(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 282 013 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
09.02.2011 Bulletin 2011/06

(51) Int Cl.:
F01D 9/06 *(2006.01)* ***F01D 25/32*** *(2006.01)*

(21) Application number: **10167146.9**

(22) Date of filing: **24.06.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR
Designated Extension States:
BA ME RS

(30) Priority: **30.06.2009 US 494419**

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

(72) Inventors:
- **Guo, Tao**
  Niskayuna, NY 12309 (US)
- **Liu, Xiaoyue**
  Clifton Park, NY 12065 (US)
- **Slepski, Jonathon Edward**
  Clifton Park, NY 12065 (US)

(74) Representative: **Gray, Thomas**
GE International Inc.
Global Patent Operation - Europe
15 John Adam Street
London WC2N 6LU (GB)

(54) Moisture removal provisions for steam turbine

(57) Disclosed herein is a moisture removal system (100) for a steam turbine including at least one perforated ring (110) in an outer casing enclosing a stage of the steam turbine. The ring (110) is configured to allow moisture to pass therethrough out of a steam path of the steam turbine.

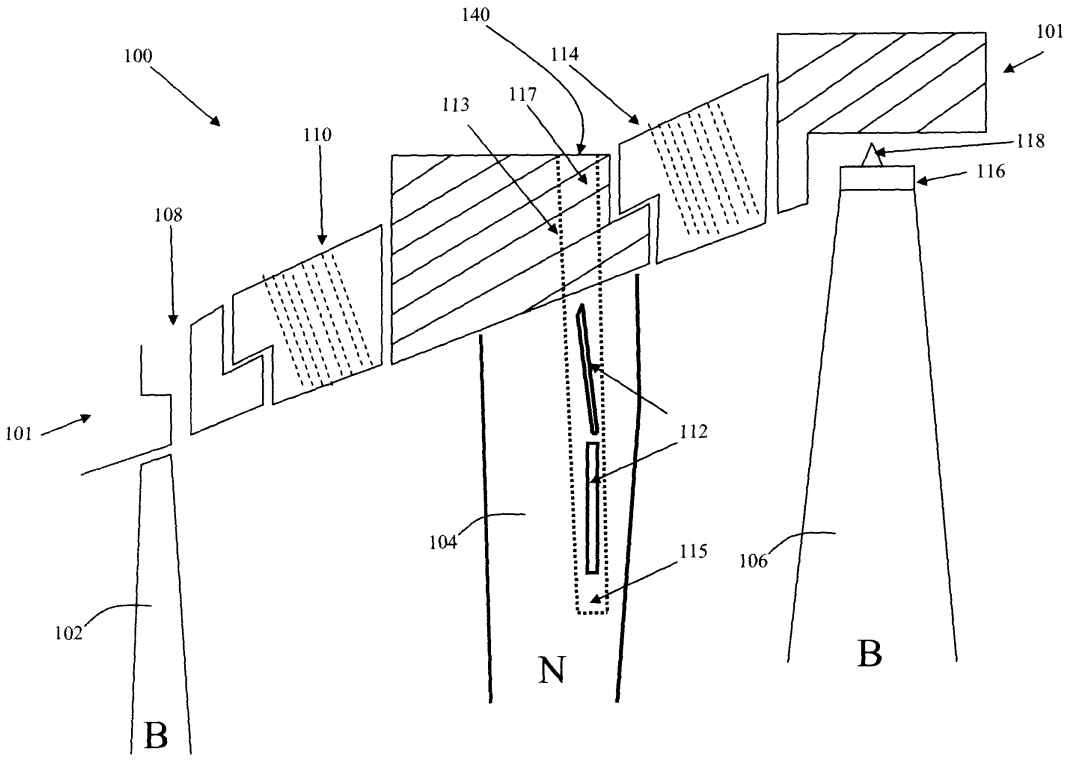

FIG. 1

EP 2 282 013 A2

Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to a steam turbine and more particularly to strategically positioned moisture removal provisions for a steam turbine.

BACKGROUND OF THE INVENTION

[0002] As steam expands inside a steam turbine, its temperature and pressure decrease. At a certain location within the turbine steampath, the steam can expand across a saturation line, condensation begins, and water can form. Accordingly, within the last few stages of a steam turbine, especially in front of the last stage bucket (LSB), the steam can be "wet", i.e., a mixture of steam and water droplets. These water droplets have negative effects on the turbine performance and can cause erosion to the rotating blades, especially near the tip region of the long rotating blade where the blade speed is high.

[0003] To improve reliability and avoid erosion of the steam turbine last stage bucket (LSB), special design features are typically implemented to prevent the condensed/accumulated water on the outer casing and/or nozzle surface from impacting on the rotating blades and /or blade covers. One common approach is to use a continuous outer wall with an "overshooting" nozzle so the water on the outer casing can travel through the gap between the rotating blade cover and the casing without being re-entrained into the steampath. The problem with this design approach is that the flow exiting the "overshooting" nozzle will directly impinge on the LSB cover. Since the LSB inlet flow Mach number is in general very high (can approach sonic or even become supersonic for long LSBs), the blockage of the LSB cover can cause significant penalty to the turbine last stage performance.

[0004] Another approach is to add a moisture removal slot right before the LSB, in order to make sure the water on the outer wall is removed. But the slot can disrupt the continuity of the outer wall and cause disturbance to the main flow which in turn has negative effect on the turbine performance. Other approaches involving moisture removal provisions include using grooves to remove the water accumulated on the outer casing at the nozzle inlet or using slotted hollow nozzles to remove the deposited water on the nozzle surface.

[0005] Since the water droplets inside a turbine have a wide size range, and the trajectories of water droplets are strongly depended on the droplet size, none of the above moisture removal methods does a satisfactory job in removing the moisture from the turbine steampath.

BRIEF DESCRIPTION OF THE INVENTION

[0006] Disclosed herein is a moisture removal system for a steam turbine including at least one perforated ring in an outer casing enclosing a stage of the steam turbine. The ring is configured to allow moisture to pass therethrough out of a steam path of the steam turbine.

[0007] A first aspect of the invention provides a moisture removal system for a steam turbine, the system comprising: a ring for positioning in an outer casing enclosing a stage of the steam turbine, wherein the ring includes one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine.

[0008] A second aspect of the invention provides a moisture removal system for a steam turbine, the steam turbine having a last stage bucket, a next-to-last stage bucket, and a nozzle positioned between the last stage bucket and the next-to-last stage bucket, the nozzle and buckets positioned within an outer casing, the moisture removal system comprising: at least one moisture removal slot extending through the outer casing, wherein one moisture removal slot is positioned to be in-line with a trailing edge of a rotating blade of the next-to-last stage bucket; a first ring in the outer casing, the first ring positioned downstream of the moisture removal slot and upstream of the nozzle, the first ring including one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine; a channel extending from a first end within the nozzle and through the outer casing to a second end; a pressure side slot on a pressure side of the nozzle, the pressure side slot in fluid communication with the first end of the channel; a suction side slot on a suction side of the nozzle, the suction side slot in fluid communication with the first end of the channel, the pressure side slot and the suction side slot configured to allow moisture from a surface of the nozzle to flow through the slots into the first end of the channel; a second ring in the outer casing, the second ring positioned downstream of the nozzle and upstream of the last stage bucket, the second ring including one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine; and one of: a recessed bucket cover on the last stage bucket or an overshooting bucket cover on the last stage bucket.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] There follows a detailed description of embodiments of the invention by way of example only with reference to the accompanying drawings, in which:

FIG. 1 shows a cross-sectional view of a last stage of a steam turbine and a next-to-last stage bucket, including a moisture removal system according to embodiments of the disclosure.

FIG. 2 shows an enlarged view of a nozzle of a steam turbine including a moisture removal system accord-

ing to embodiments of the disclosure.

FIG. 3 shows a cross-sectional view of a last stage bucket of a steam turbine.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Turning to FIG. 1, a moisture removal system 100 for a steam turbine according to embodiments of the invention is shown. While the entire steam turbine is not shown in FIG. 1, an exemplary stage of the steam turbine and a next-to-last stage bucket are shown in FIG. 1. As shown in FIG. 1, a nozzle 104 is positioned between a next-to-last stage bucket 102 and a last stage bucket 106. Next-to-last stage bucket 102, nozzle 104 and last stage bucket 106 are positioned within an outer casing 101. As known in the art, steam travels downstream through the steam turbine, commonly referred to as the steampath, towards last stage bucket 106. As the steam moves through the steam turbine, condensation can begin, and moisture (e.g., water, steam or a mixture of water and steam) can form. As discussed herein, moisture removal system 100 provides a systematic approach to providing provisions to remove as much moisture as possible from the steampath, especially immediately prior to, or close to, last stage bucket 106.

[0011] Moisture removal system 100 includes at least one first ring 110 in outer casing 101, positioned between a nozzle and a bucket of a steam turbine. For example, in the embodiment shown in FIG. 1, first ring 110 is positioned downstream of next-to-last stage bucket 102 and upstream of nozzle 104. First ring 110 is perforated, or porous, i.e., it includes one or more holes extending from an inner diameter to an outer diameter of first ring 110. These holes are configured to allow moisture to pass through first ring 110 out of a steam path of the steam turbine.

[0012] Moisture removal system 100 can further include at least one second ring 114 in outer casing 101, also positioned between a nozzle and bucket of a steam turbine. For example, as in the embodiment shown in FIG. 1, second ring 114 can be positioned downstream of nozzle 104 and upstream of last stage bucket 106. Second ring 114 is also perforated, or porous, i.e., it includes one or more holes extending from an inner diameter to an outer diameter of second ring 114. These holes are configured to allow moisture to pass through second ring 114 out of a steam path of the steam turbine. As such, second ring 114 can be positioned to remove any remaining moisture that was not removed by earlier provisions, as well as newly condensed water formed on outer casing 101. For example, as in the embodiment shown in FIG. 1, second ring 114 can be positioned directly upstream of last stage bucket 106.

[0013] Compared with slots or grooves through outer casing 101, perforated rings 110, 114 are less disruptive to the steampath flow and so can be designed to cover a relatively larger axial segment which is advantageous for moisture removal. In addition, compared with slots or grooves through outer casing 101, perforated rings 110, 114 are less reflective (thus tending toward better removal of moisture) to those moisture droplets that spin off the trailing edge of a previous rotating blade and are impinging on outer casing 101.

[0014] Moisture removal system 100 can further include at least one moisture removal slot 108 which extends through outer casing 101. Moisture removal slots 108 can be positioned in outer casing 101 wherever moisture is desired to be removed, for example, as in the embodiment shown FIG. 1, a moisture removal slot 108 can be positioned upstream of first ring 110, and in-line with a trailing edge of the rotating blade of next-to-last stage bucket 102. Thus, moisture removal slots 108 can be positioned to remove large droplets of moisture that are thrown off of the rotating blade of a previous stage of the steam turbine, for example, next-to-last stage bucket 102.

[0015] Moisture removal system 100 can further include a channel 113 extending from a first end 115 within nozzle 104 and through outer casing 101 to a second end 117. Channel 113 is in fluid communication with slots 112 on both a pressure side and a suction side of nozzle 104. As shown in more detail in FIG. 2, at least one suction side slot 112a is provided on a suction side of nozzle 104, and at least one pressure side slot 112b is provided on a pressure side of nozzle 104. Both slots 112a and 112b are in fluid communication with first end 115 of channel 113 and are configured to allow moisture from a surface of nozzle 104 to flow through slots 112a, 112b into first end 115 of channel 113 and ultimately through second end 117 and through outer casing 101. As such, slots 112a, 112b are used to catch those moisture droplets that more or less follow the main steampath flow but are subsequently deposited on a surface of nozzle 104. As shown in FIGS. 1 and 2, slots 112a, 112b may extend substantially longitudinally along nozzle 104. Second end 117 of channel 113 can be connected to a source of exhaust pressure 140 in order to draw moisture droplets through channel 113 out of the steampath.

[0016] With moisture removal system 100 in place, a recessed or overshooting bucket cover design can be implemented. For example, as shown in FIG. 1, a bucket cover 116 on last stage bucket 106 can be recessed into outer casing 101. With a recessed last stage bucket design, the flow exiting nozzle 104 will not directly impinge on last stage bucket cover 116, and the blockage of last stage bucket cover 116 will be significantly reduced, therefore improving the turbine last stage performance. Alternatively, as shown in FIG. 3, bucket cover 116 can be overshooting, i.e., not within outer casing 101. As known in the art, bucket cover 116 can optionally include a tooth 118, extending from bucket cover 116 towards outer casing 101, to reduce steam leakage from a tip of bucket cover 116, in order to improve turbine performance.

[0017] Moisture removal system 100 disclosed herein

can be utilized in any turbine where moisture is desired to be removed, for example, nuclear low pressure steam turbines or combined cycle low pressure steam turbines.

[0018] The terms "first," "second," and the like, herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another, and the terms "a" and "an" herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item. The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context, (e.g., includes the degree of error associated with measurement of the particular quantity). The suffix "(s)" as used herein is intended to include both the singular and the plural of the term that it modifies, thereby including one or more of that term (e.g., the metal(s) includes one or more metals). Ranges disclosed herein are inclusive and independently combinable (e.g., ranges of "up to about 25 wt%, or, more specifically, about 5 wt% to about 20 wt %", is inclusive of the endpoints and all intermediate values of the ranges of "about 5 wt% to about 25 wt%," etc).

Claims

1. A moisture removal system (100) for a steam turbine, the system comprising:

   a ring for positioning in an outer casing (101) enclosing a stage of the steam turbine, wherein the ring includes one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine.

2. The moisture removal system of claim 1, wherein the ring is positioned between a bucket and a nozzle (104) of the stage.

3. The moisture removal system of claim 2, further comprising at least one moisture removal slot (108) extending through the outer casing (101), the slot configured to allow moisture to pass therethrough out of the steam path of the steam turbine.

4. The moisture removal system of claim 3, wherein one moisture removal slot (108) is positioned to be in-line with a trailing edge of a rotating blade of a previous stage bucket.

5. The moisture removal system of claim 2, further comprising:

   a channel (113) extending from a first end within the nozzle (104) and through the outer casing (101) to a second end;
   a pressure side slot on a pressure side of the nozzle (104), the pressure side slot in fluid communication with the first end of the channel (113); and
   a suction side slot on a suction side of the nozzle (104), the suction side slot in fluid communication with the first end of the channel (113), the pressure side slot and the suction side slot configured to allow moisture from a surface of the nozzle (104) to flow through the slots into the first end of the channel (113).

6. The moisture removal system of claim 5, wherein the pressure side slot and the suction side slot extend substantially longitudinally along the nozzle.

7. The moisture removal system of claim 5 or 6, wherein the second end of the channel is connected to a source of exhaust pressure.

8. The moisture removal system of any of the preceding claims, wherein the ring includes a plurality of rings, at least one first ring positioned downstream of a next-to-last stage bucket (106) and upstream of a nozzle (104), and at least one second ring positioned upstream of a last stage bucket (106) and downstream of the nozzle (104), wherein the plurality of rings each include one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine.

9. The moisture removal system of claim 8, further comprising:

   a channel (113) extending from a first end within the nozzle (104) and through the outer casing (101) to a second end;
   a pressure side slot on a pressure side of the nozzle (104), the pressure side slot in fluid communication with the first end of the channel (113); and
   a suction side slot on a suction side of the nozzle (104), the suction side slot in fluid communication with the first end of the channel (113), the pressure side slot and the suction side slot configured to allow moisture from a surface of the nozzle (104) to flow through the slots into the first end of the channel (113).

10. The moisture removal system of claim 9, wherein the pressure side slot and the suction side slot extend substantially longitudinally along the nozzle.

11. The moisture removal system of claim 9 or 10, wherein the second end of the channel is connected to a source of exhaust pressure.

12. The moisture removal system of claim 8, further com-

prising at least one moisture removal slot (108) extending through the outer casing (101), the slot configured to allow moisture to pass therethrough out of the steam path of the steam turbine.

13. The moisture removal system of claim 12, wherein one moisture removal slot (108) is positioned to be in-line with a trailing edge of a rotating blade of the next-to-last stage bucket (106).

14. The moisture removal system of claim 8, further comprising one of: a recessed bucket cover (116) on the last stage bucket (106) or an overshooting bucket cover on the last stage bucket (106).

15. A moisture removal system for a steam turbine, the steam turbine having a last stage bucket, a next-to-last stage bucket, and a nozzle positioned between the last stage bucket and the next-to-last stage bucket, the nozzle and buckets positioned within an outer casing, the moisture removal system comprising:

at least one moisture removal slot extending through the outer casing, wherein one moisture removal slot is positioned to be in-line with a trailing edge of a rotating blade of the next-to-last stage bucket;
a first ring in the outer casing, the first ring positioned downstream of the moisture removal slot and upstream of the nozzle, the first ring including one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine;
a channel extending from a first end within the nozzle and through the outer casing to a second end;
a pressure side slot on a pressure side of the nozzle, the pressure side slot in fluid communication with the first end of the channel;
a suction side slot on a suction side of the nozzle, the suction side slot in fluid communication with the first end of the channel, the pressure side slot and the suction side slot configured to allow moisture from a surface of the nozzle to flow through the slots into the first end of the channel;
a second ring in the outer casing, the second ring positioned downstream of the nozzle and upstream of the last stage bucket, the second ring including one or more holes extending from an inner diameter to an outer diameter of the ring, the holes configured to allow moisture to pass therethrough out of a steam path of the steam turbine; and
one of a recessed bucket cover on the last stage bucket or an overshooting bucket cover on the last stage bucket.

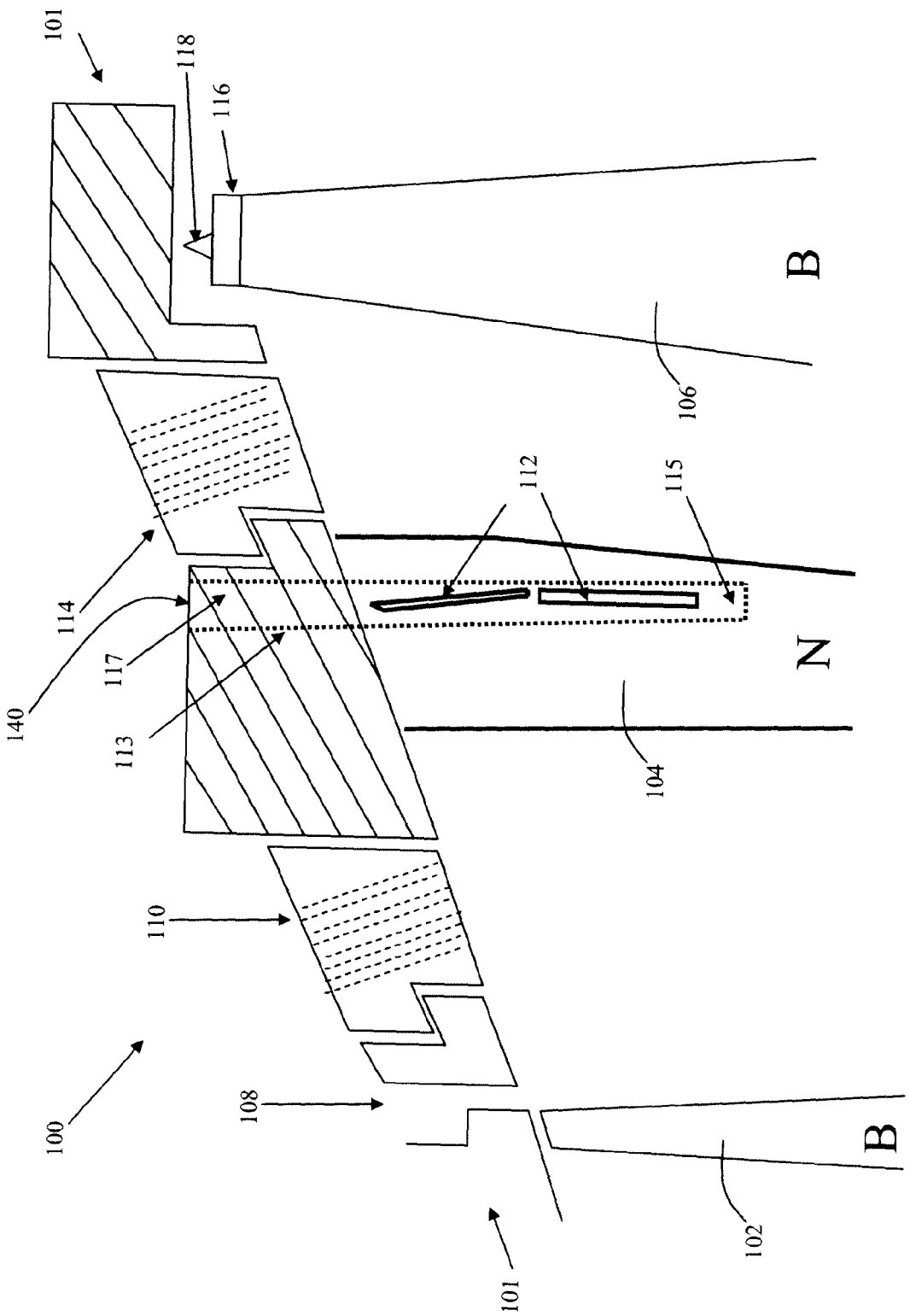
101
118
116
B
106
112
115
114
117
140
113
N
104
110
100
108
B
102
101

FIG. 1

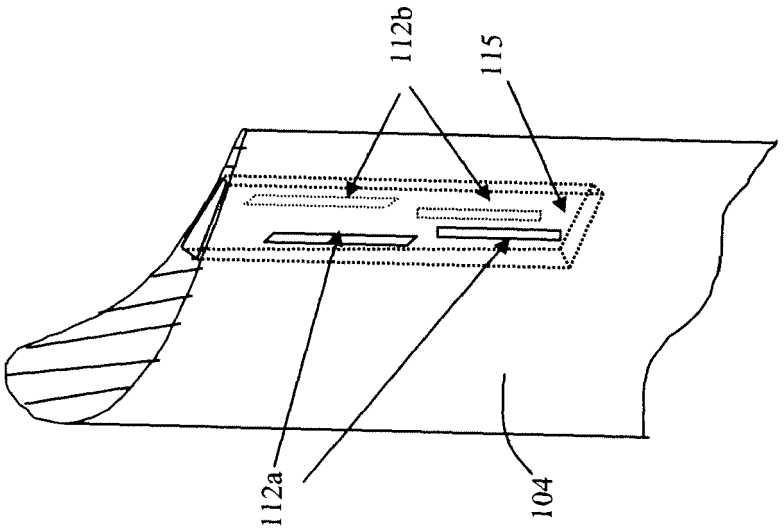

FIG. 2

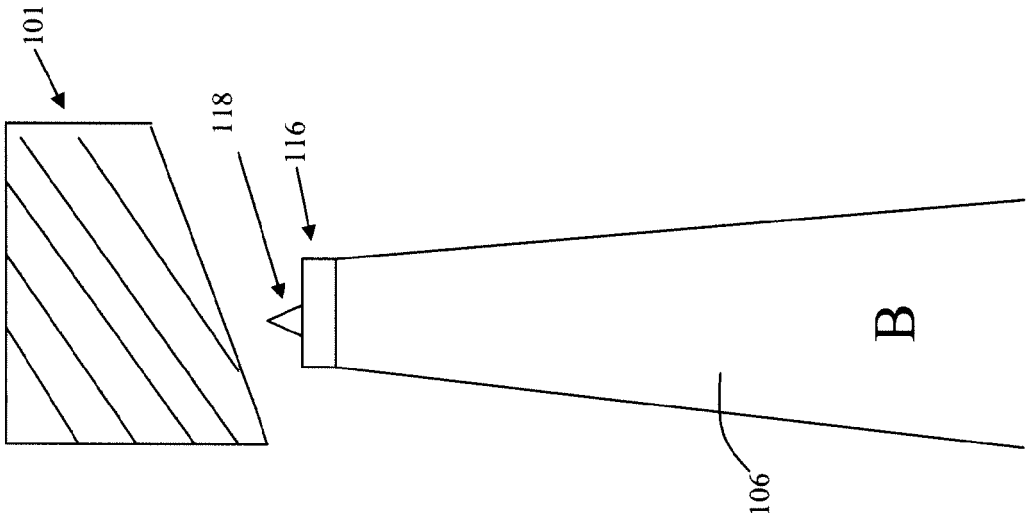

FIG. 3