from seal member **151**. Flow deflector **208** directs second steam flow **162** that is flowing through cooling flow path **156**, and in particular, flowing through second section **160**, into the anti-swirl device **206**. Anti-swirl device **206** is configured to reduce and/or eliminate swirl **184** present within second flow path **162**. Alternatively, anti-swirl device **206** reverses steam swirl **184** present within second steam flow **162** to increase relative velocity to enhance heat exchange from rotor **114** and into second steam flow **162**.

Anti-swirl device **206** reduces and/or eliminates effects of swirl **184** present in second steam flow **162** to facilitate increasing relative velocity of second steam flow **162** to rotor **114**. Second steam flow **162** passes anti-swirl device **206** and contacts rotor **114** to facilitate heat transfer from rotor **114** into second steam flow **162**. More particularly, during operation, second steam flow **162** is directed past anti-swirl device **206** and contacts at least one of rotor body **123**, roots **122**, blades **118** and wheelspace **164** to facilitate heat transfer therefrom. Second steam flow **162** continues to flow and mixes with primary steam flow **138**.

FIG. **8** is an exemplary flowchart **800** illustrating a method **802** of manufacturing a steam turbine, for example steam turbine **100** (shown in FIG. **1**). Method **802** includes coupling **804** a stator, for example stator **126** (shown in FIG. **1**) to a housing, such as housing **124** (shown in FIG. **1**). A steam inlet, for example steam inlet **136** (shown in FIG. **1**), is coupled **806** in flow communication to the housing. Method **802** also includes forming **808** a first flow path, such as first flow path **130** (shown in FIG. **1**), within the housing and in flow communication with the steam inlet. Method **802** further includes coupling **810** a rotor, such as rotor **114** (show in FIG. **1**), to the housing and within the stator, wherein the rotor comprises a plurality of blades, for example blades **118** (shown in FIG. **1**), and a wheelspace such as, for example wheelspace **164** (shown in FIG. **1**).

In the exemplary method **802**, a seal assembly, for example seal assembly (shown in FIG. **1**), is coupled **812** to the housing. The seal assembly includes a plurality of seals, such as seal member **151** (shown in FIG. **2**), defining a second flow path, such as second flow path **156** (shown in FIG. **2**), in flow communication with the rotor and configured to discharge a second steam flow, for example second steam flow **162** (shown in FIG. **2**) toward the rotor at a rotor wheelspace. Method **802** includes coupling **814** an anti-swirl device, for example anti-swirl device **186** (shown in FIG. **1**), to the seal assembly and between the rotor wheelspace and the seals. Coupling **814** the anti-swirl device includes coupling a vane, for example vane **188** (shown in FIG. **2**), within the cooling flow path and downstream of the seals **151**. Method **802** further includes coupling **816** a spring loaded device, such as spring loaded device **192** (shown in FIG. **2**), to the anti-swirl device.

A technical effect of the systems and methods described herein includes at least one of: (a) coupling an anti-swirl device to an exit side of a packing head; (b) reducing and/or reversing a steam swirl present in cooling steam to enhance heat transfer from the steam turbine; (c) enhancing a cooling effect on a rotor of a steam turbine; (d) reducing manufacturing, operating, and/or maintenance costs of a turbine component; and (e) increasing an operating life of a steam turbine.

The exemplary embodiments described herein facilitate heat transfer from a rotor of a steam turbine. The embodiments described use an anti-swirl device coupled to an exit side of a packing head to reduce and/or to reverse steam swirl of cooling steam as the cooling steam exits the packing head and flows toward the rotor. The anti-swirl device alters the steam swirl to enhance the heat transfer from the steam turbine, and in particular, the rotor. By enhancing cooling of the rotor, the embodiments described herein reduce operating and/or maintenance costs. Moreover, the embodiments described herein increase the operating life of the steam turbine.

Exemplary embodiments of a steam turbine and methods for assembling the steam turbine are described above in detail. The methods and systems are not limited to the specific embodiments described herein, but rather, components of systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. For example, the methods may also be used in combination with other manufacturing systems and methods, and are not limited to practice with only the systems and methods as described herein. Rather, the exemplary embodiment can be implemented and utilized in connection with many other thermal applications.

Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

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 languages of the claims.

What is claimed is:

1. A steam turbine comprising:

a housing comprising an inlet configured to discharge a primary steam flow into said housing;

a stator coupled to said housing;

a rotor coupled to said housing and located within said stator, said rotor and said stator define a primary flow path there between, said primary flow path is in flow communication with the primary steam flow, said rotor comprising a rotor wheelspace;

a seal assembly coupled to said housing, said seal assembly comprising a packing head and a plurality of seals, said packing head defines a cooling flow path that is in flow communication with said rotor at said rotor wheelspace, said cooling flow path is configured to discharge a cooling steam flow towards said rotor wheelspace; and

an anti-swirl device coupled to said seal assembly between said rotor wheelspace and said packing head.

2. The steam turbine of claim **1**, wherein said anti-swirl device is located within said cooling flow path.

3. The steam turbine of claim **1**, wherein said plurality of seals comprises an upstream seal and a downstream seal with respect to said cooling steam flow and said anti-swirl device is coupled to said downstream seal.

4. The steam turbine of claim **3**, wherein said anti-swirl device comprises a vane coupled to said downstream seal.

5. The steam turbine of claim **1**, wherein said plurality of seals comprises an upstream seal and a downstream seal with respect to the cooling steam flow and said anti-swirl device is located within said cooling flow path and between said rotor wheelspace and said downstream seal.

6. The steam turbine of claim **1**, wherein said anti-swirl device comprises a vane and a spring-loaded device coupled to said vane, said spring-loaded device configured to move said vane between a first position and a second position within said cooling flow path.

7. The steam turbine of claim **1**, wherein said anti-swirl device comprises a flow deflector.

8. The steam turbine of claim **1**, wherein said anti-swirl device comprises a spring-loaded brush.

9. The steam turbine of claim **1**, wherein said anti-swirl device is configured to reduce a swirl of the cooling steam flow.

10. The steam turbine of claim **1**, wherein said anti-swirl device is configured to reduce a velocity of the cooling steam flow.

11. A rotor assembly coupled to a housing and located within a primary flow path, said rotor assembly comprising:

a rotor coupled to the housing and comprising a rotor wheelspace;

a seal assembly coupled to said housing, said seal assembly comprising a plurality of seals that define a cooling flow path that is in flow communication with said rotor wheelspace and discharges a cooling steam flow toward said rotor wheelspace; and

an anti-swirl device coupled to said seal assembly downstream from said plurality of seals and between said rotor wheelspace and said plurality of seals, said anti-swirl device is configured to reduce a swirl of said cooling steam flow.

12. The rotor assembly of claim **11**, wherein said anti-swirl device is located within said cooling flow path.

13. The rotor assembly of claim **11**, wherein said plurality of seals comprises an upstream seal and a downstream seal with respect to the cooling steam flow and said anti-swirl device is coupled to said downstream seal.

14. The rotor assembly of claim **11**, wherein said plurality of seals comprises an upstream seal and a downstream seal with respect to the cooling steam flow and said anti-swirl device is located within said cooling flow path and between said rotor wheelspace and said downstream seal.

15. The rotor assembly of claim **11**, wherein said anti-swirl device comprises a flow deflector.

16. The rotor assembly of claim **11**, wherein said cooling flow path is configured to discharge the cooling steam flow at a predetermined pressure toward said rotor wheelspace.

17. A method of assembling a steam turbine, said method comprising:

coupling a stator to a housing;

coupling a steam inlet in flow communication to the housing;

forming a first flow path within the housing and in flow communication with the steam inlet;

coupling a rotor to the housing and within the stator, the rotor comprises a rotor wheelspace and a plurality of blades;

coupling a seal assembly to the housing, the seal assembly comprising a plurality of seals that define a second flow path in flow communication with the rotor and discharges a second steam flow toward the rotor at the rotor wheelspace; and

coupling an anti-swirl device to the seal assembly downstream from the plurality of seals and between the rotor wheelspace and the plurality of seals.

18. The method of claim **17**, wherein coupling the anti-swirl device comprises coupling a vane to a downstream seal of the plurality of seals.

19. The method of claim **17**, wherein coupling the anti-swirl device comprises coupling a vane to the seal assembly and within the cooling flow path.

20. The method of claim **17**, further comprising coupling a spring mechanism to the anti-swirl device.

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