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(71) Applicant: **General Electric Company
Schenectady, New York 12345 (US)**

(72) Inventors:
- **Zhang, Xiuzhang James
Greenville, SC South Carolina 29615 (US)**
- **Benson, Adebukola Oluwaseun
Greenville, SC South Carolina 29615 (US)**
- **Pilson, Richard Ryan
Greenville, SC South Carolina 29615 (US)**
- **Tesh, Stephen William
Greenville, SC South Carolina 29615 (US)**

(74) Representative: **Cleary, Fidelma et al
GPO Europe
GE International Inc.
The Ark
201 Talgarth Road
Hammersmith
London W6 8BJ (GB)**

(54) Turbine component having cooling passages with varying diameter

(57) Systems and devices configured to cool turbine components in a turbine by passing a cooling flow through the turbine component 100 via a cooling passage 110 with a variable diameter are disclosed. In one embodiment, a turbine component 100 includes: at least one elongated cooling passage 110 extending from a root 120 of a turbine bucket to a tip 132 of the bucket, wherein the elongated cooling passage 110 has a variable diameter along a length of the bucket.

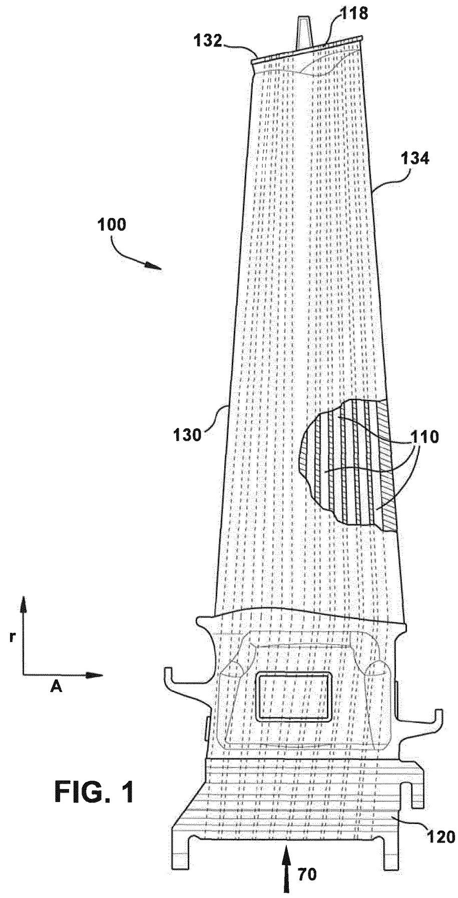

FIG. 1

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Description

[0001] The subject matter disclosed herein relates to cooling passages in turbine components, more specifically, to turbine nozzles, shrouds, and/or buckets having shaped tube electrochemical machined (STEM) cooling holes with a varying diameter (e.g., a convergent shape, a divergent shape, etc.) therein.

[0002] In some turbines (e.g., gas turbines), efficiencies are directly proportional to the temperature of turbine gases flowing along the hot gas path and driving the turbine blades. These gas turbines typically have operating temperatures on the order of approximately 2700 degrees Fahrenheit (1482 degrees Celsius), a temperature which may stress and/or damage turbine components (e.g., turbine buckets, shrouds, nozzles, etc.). To withstand these high temperatures, the components are manufactured from advanced materials and typically include smooth bore cooling passages with a constant diameter for flowing a cooling medium, typically compressor discharge air, through the buckets. These passages also typically extend from the radially inner bucket root to the radially outer bucket tip with a consistent diameter.

[0003] Many power generation turbine buckets use Shaped Tube Electrochemical Machining (STEM) drilled circular round holes to form the radial cooling flow passages inside the turbine airfoils. STEM is used for non-contact drilling of small, deep holes in electrically conductive materials, with high aspect ratios (e.g., a ratio of the length or depth of the hole to the largest lateral dimension (e.g., diameter of the hole), which in certain specific applications can be as small as a few millimeters) such as 300:1. The STEM process removes stock by electrolytic dissolution, utilizing a flow of electric current between an electrode and the workpiece through an electrolyte flowing in the intervening space to form the radial cooling flow passages.

[0004] While smooth-bore passages have been utilized, turbulence promoters, (e.g., turbulators), are also used in many gas turbine buckets to enhance the internal heat transfer coefficient. This heat transfer enhancement may increase the heat transfer coefficient to more than two times greater than smooth-bore passages for the same cooling flow rate. Turbulators conventionally comprise internal ridges or roughened surfaces along the interior surfaces of the cooling passages. However, formation of these smooth-bore passages and/or turbulators may be limited by wall thickness requirements within the turbine bucket, particularly in proximity to a tip and/or trailing edge of the turbine bucket which typically has very small/thin dimensions. These limitations result in the smooth-bore passages having a small diameter near root sections of the turbine bucket so as to meet wall thickness requirements in the tip.

[0005] Turbine components (e.g., turbine nozzles, shrouds, and/or buckets) having shaped tube electrochemical machined (STEM) cooling holes with a varying diameter (e.g., a convergent shape, a divergent shape, etc.) are disclosed.

[0006] A first aspect of the invention includes: a turbine component including: at least one elongated cooling passage extending from a root of the bucket to a tip of the bucket, wherein the elongated cooling passage has a variable diameter along a length of the bucket.

[0007] A second aspect of the invention includes: turbine bucket including: a root configured to connect to a turbine; a base disposed on the root and configured to extend into a turbine flowpath, the base having an airfoil shape and including a tip; and at least one elongated cooling passage formed in the root and the base, the at least one elongated cooling pass including: a first section disposed proximate the root and including an aperture at a terminus of the at least one elongated cooling passage, the first section extending into the base, and a second section fluidly connected to the first section and disposed proximate the tip, wherein a second diameter of the second section is smaller than a first diameter of the first section.

[0008] A third aspect of the invention includes: a turbine including: a stator; a working fluid passage substantially surrounded by the stator; a rotor disposed radially inboard of the stator and in the working fluid passage; and a turbine bucket connected to the rotor, the turbine bucket including: at least one elongated cooling passage extending from a root of the turbine bucket to a tip of the turbine bucket, wherein the elongated cooling passage has a variable diameter along a length of the turbine bucket.

[0009] These and other features of this invention will be more readily understood from the following detailed description of the various aspects of the invention taken in conjunction with the accompanying drawings that depict various embodiments of the invention, in which:

FIG. 1 shows a turbine component in accordance with embodiments of the invention;

FIG. 2 shows a turbine component in accordance with embodiments of the invention;

FIG. 3 shows a cooling passage in accordance with embodiments of the invention;

FIG. 4 shows a cooling passage in accordance with embodiments of the invention;

FIG. 5 shows a cooling passage in accordance with embodiments of the invention;

FIG. 6 shows a cooling passage in accordance with embodiments of the invention;

FIG. 7 shows a cooling passage in accordance with embodiments of the invention;

FIG. 8 shows a cross sectional view of a cooling passage in accordance with embodiments of the invention;

FIG. 9 shows a cross sectional view of a cooling passage in accordance with embodiments of the invention;

FIG. 10 shows a cross sectional view of a cooling passage in accordance with embodiments of the invention;

FIG. 11 shows a schematic block diagram illustrating portions of a combined cycle power plant system according to embodiments of the invention; and

FIG. 12 shows a schematic block diagram illustrating portions of a single-shaft combined cycle power plant system according to embodiments of the invention.

[0010] It is noted that the drawings of the invention are not necessarily to scale. The drawings are intended to depict only typical aspects of the invention, and therefore should not be considered as limiting the scope of the invention. It is understood that elements similarly numbered between the FIGURES may be substantially similar as described with reference to one another. Further, in embodiments shown and described with reference to FIGS. 1-12, like numbering may represent like elements. Redundant explanation of these elements has been omitted for clarity. Finally, it is understood that the components of FIGS. 1-12 and their accompanying descriptions may be applied to any embodiment described herein.

[0011] Aspects of the invention provide for turbine components (e.g., nozzles, shrouds, buckets, etc.) having STEM shaped cooling passages with a varying diameter (e.g., convergent, divergent, etc.).

[0012] As noted herein, cooling passages through turbine components are conventionally cylindrical passageways with a substantially constant diameter from root to tip. The diameter of the coolant passages is constant and is therefore limited by the thinnest part of the turbine component (e.g., the blade tip, the trailing edge, the nozzle trailing edge, etc.).

[0013] In contrast to conventional approaches, aspects of the invention include a turbine component (e.g., turbine bucket, turbine nozzle, nozzle trailing edge, shroud, etc.) having cooling passages with a varying diameter (e.g., a cooling passage which has a first diameter in one portion of the turbine bucket which varies in dimensional size from a second diameter of the cooling passage in a second portion of the turbine bucket, convergent cooling passages, divergent cooling passages, etc.). In an embodiment, the cooling passage diameter may decrease/diminish (e.g., gradually, telescopically, stepwise, etc.) across a length of the cooling passage in a convergent manner. In one embodiment, the varying diameter of the cooling passage has a larger dimension proximate a root of a turbine component (e.g., bucket) relative to a diameter of the cooling passage proximate a tip of the turbine bucket (e.g., a small diameter cooling passage proximate the tip of the turbine bucket which has an increasingly larger diameter as the cooling passage extends through mid and lower points of an airfoil span of the turbine bucket). The thickness/diameter of the cooling passage may be greater at the turbine bucket root where a cooling fluid flow may be introduced, this thickness increasing the sectional area proximate the root and increasing flow of the cooling fluid there through. In an embodiment, the cooling passage may include an aperture (e.g., metering feature) through the nozzle trailing edge configured to manipulate/control characteristics of a cooling flow through the cooling passage.

[0014] Turning to FIG. 1, a turbine bucket 100 is shown including a set of cooling passages 110 in accordance with embodiments. Turbine bucket 100 includes a base (e.g., an airfoil) 130 connected to a root 120 which is configured to connect to a turbine system. In an embodiment, set of cooling passages 110 may be formed/shaped through shaped tube electrochemical machining (STEM). Set of cooling passages 110 extend substantially radially from root 120 toward a tip 132 of base 130. Base 130 is shaped as an airfoil and includes a trailing edge 134 with a relatively thin thickness. Set of cooling passages 110 may enable a cooling flow 70 to pass through turbine component 100 and may include a varying diameter (e.g., convergent, divergent, etc.). In one embodiment, a diameter of set of cooling passages 110 may vary in proportion/relation to a thickness of turbine bucket 100. Cooling passages 110 are defined by an interior surface of turbine bucket 100 and may include an aperture 118 which allows cooling flow 70 to enter a flow path of a turbine.

[0015] As used herein, the terms "axial" and/or "axially" refer to the relative position/direction of objects along axis A, which is substantially perpendicular to the axis of rotation of the turbomachine (in particular, the rotor section). As further used herein, the terms "radial" and/or "radially" refer to the relative position/direction of objects along axis (r), which is substantially perpendicular with axis A and intersects axis A at only one location. Additionally, the terms "circumferential" and/or "circumferentially" refer to the relative position/direction of objects along a circumference which surrounds axis A but does not intersect the axis A at any location.

[0016] Turning to FIG. 2, a portion of a rotor 10 is shown including a first wheel 12 and a second wheel 14. Each of the wheels 12 and 14 carries a circumferential array of buckets 16 and 18, respectively. Circumferential arrays of first and second-stage nozzle vanes 20 and 22 are also shown. It will be appreciated that the buckets 16 and 18 and nozzle vanes 20 and 22 lie in the working fluid flowpath 21 of the turbine. Nozzle vane 22 is carried by an inner shell 24 which disposes nozzle vanes 20 and 22 in the flowpath. The trailing edges of the nozzle vanes 20 and 22 are cooled by a flow of liquid (e.g., air, compressor discharge, etc.) into a trailing edge cavity 26 for flow through cooling passages 110 through the trailing edge tip 34 into the flowpath. In one embodiment, set of cooling passages 110 may extend to a nozzle trailing edge 34, a diameter of the cooling passages 110 decreasing relative to a proximity to the trailing edge 34 (e.g., convergently, divergently, etc.).

[0017] Turning to FIG. 3, a portion of a turbine component 200 is shown including a cooling passage 210 with a set of sections 220, 230, and 240, with varied diameter in accordance with embodiments of the invention. Cooling passage 210 is defined by an inner surface 280 of turbine component 200. In an embodiment, cooling passage 210 includes a first section 220 fluidly connected to a second section 230 and a third section 240. As can be seen, first section 220 may include a first diameter A, second section 230 may include a second diameter B, and/or third section 240 may include a third diameter C. In this embodiment, first section 220, second section 230, and third section 240 may form a step (e.g., incremental, tiered, telescoped, etc.) shaped cooling passage 210, whereby a diameter of cooling passage 210 decreases incrementally/stepwise as cooling passage 210 extends (e.g., radially) through turbine component 200. In one embodiment, cooling flow 70 may flow in a convergent direction through first section 220 to second section 230 and/or third section 240. Diameter A of first section 220 may be greater than diameter B of second section 230, and diameter B of second section 230 may be greater than diameter C of third section 240. In one embodiment, inner surface 280 may have a substantially uniform material composition (e.g., metal, ceramic, etc.) throughout cooling passage 210. In an embodiment, inner surface 280 comprises a machined surface of turbine component 200. It is understood that while embodiments are described with reference to particular cooling passages, these embodiments may be combinable and/or applicable to any cooling passages described herein, including cooling passages 110, 210, 310, 410, etc.

[0018] Turning to FIG. 4, a portion of a turbine component 300 including a cooling passage 310 is shown in accordance with embodiments. Cooling passage 310 has a diameter D which varies gradually (e.g., from a dimension D_1, D_2,.....D_{1+N}, etc.) in a convergent fashion from a base 302 of turbine component 300 toward a tip 304 of turbine component 300. An interior surface of cooling passage 310 may be angled and have a substantially coned/frusto-conical shape.

[0019] Turning to FIG. 5, a portion of a turbine component 400 including a cooling passage 410 is shown in accordance with embodiments. Cooling passage 410 may include a first section 420 with a substantially coned shape fluidly connected to a second section 430 with a reduced diameter 'G.' First section 420 may have a diameter E which gradually diminishes (e.g., from E_1, to E_2, to E_{1+N}) between a root 402 of turbine component 400 and second section 430. It is understood that the descriptions and/or combinations of cooling passage sections described herein are merely exemplary, and that any combination, modification, orientation, and/or arrangement of cooling passage sections may be included in accordance with embodiments.

[0020] Turning to FIG. 6, a portion of a turbine component 500 including a cooling passage 510 is shown in accordance with embodiments. Cooling passage 510 may have a coned/frusto-conical shape and include a turbulator 550 disposed on a surface 518 of cooling passage 510. Turbulator 550 may extend into a flow path of cooling flow 70 and may be configured to induce and/or enhance turbulent flow. In an embodiment, turbulator 550 may include a set of sections (e.g., rings, tabs, protrusions, etc.) disposed within cooling passage 510. In an embodiment, the set of sections of turbulator 550 may be disposed at a proximity relative one another which is in a range of about 7 to about 13 times a relative protrusion height (e.g., how far each section protrudes into cooling passage 510) of each of the sections of turbulator 550. In one embodiment, the set of sections may be disposed at a substantially regular interval relative to one another. In another embodiment, shown in FIG. 7, a portion of a turbine component 600 may include a cooling passage 610 as shown in accordance with embodiments. Cooling passage 610 may include a turbulator 650 disposed on a surface of cooling passage 610 with a substantially swirl shaped configuration. Turbulator 650 may include a first end 622 disposed proximate a root portion 612 of turbine component 600, and second end 624 disposed proximate a tip portion 614 of turbine component 600. Turbulator 650 may be disposed circumferentially about cooling passage 610 while extending radially outward through cooling passage 610. In an embodiment, flow 70 may travel through cooling passage 610 in a divergent direction (e.g., from a first section of cooling passage 610 with a first diameter to a second section of cooling passage 610 with a second diameter which is greater than the first diameter) from tip portion 614 toward root portion 612. It is understood that cooling flow 70 as described in embodiments herein may flow in any direction, and that the embodiments described herein are merely exemplary.

[0021] Turning to FIG. 8, a portion of a turbine component 700 including a cooling passage 710 is shown according to embodiments. In this embodiment, cooling passage 710 includes a first portion 714 which is fluidly connected to a metering feature 712. Metering feature 712 includes an aperture 716 disposed at a terminus of cooling passage 710. In an embodiment, a flow 70 (e.g., air) may travel axially (e.g., through a radial end of a bucket, through an axial end of a nozzle, etc.) through cooling passage 710. Metering feature 712 may fluidly connect cooling passage 710 to a fluid passage of a turbine. In an embodiment, metering feature 712 and/or aperture 716 may be adjustable/variable in diameter. Metering feature 712 and/or aperture 716 may control/meter cooling flow 70 in and/or through cooling passage 710 and may be modified/machined by a technician to adjust flow characteristics through cooling passage 710 (e.g., during maintenance, diagnostics, testing, cold flows, etc.). In an embodiment, aperture 716 and/or metering feature 712 may be machined to tune cooling passage 710 to meet design/nominal amounts and flow results. In one embodiment, aperture 716 and/or metering feature 712 may be adjusted (e.g., increased, drilled out, etc,) during cold testing of the component to correct manufacturing irregularities/errors.

[0022] In an embodiment, a technician may increase (e.g., drill, bore, STEM, etc.) a diameter of metering feature 712 and/or aperture 716 in order to adjust the heat transfer coefficient within cooling passage 710. In another embodiment, shown in FIG. 9, a turbine component 800 may include a cooling passage 810 with a telescoping (e.g., incremental, stepped, etc.) shape and a metering feature 812. Cooling passage 810 may include a first section 814 with a diameter which is greater than a diameter of a second section 818. In an embodiment, cooling passage 810 may include a metering feature 812 which is fluidly connected to second section 818. Metering feature 812 may include an aperture 816 and enable cooling flow 70 to enter and/or exit cooling passage 810. In another embodiment, shown in FIG. 10, a turbine component 850 may include a cooling passage 870 with a substantially constant diameter and a set of turbulators 880 disposed on a surface thereof. Turbine component 850 may include a metering feature 874 with an aperture 878 configured to meter/control cooling flow 70 through cooling passage 870.

[0023] Turning to FIG. 11, a schematic view of portions of a multi-shaft combined cycle power plant 900 is shown. Combined cycle power plant 900 may include, for example, a gas turbine 980 operably connected to a generator 970. Generator 970 and gas turbine 980 may be mechanically coupled by a shaft 915, which may transfer energy between a drive shaft (not shown) of gas turbine 980 and generator 970. Also shown in FIG. 11 is a heat exchanger 986 operably connected to gas turbine 980 and a steam turbine 992. Heat exchanger 986 may be fluidly connected to both gas turbine 980 and a steam turbine 992 via conventional conduits (numbering omitted). Gas turbine 980 and/or steam turbine 992 may include component 100 and/or set of cooling passages 110 of FIG. 1 or other embodiments described herein. Heat exchanger 986 may be a conventional heat recovery steam generator (HRSG), such as those used in conventional combined cycle power systems. As is known in the art of power generation, HRSG 986 may use hot exhaust from gas turbine 980, combined with a water supply, to create steam which is fed to steam turbine 992. Steam turbine 992 may optionally be coupled to a second generator system 970 (via a second shaft 915). It is understood that generators 970 and shafts 915 may be of any size or type known in the art and may differ depending upon their application or the system to which they are connected. Common numbering of the generators and shafts is for clarity and does not necessarily suggest these generators or shafts are identical. In another embodiment, shown in FIG. 12, a single shaft combined cycle power plant 990 may include a single generator 970 coupled to both gas turbine 980 and steam turbine 992 via a single shaft 915. Steam turbine 992 and/or gas turbine 980 may include set of cooling passages 110 of FIG. 1 or other embodiments described herein.

[0024] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0025] 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.

[0026] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A turbine component comprising:

    a base portion; and

    at least one elongated cooling passage extending from a root of the base portion to a tip of the base portion, wherein the elongated cooling passage has a variable diameter along a length of the turbine component.

2. The turbine component of clause 1, wherein the at least one elongated cooling passage includes a Shaped Tube Electrochemical Machining (STEM) drilled passage.

3. The turbine component of any preceding clause, wherein a diameter of the at least one elongated cooling passage varies incrementally between the root of the turbine component and the tip of the turbine component.

4. The turbine component of any preceding clause, wherein the at least one elongated cooling passage

has a frusto-conical shape.

5. The turbine component of any preceding clause, wherein the at least one elongated cooling passage includes:

a first section proximate the root, the first section having a first diameter, and

a second section fluidly connected to the first section, the second section located proximate the tip and having a second diameter.

6. The turbine component of any preceding clause, wherein the first diameter is larger than the second diameter.

7. The turbine component of any preceding clause, wherein the at least one elongated cooling passage includes at least one turbulator disposed on a surface of the elongated cooling passage.

8. The turbine component of any preceding clause, wherein the at least one turbulator includes at least one of: a segmented turbulator and a swirl shaped turbulator.

9. The turbine component of any preceding clause, wherein the at least one elongated cooling passage includes a metering feature disposed substantially proximate the tip of the turbine component.

10. A turbine bucket comprising:

a root configured to connect to a turbine;

a base disposed on the root and configured to extend into a turbine flowpath, the base having an airfoil shape and including a tip; and

at least one elongated cooling passage formed in the root and the base, the at least one elongated cooling pass including:

a first section disposed proximate the root and including an aperture at a terminus of the at least one elongated cooling passage, the first section extending into the base, and

a second section fluidly connected to the first section and disposed proximate the tip, wherein a second diameter of the second section is smaller than a first diameter of the first section.

11. The turbine bucket of any preceding clause, wherein the at least one elongated cooling passage includes a Shaped Tube Electrochemical Machining (STEM) drilled passage.

12. The turbine bucket of any preceding clausee, wherein a diameter of the at least one elongated cooling passage varies incrementally throughout the first section and the second section.

13. The turbine bucket of any preceding clause, wherein the at least one elongated cooling passage has a frusto-conical shaped passage and includes a metering feature.

14. The turbine bucket of any preceding clause, wherein the first diameter is larger than the second diameter.

15. The turbine bucket of any preceding clause, wherein the at least one elongated cooling passage includes at least one turbulator disposed on a surface of the elongated cooling passage.

16. The turbine bucket of any preceding clause, wherein the at least one turbulator includes at least one of: a segmented turbulator and a swirl shaped turbulator.

17. A turbine comprising:

a stator;

a working fluid passage substantially surrounded by the stator;

a rotor disposed radially inboard of the stator and in the working fluid passage; and

a turbine bucket connected to the rotor, the turbine bucket including:

at least one elongated cooling passage extending from a root of the turbine bucket to a tip of the turbine bucket, wherein the elongated cooling passage has a variable diameter along a length of the turbine bucket.

18. The turbine of any preceding clause, wherein the at least one elongated cooling passage is a frusto-conical shaped passage and includes a metering feature disposed substantially proximate a tip of the turbine bucket.

19. The turbine of any preceding clause, wherein the at least one elongated cooling passage includes:

a first section proximate the root, the first section having a first diameter, and

a second section fluidly connected to the first section, the second section having a second diameter and proximate the tip, wherein the first diameter is larger than the second diameter.

20. The turbine of any preceding clause, wherein the at least one elongated cooling passage includes at least one turbulator disposed on a surface of the elongated cooling passage, the at least one turbulator includes at least one of: a segmented turbulator and a swirl shaped turbulator.

Claims

1. A turbine component (100) comprising:

a base portion (130); and
at least one elongated cooling passage (110) extending from a root (120) of the base portion (130) to a tip (132) of the base portion (130), wherein the elongated cooling passage (110) has a variable diameter along a length of the turbine component (100).

2. The turbine component of claim 1, wherein the at least one elongated cooling passage (110) includes a Shaped Tube Electrochemical Machining (STEM) drilled passage.

3. The turbine component of claim 1 or claim 2, wherein a diameter of the at least one elongated cooling passage (110) varies incrementally between the root (120) of the turbine component (100) and the tip (132) of the turbine component (100).

4. The turbine component of claim 1, 2 or 3, wherein the at least one elongated cooling passage (110) has a frusto-conical shape.

5. The turbine component of any one of claims 1 to 4, wherein the at least one elongated cooling passage (110) includes:

a first section (220) proximate the root (120), the first section having a first diameter, and
a second section (230, 240) fluidly connected to the first section 220), the second section located proximate the tip (132) and having a second diameter.

6. The turbine component of claim 5, wherein the first diameter is larger than the second diameter.

7. The turbine component of any preceding claim, wherein the at least one elongated cooling passage (110) includes at least one turbulator (550) disposed on a surface of the elongated cooling passage (110).

8. The turbine component of claim 7, wherein the at least one turbulator (550) includes at least one of: a segmented turbulator and a swirl shaped turbulator.

9. The turbine component of any preceding claim, wherein the at least one elongated cooling passage (110) includes a metering feature disposed substantially proximate the tip of the turbine component.

10. The turbine component of any preceding claim, the turbine component comprising:

a turbine bucket (100) including a root (120) configured to connect to a turbine wherein:

the base portion (130) include a base disposed on the root (120) and configured to extend into a turbine flowpath, the base having an airfoil shape and including a tip; and
the at least one elongated cooling passage (110) is formed in the root (120) and the base, the at least one elongated cooling passage (110) including:

a first section (220) disposed proximate the root (120) and including an aperture at a terminus of the at least one elongated cooling passage, the first section extending into the base, and
a second section (230, 240) fluidly connected to the first section (220) and disposed proximate the tip, wherein a second diameter of the second section is smaller than a first diameter of the first section.

11. The turbine component of claim 10, wherein the at least one elongated cooling passage (110) has a frusto-conical shaped passage and includes a metering feature.

12. A turbine comprising:

a stator;
a working fluid passage substantially surrounded by the stator;
a rotor (10) disposed radially inboard of the stator and in the working fluid passage; and
a turbine bucket (16, 18; 100) connected to the rotor (10), the turbine bucket including:

at least one elongated cooling passage (110) extending from a root of the turbine bucket to a tip of the turbine bucket, wherein the elongated cooling passage has a variable diameter along a length of the turbine bucket.

13. The turbine of claim 12, wherein the at least one elongated cooling passage (110) is a frusto-conical shaped passage and preferably includes a metering feature disposed substantially proximate a tip of the turbine bucket.

14. The turbine of claim 12 or claim 13, wherein the at least one elongated cooling passage (110) includes:

a first section proximate the root, the first section having a first diameter, and
a second section fluidly connected to the first section, the second section having a second diameter and proximate the tip, wherein the first diameter is larger than the second diameter.

15. The turbine of claim 12, 13 or 14, wherein the at least one elongated cooling passage (110) includes at least one turbulator (550) disposed on a surface of the elongated cooling passage, the at least one turbulator includes at least one of: a segmented turbulator and a swirl shaped turbulator.

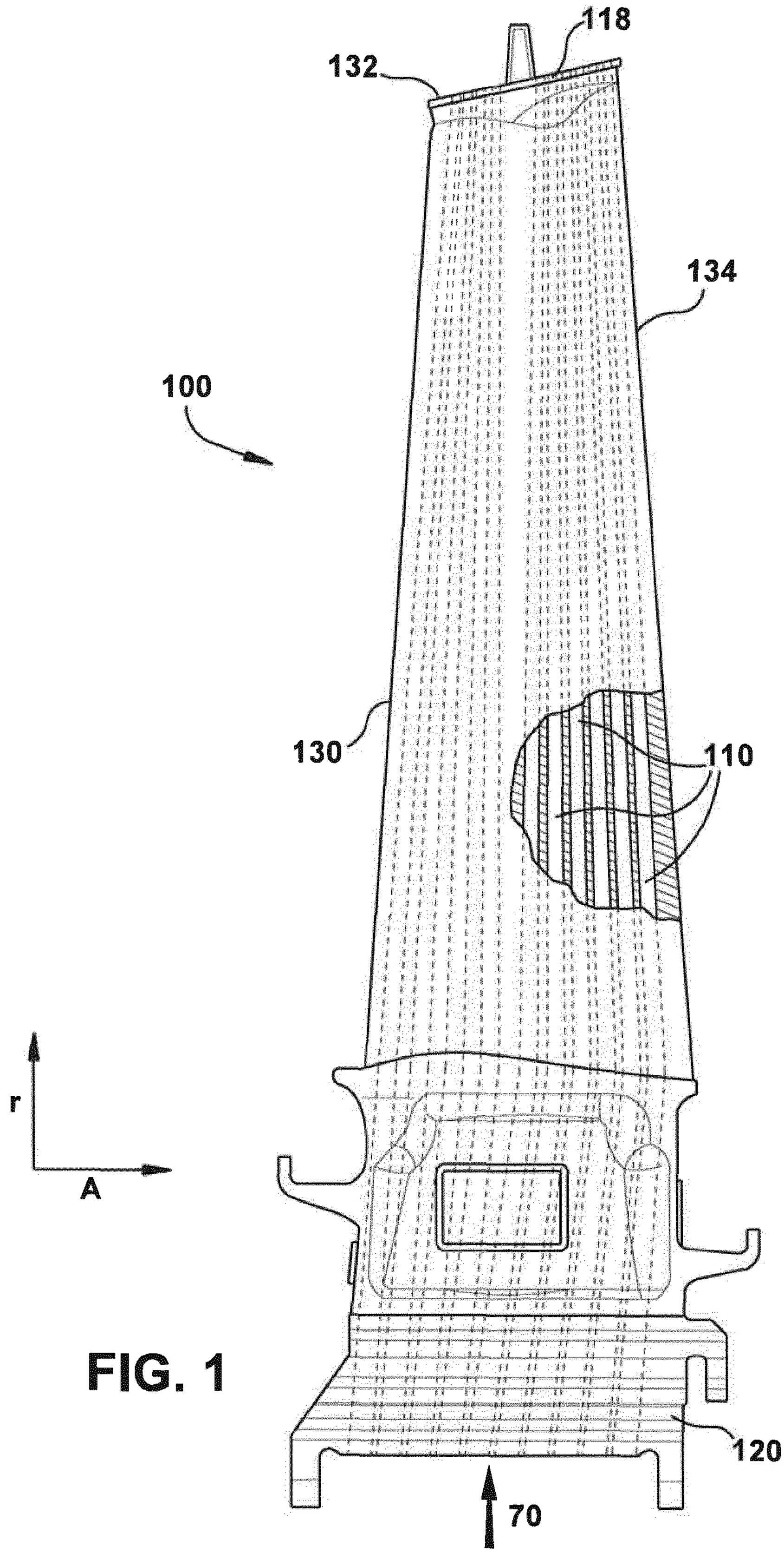


FIG. 1

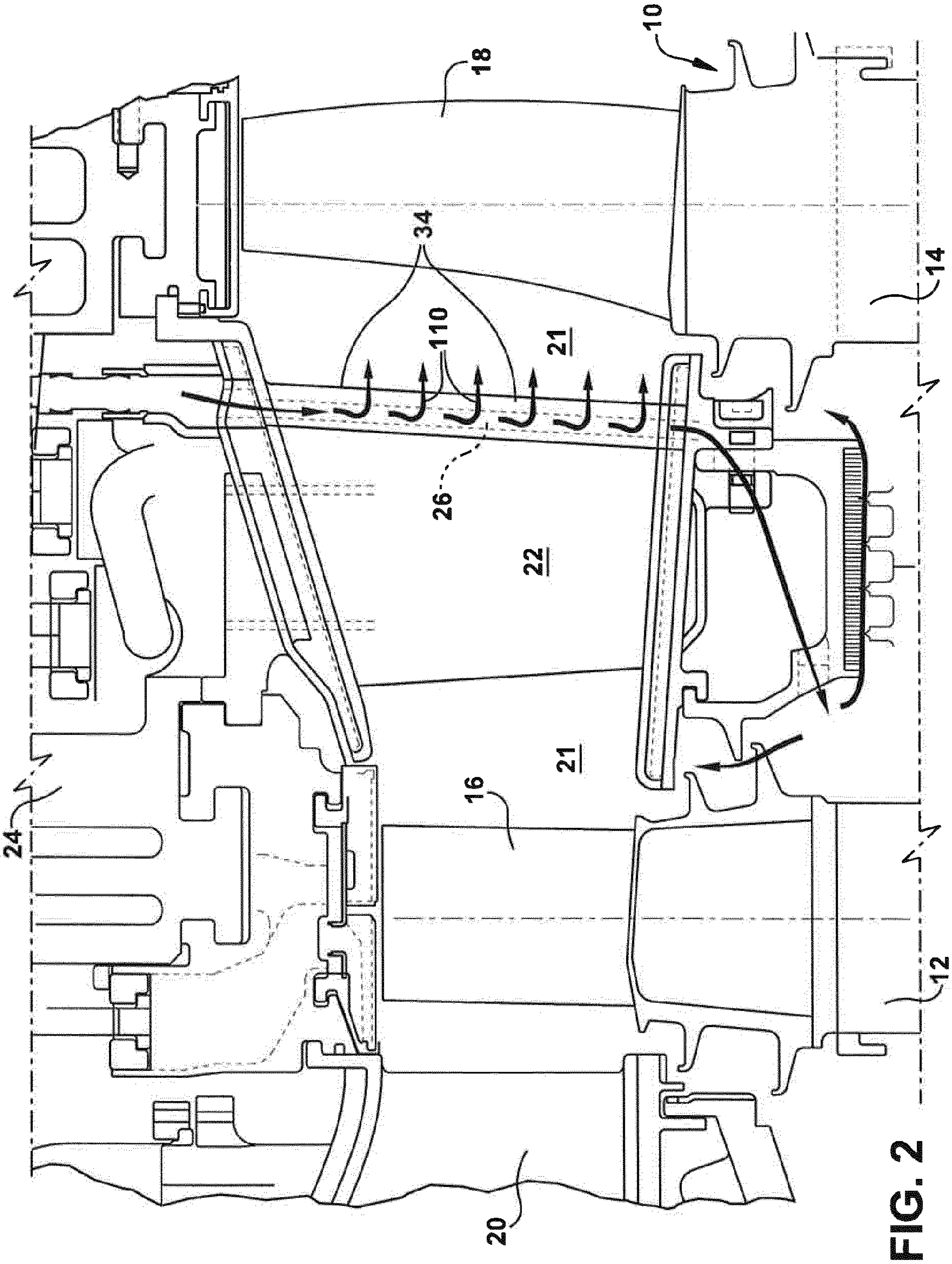


FIG. 2

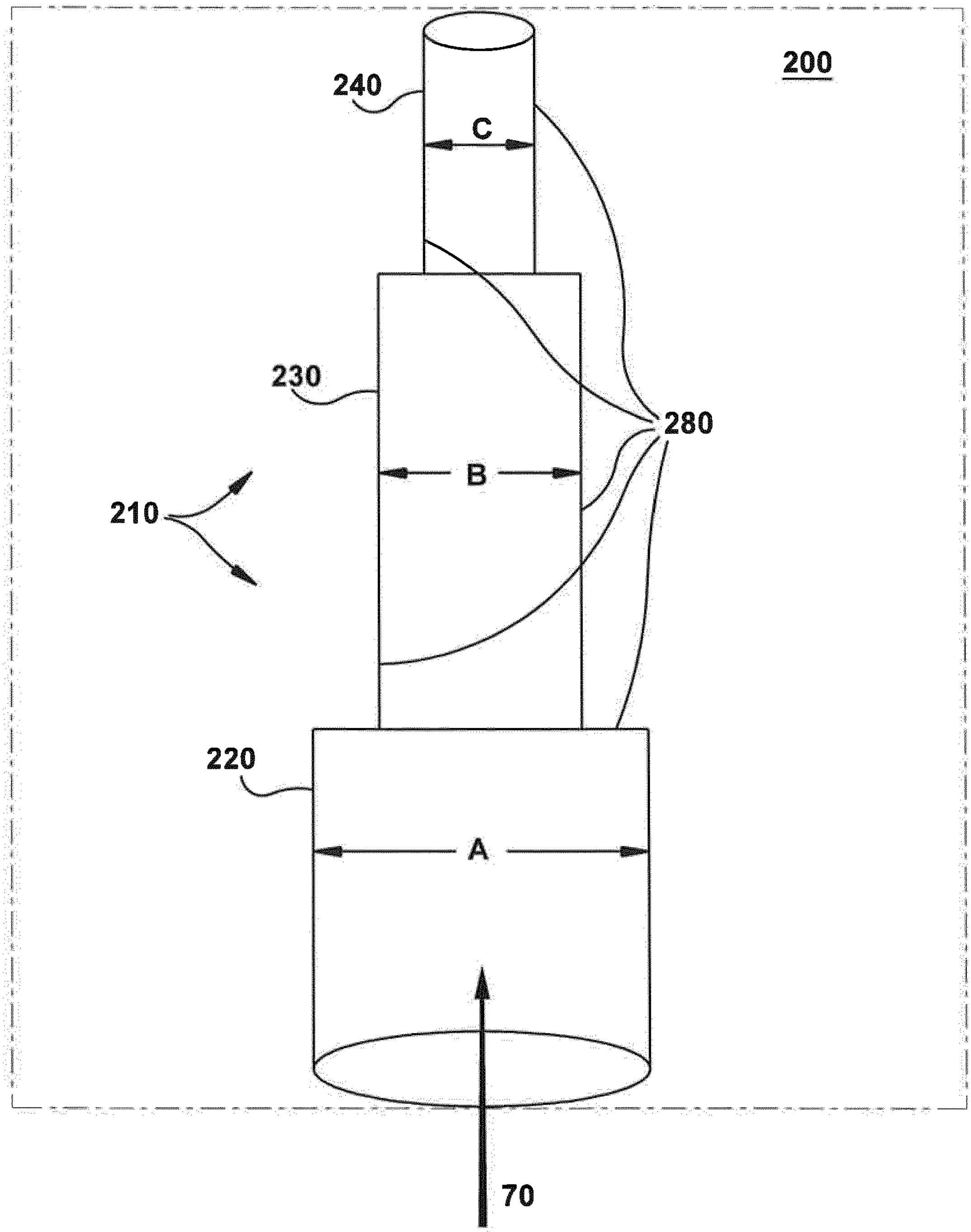


FIG. 3

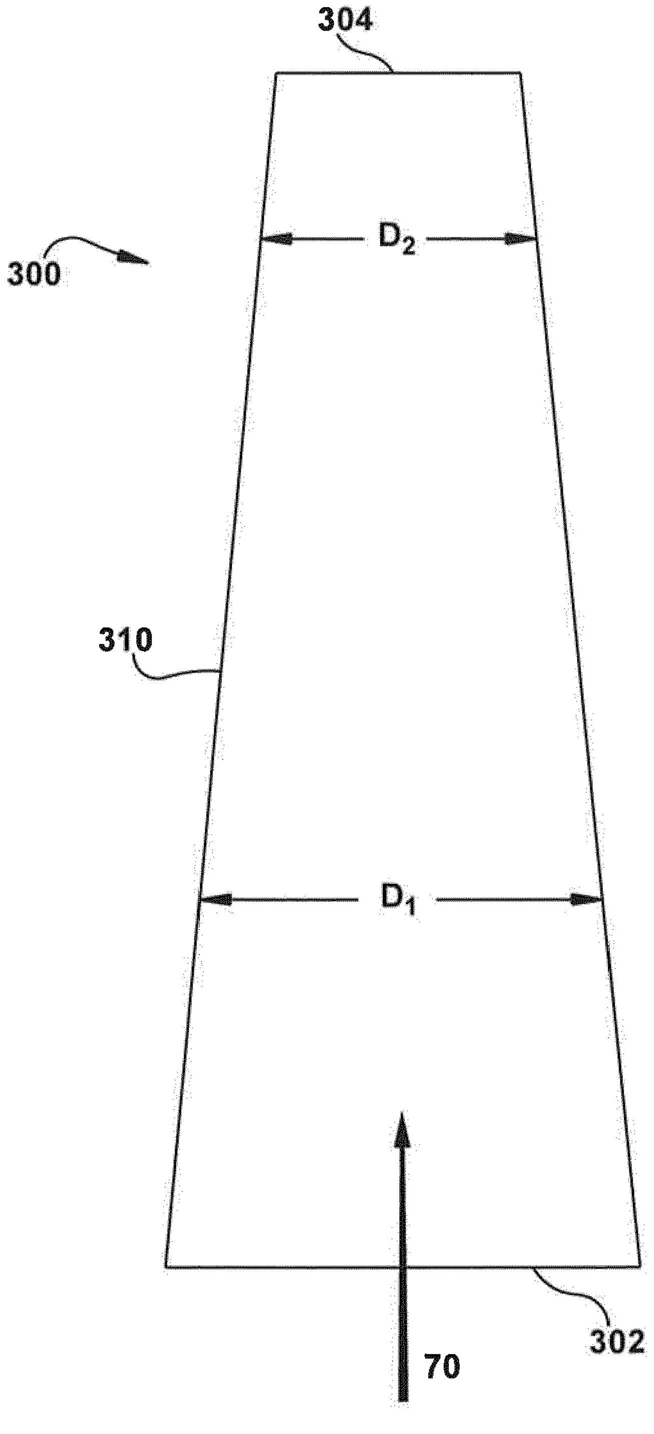


FIG. 4

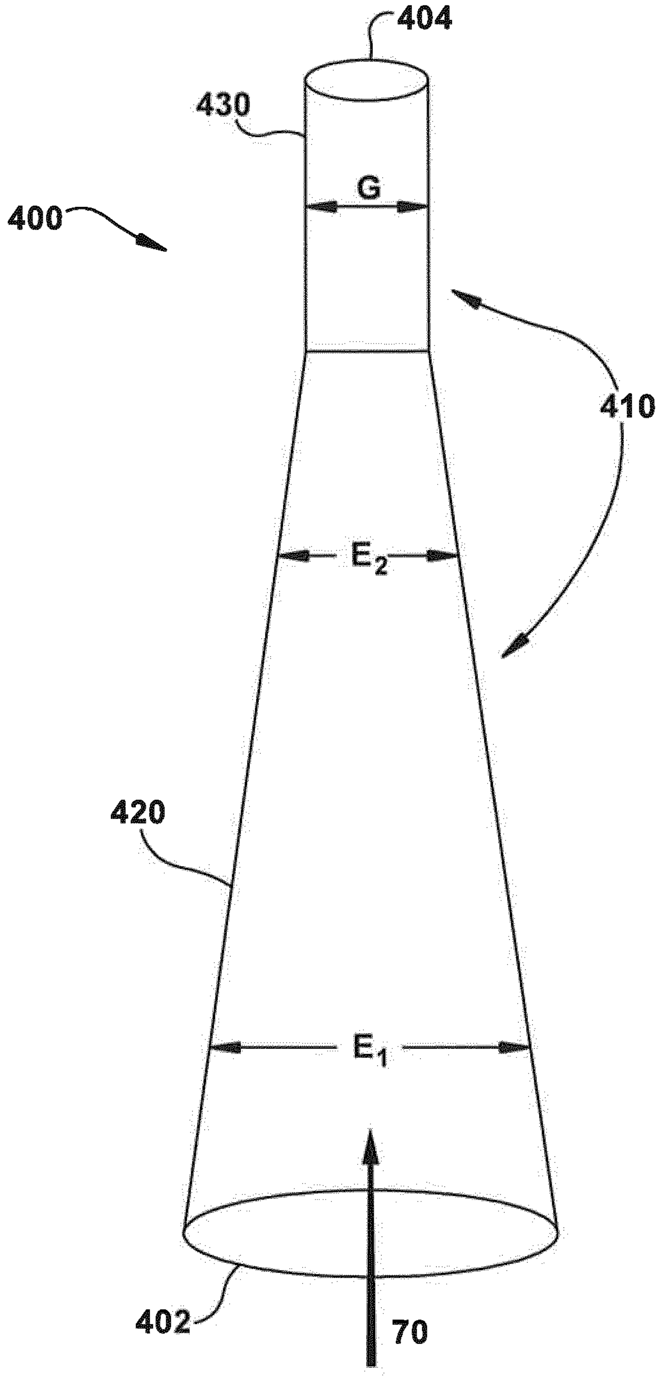


FIG. 5

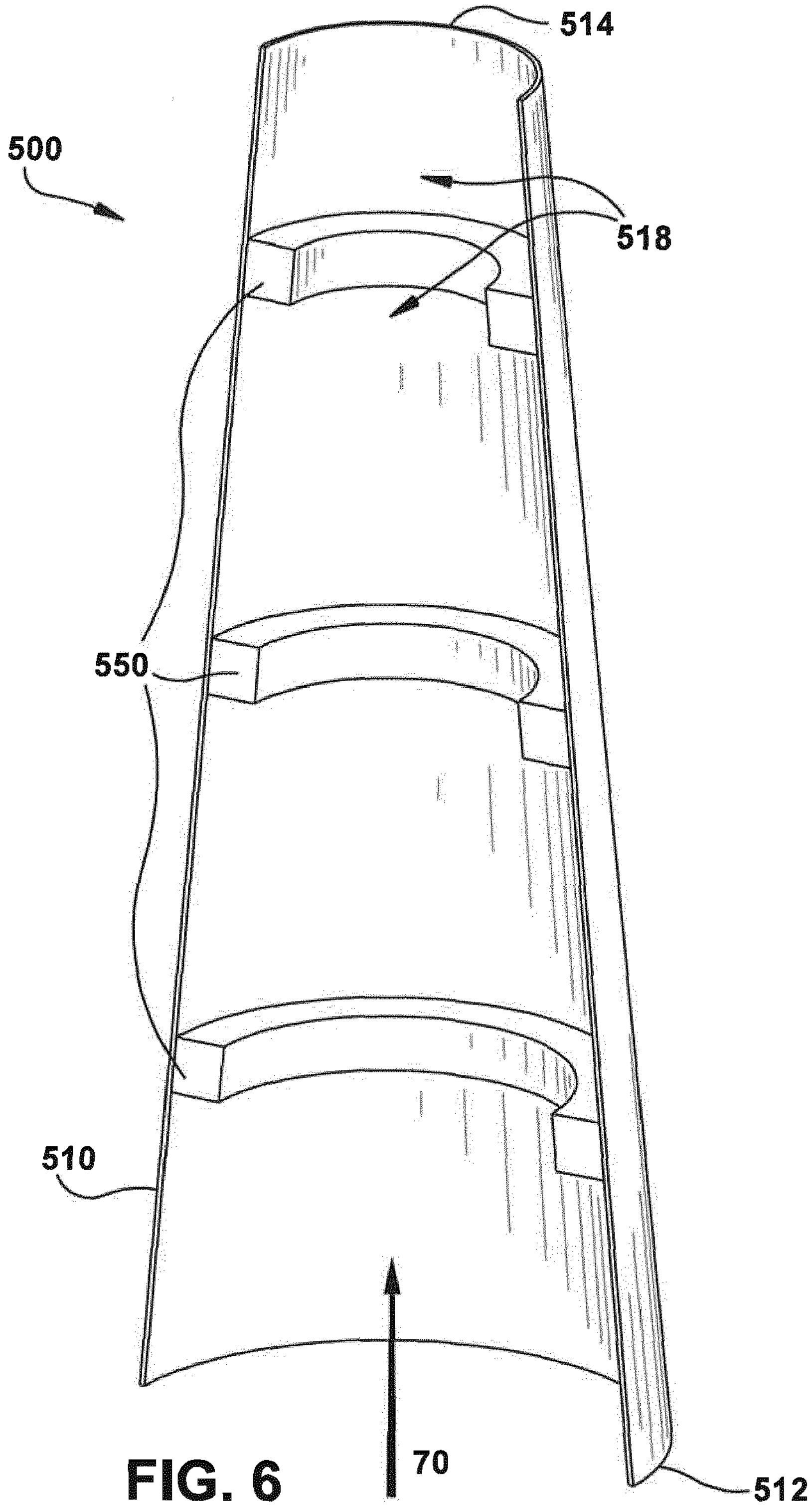


FIG. 6

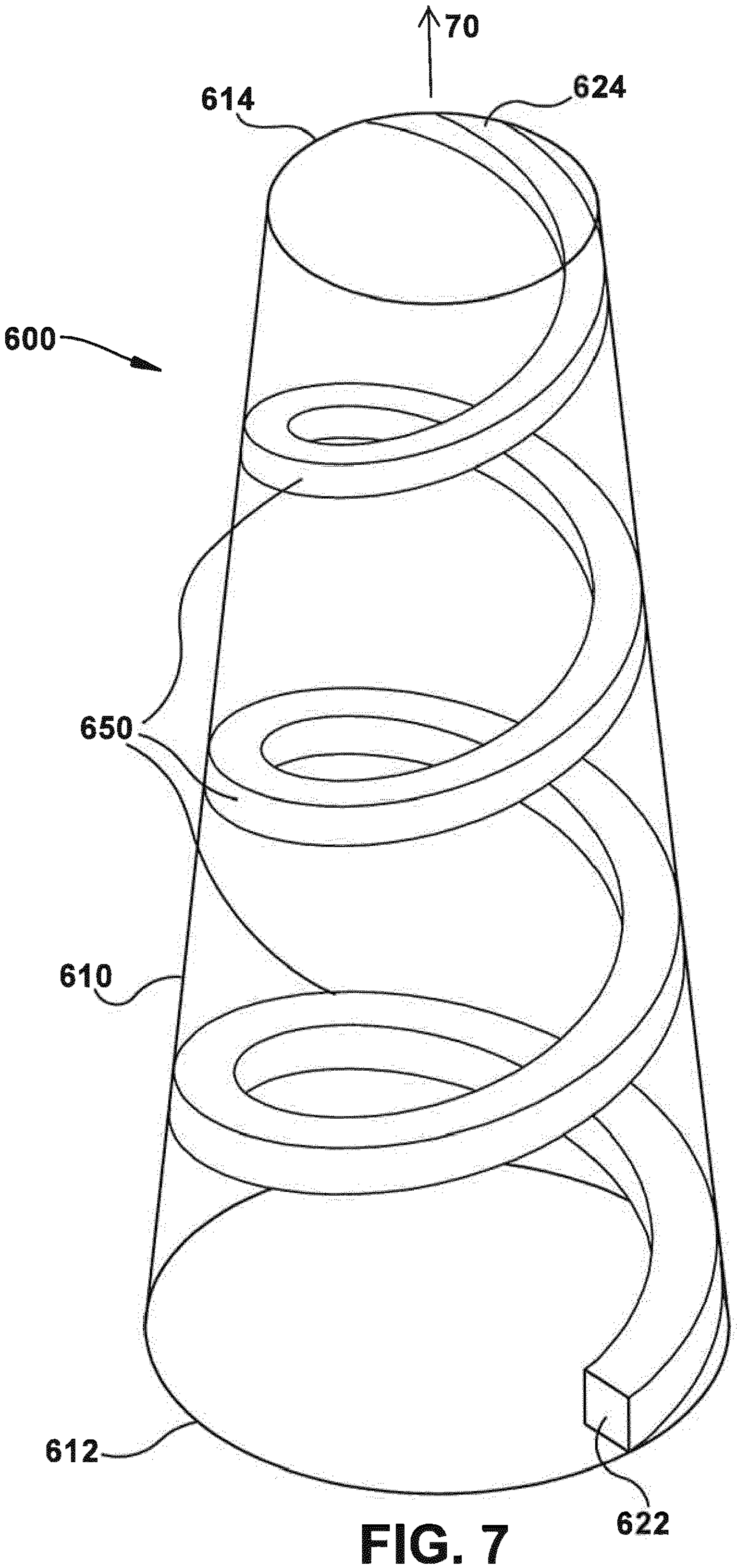


FIG. 7

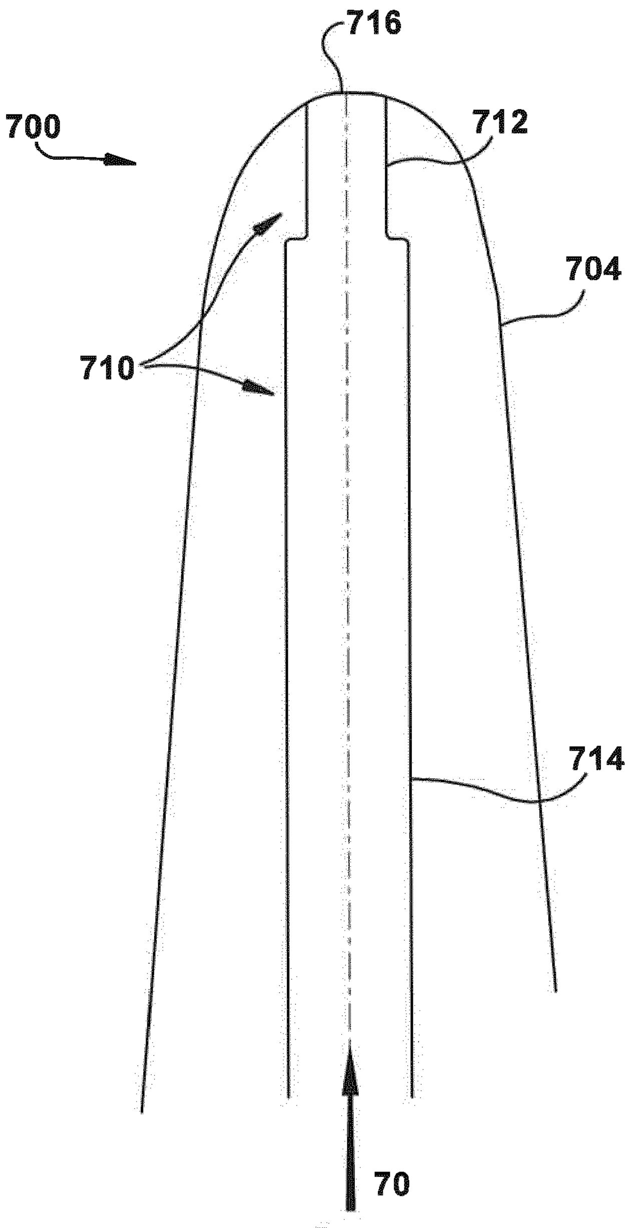


FIG. 8

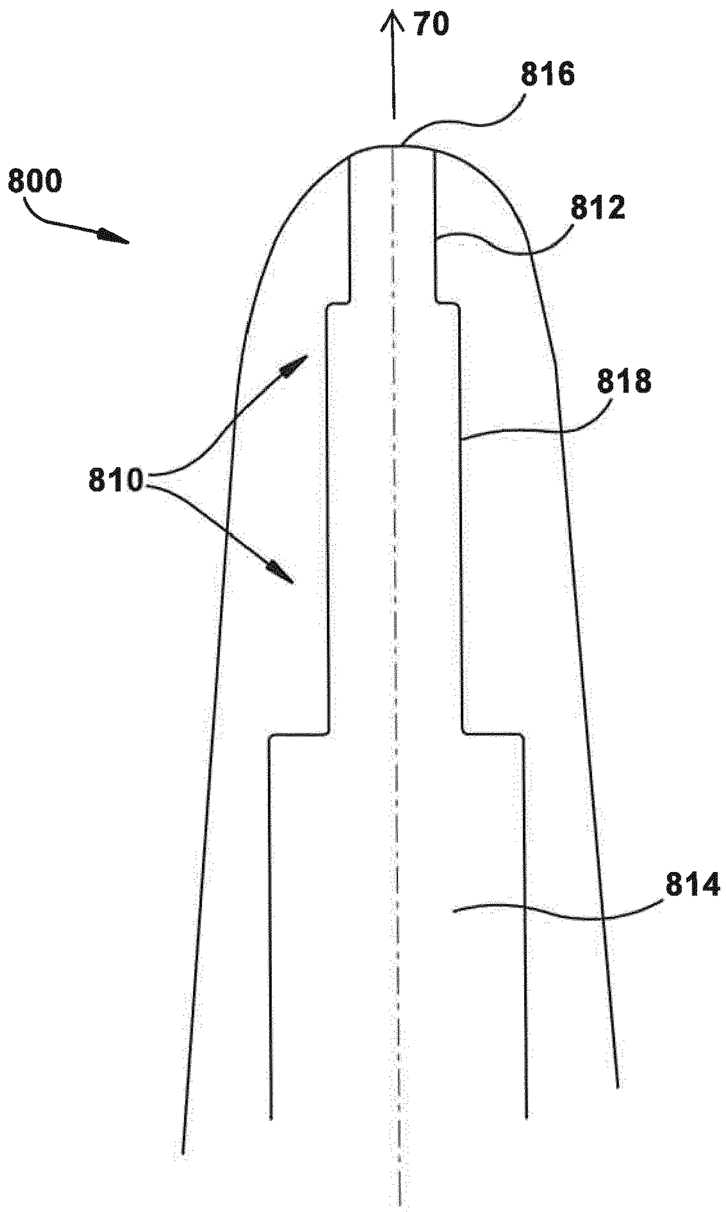


FIG. 9

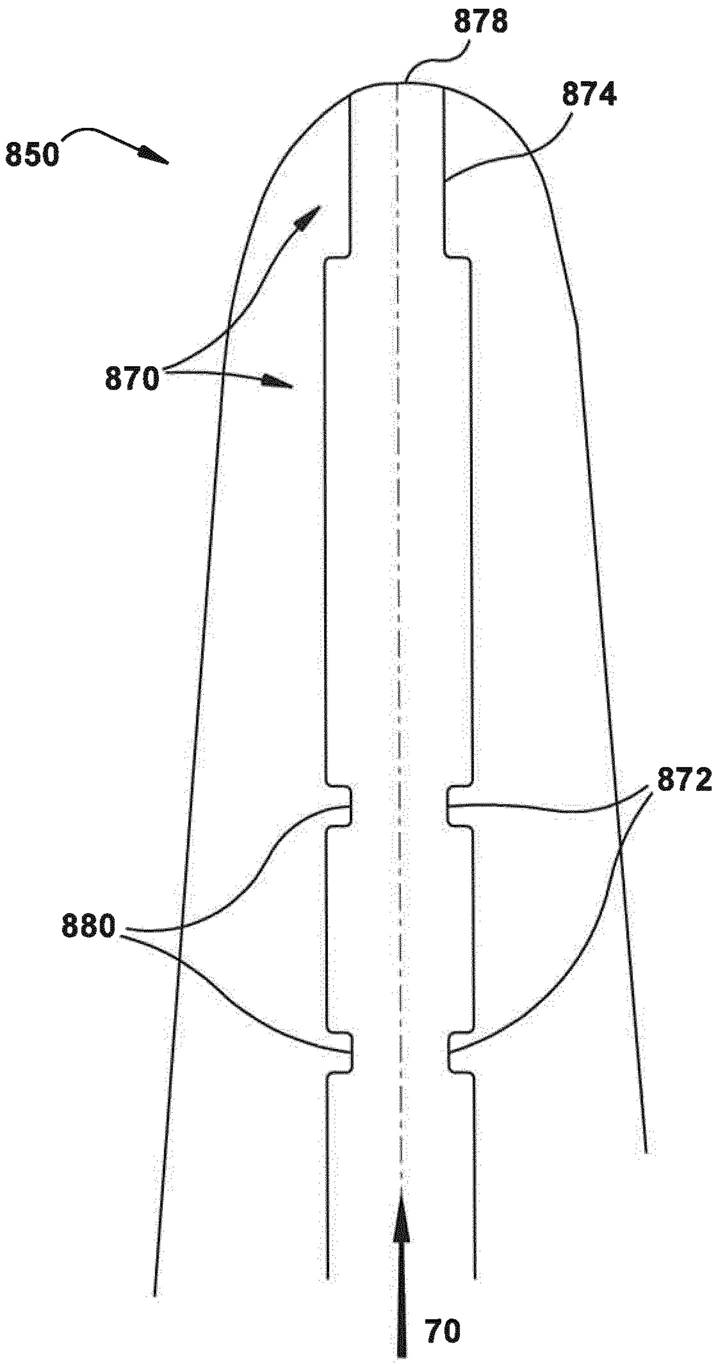
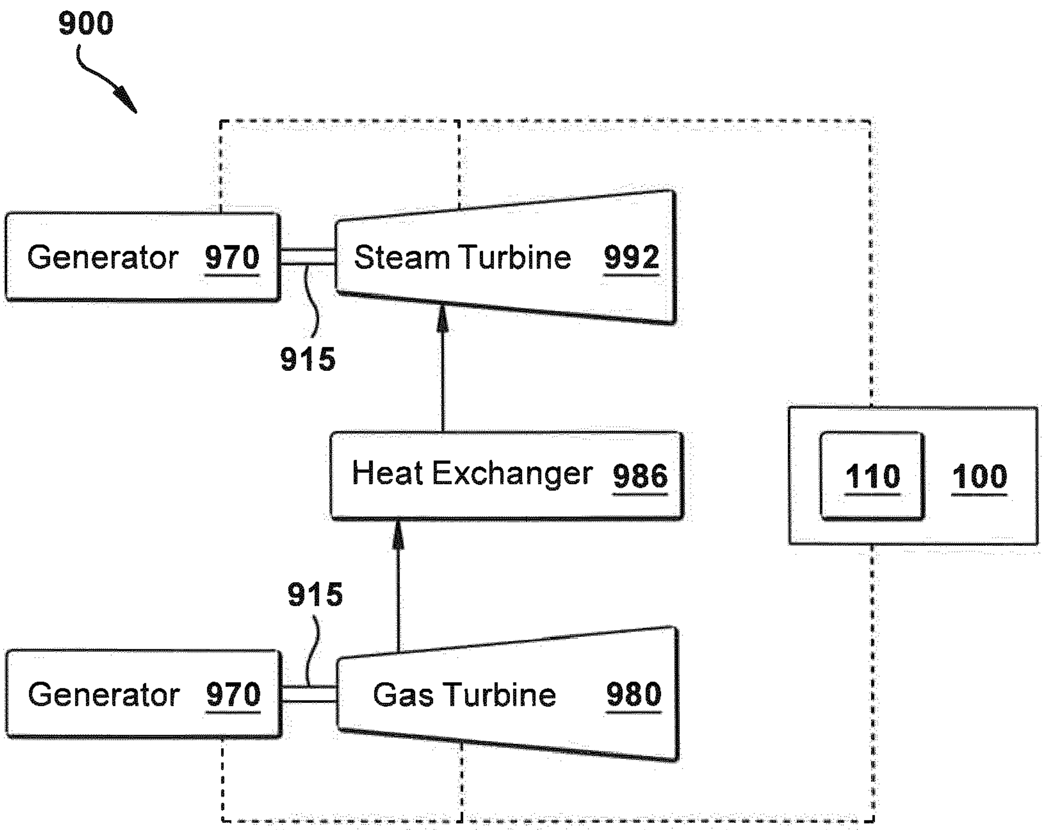


FIG. 10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Steam Turbine 992
915
Heat Exchanger 986
110
100
915
Generator 970
Gas Turbine 980

FIG. 11

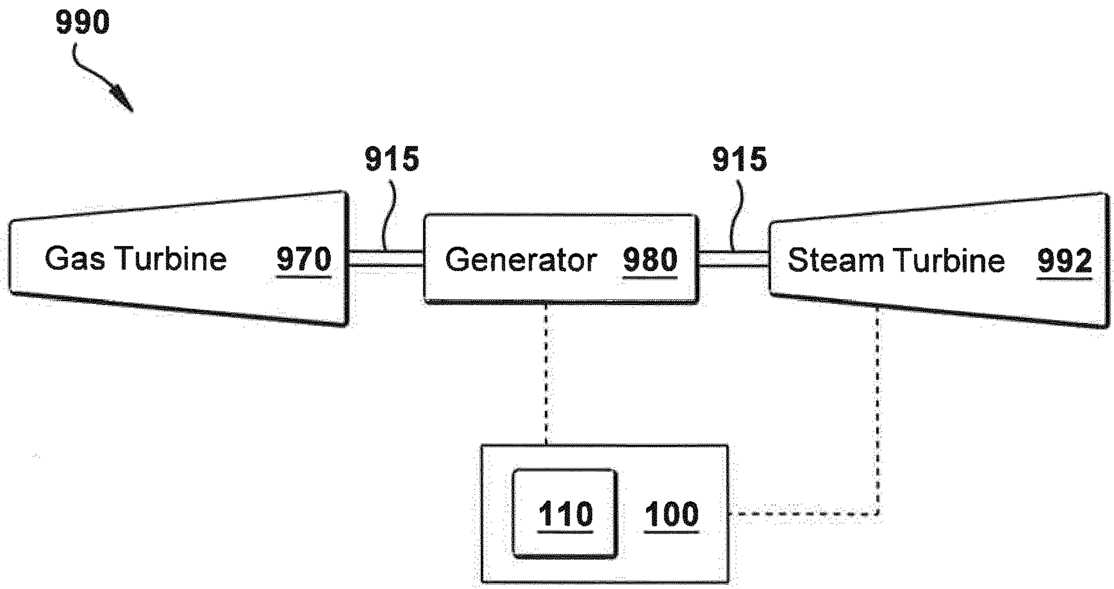
990
915
915
Gas Turbine 970
Generator 980
Steam Turbine 992
110
100

FIG. 12

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EUROPEAN SEARCH REPORT

Application Number
EP 13 19 5501

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2009/297361 A1 (DAHMER MATTHEW T [US] ET AL) 3 December 2009 (2009-12-03) * page 2, paragraph 23 - page 3, paragraph 26; figures 1,6,7 *	1-6,10, 12,14 9,11,13, 15	INV. F01D5/18
X	US 6 234 752 B1 (WEI BIN [US] ET AL) 22 May 2001 (2001-05-22) * column 6, line 58 - column 8, line 39; figures 1-7 *	1,2,7,8	
X Y	EP 1 561 902 A2 (UNITED TECHNOLOGIES CORP [US]) 10 August 2005 (2005-08-10) * column 4, paragraph 20 - column 5, paragraph 23; figure 7 *	1,2,7,8 15	
Y	DE 10 2010 017363 A1 (GEN ELECTRIC [US]) 30 December 2010 (2010-12-30) * figure 7 *	9,11,13	
X	EP 0 207 799 A2 (WESTINGHOUSE ELECTRIC CORP [US]) 7 January 1987 (1987-01-07) * the whole document *	1,4, 11-13	TECHNICAL FIELDS SEARCHED (IPC)
X	US 2005/047914 A1 (TOMBERG STEVEN E [US]) 3 March 2005 (2005-03-03) * page 2, paragraph 19 - page 2, paragraph 23; figure 2 *	1,3,5-7, 10,12,14	F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 April 2014	Rau, Guido

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11-04-2014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009297361 A1	03-12-2009	NONE	
US 6234752 B1	22-05-2001	NONE	
EP 1561902 A2	10-08-2005	CN 1654783 A	17-08-2005
		EP 1561902 A2	10-08-2005
		RU 2299991 C2	27-05-2007
		US 2005175454 A1	11-08-2005
DE 102010017363 A1	30-12-2010	CH 701304 A2	31-12-2010
		CN 101929358 A	29-12-2010
		DE 102010017363 A1	30-12-2010
		JP 2011007181 A	13-01-2011
		US 2010329862 A1	30-12-2010
EP 0207799 A2	07-01-1987	CA 1262868 A1	14-11-1989
		CN 86104500 A	04-02-1987
		EP 0207799 A2	07-01-1987
		IE 861475 L	03-01-1987
		JP S6210402 A	19-01-1987
US 2005047914 A1	03-03-2005	CH 698804 B1	30-10-2009
		FR 2859235 A1	04-03-2005
		JP 2005076639 A	24-03-2005
		US 2005047914 A1	03-03-2005

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