



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
20.10.2010 Bulletin 2010/42

(51) Int Cl.:
F23R 3/06 (2006.01)

(21) Application number: **10159603.9**

(22) Date of filing: **12.04.2010**

(84) Designated Contracting States:
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:
AL BA ME RS

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(30) Priority: **13.04.2009 US 422536**

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(54) **Combined convection/effusion cooled one-piece can combustor**

(57) An industrial turbine engine comprises a combustion section, an air discharge section downstream of the combustion section, a transition region between the combustion and air discharge section, a combustion transition piece (120) and a sleeve (129). The transition piece (120) defines an interior space (304) for combusted gas flow. The sleeve (129) surrounds the combustor transition piece (120) so as to form a flow annulus (124) between the sleeve (129) and the transition piece (120). The sleeve (129) includes a first set of apertures (400)

for directing cooling air (I) from compressor discharge air into the flow annulus (124). The transition piece (120) includes an outer surface (300a) bounding the flow annulus (124) and an inner surface (300b) bounding the interior space (304), and includes a second set of apertures (200) for directing cooling air in the flow annulus (124) to the interior space (304). Each of the second set of apertures (200) extends from an entry portion (200a) on the outer surface (300a) to an exit portion (200b) on the inner surface (300b).

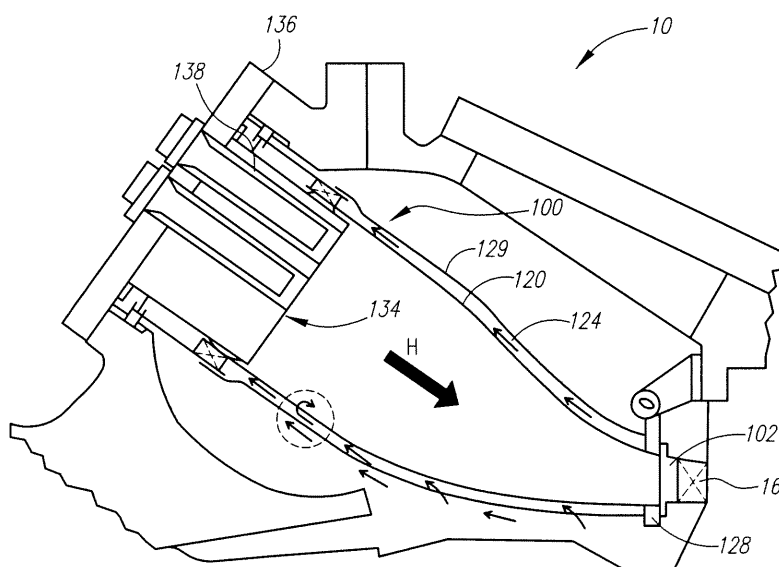


Fig. 1

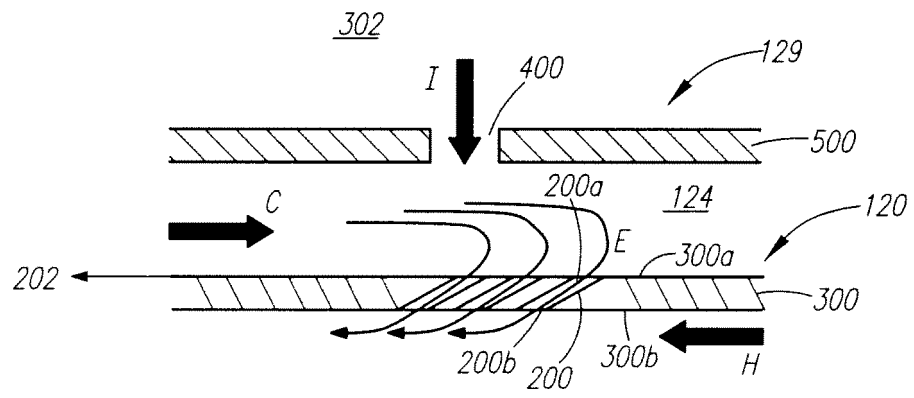


Fig. 3

Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates generally to means of cooling components of a gas turbine, and more particularly, to the cooling of a one-piece can combustor by a combination of convection cooling and effusion cooling.

DESCRIPTION OF THE RELATED ART

[0002] A gas turbine can operate with great efficiency if the turbine inlet temperature can be raised to a maximum. However, the combustion chamber, from which combusted gas originates before entering the turbine inlet, reaches operating temperatures well over 1500 °F and even most advanced alloys cannot withstand such temperatures for extended periods of use. Thus, the performance and longevity of a turbine is highly dependent on the degree of cooling that can be provided to the turbine components which are exposed to extreme heating conditions.

[0003] The general concept of using compressor discharge air to cool turbine components is known in the art. However, developments and variations in turbine designs are not necessarily accompanied by specific structures that are implemented with cooling mechanisms for the turbine components. Thus, there is a need to embody cooling mechanisms into newly developed turbine designs.

BRIEF DESCRIPTION OF THE INVENTION

[0004] Accordingly, it is an aspect of the present invention to enhance conventional gas turbines.

[0005] To achieve the foregoing and other aspects and in accordance with the present invention, an industrial turbine engine is provided that comprises a combustion section, an air discharge section downstream of the combustion section, a transition region between the combustion and air discharge section, a combustor transition piece defining the combustion section and transition region, and a sleeve. Said transition piece is adapted to carry combusted gas flow to a first stage of the turbine corresponding to the air discharge section. The transition piece defines an interior space for combusted gas flow. The sleeve surrounds the combustor transition piece so as to form a flow annulus between the sleeve and the transition piece. Said sleeve includes a first set of apertures for directing cooling air from compressor discharge air into the flow annulus. The transition piece includes an outer surface bounding the flow annulus and an inner surface bounding the interior space. The transition piece includes a second set of apertures for directing cooling air in the flow annulus to the interior space. Each

of the second set of apertures extends from an entry portion on the outer surface to an exit portion on the inner surface.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0006] 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 an example embodiment of a one-piece can combustor in which the present invention can be implemented.

FIG. 2 shows a close-up, perspective view of a sleeve with cooling air entry holes surrounding a transition piece with effusion holes.

FIG. 3 shows a cross-sectional view across the cooling air entry holes of the sleeve and effusion holes of the transition piece.

DETAILED DESCRIPTION OF THE INVENTION

[0007] Example embodiments that incorporate one or more aspects of the present invention are described and illustrated in the drawings. These illustrated examples are not intended to be a limitation on the present invention. For example, one or more aspects of the present invention can be utilized in other embodiments and even other types of devices.

[0008] FIG. 1 shows an embodiment of a single piece combustor 10 in which the present invention can be implemented. This example embodiment is a can-annular reverse-flow combustor 10 although the invention is applicable to other types of combustors. The combustor 10 generates gases needed to drive the rotary motion of a turbine by combusting air and fuel within a confined space and discharging the resulting combustion gases through a stationary row of vanes. In operation, discharge air from a compressor reverses direction as it passes over the outside of the combustors 10 and again enters the combustor 10 en route to the turbine. Compressed air and fuel are burned in the combustion chamber. The combustion gases flow at high velocity into a turbine section via a transition piece 120. As discharge air flows over the outside surface of the transition piece 120, it provides convective cooling to the combustor components.

[0009] In FIG. 1, a transition piece 120 transitions directly from a circular combustor head-end 100 to a turbine annulus sector 102 (corresponding to the first stage of the turbine indicated at 16) with a single piece. The single piece transition piece 120 may be formed from two halves or several components welded or joined together for ease of assembly or manufacture. A sleeve 129 also transitions directly from the circular combustor head-end 100 to an aft frame 128 of the transition piece 120 with a single piece. The single piece sleeve 129 may be formed

from two halves and welded or joined together for ease of assembly. The joint between the sleeve 129 and the aft frame 128 forms a substantially closed end to a cooling annulus 124. It should be noted that "single" also means multiple pieces joined together wherein the joining is by any appropriate means to join elements, and/or unitary, and/or one-piece, and the like.

[0010] In FIG. 1, there is an annular flow of the discharge air that is convectively processed over the outside surface of the transition piece 120. In the example embodiment, the discharge air flows through the sleeve 129 which forms an annular gap so that the flow velocities can be sufficiently high to produce high heat transfer coefficients. The sleeve 129 surrounds the transition piece 120 forming a flow annulus 124 therebetween. As indicated by arrows, cross flow cooling air traveling in the annulus 124 continues to flow upstream in a direction perpendicular to cooling air flowing through holes, slots, openings or other apertures 400 formed about the circumference of the sleeve 129. The sleeve 129 has a series of holes, slots, openings or other apertures 400 that allow the discharge air to move into the sleeve 129 at velocities that properly balance the competing requirements of high heat transfer and low pressure drop. A circled area of the transition piece 120 will be discussed in more detail in FIGS. 2- 3.

[0011] In conventional combustors, a combustor liner and a flow sleeve are generally found upstream of the transition piece and the sleeve respectively. However, in the one-piece can combustor of FIG. 1, the combustor liner and the flow sleeve have been eliminated in order to provide a combustor of shorter length. The major components in a one-piece can combustor include a circular cap 134, an end cover 136 supporting a plurality of fuel nozzles 138, the transition piece 120 and sleeve 129.

[0012] FIG. 2 shows a close-up, perspective view of the transition piece 120 and the sleeve 129. The sleeve 129 is radially outward with respect to the transition piece 120 and surrounds the transition piece 120 forming the flow annulus 124 in between. The sleeve 129 is formed with a plurality of first apertures or holes 400 to allow compressor discharge air to enter the flow annulus 124 from the exterior space 302. The single-piece transition piece 120 is formed with a plurality of second apertures or effusion holes 200. It must be noted that FIG. 2 shows one example arrangement of the first and second apertures 200, 400 which is not to be construed as a limitation on the invention. The formation of the apertures 200, 400 may be at or extend to other selected areas or over the entire surface of the transition piece 120 and the sleeve 129 respectively. The apertures 200, 400 may be formed in a circumferentially dispersed manner or may extend from an upstream portion to a downstream portion of the transition piece 120 and the sleeve 129 respectively. Moreover, FIG. 2 shows only one of multiple possible arrangements in which the plurality of apertures 200, 400 can be patterned. For example, FIG. 2 shows the second apertures 200 in orthogonal arrangement about one an-

other. In another example, each second aperture 200 in a row may be slightly offset relative to second apertures in an adjacent row. The first apertures 400 are also arranged in rows and columns but the spacing between the first apertures 400 may differ in a row direction relative to a column direction. The spacing between the first apertures 400 may also differ from the second apertures 200 as shown in FIG. 3 in part due to the difference in their sizes. Such variety in arrangement is within the scope of the present invention.

[0013] FIG. 3 shows a cross-section through the sleeve 129 and the transition piece 120. Again, a limited number of apertures 200, 400 are shown on the transition piece 120 and the sleeve 129 for simplicity of illustration. In particular, FIG. 3 shows a wall 500 that is part of the sleeve 129 and a wall 300 that is part of the transition piece 120. The wall 500 separates an exterior space 302 from the flow annulus 124. The distance between the wall 300 and the wall 500 may range from 0.5 inch to 3.0 inches.

[0014] The first apertures 400 are configured to be normal to the wall 500 such that air flow I is adapted to not strike or directly impinge an outer surface 300a of the transition piece 120 perpendicularly. The first apertures 400 may be formed directly above the second apertures 200 (FIG. 3), may be formed to be offset from the second apertures 200 (FIG. 2) so that no second apertures are found below the first apertures 400, or may be formed to be above an area of the wall 300 that in part includes the second apertures 200 and in part does not include the second apertures 200. In a configuration where the first apertures 400 are not directly above the second apertures 200, a greater portion of the air flow I is allowed to flow over an outer surface 300a of the transition piece 120 rather than enter the apertures 200 upon arrival at the outer surface 300a.

[0015] FIG. 3 also shows an outer surface 300a and an inner surface 300b of the wall 300. The area above the wall 300 is the flow annulus 124 while the area below the wall is the interior space 304 of the transition piece 120. A right side of FIG. 3 corresponds to an upstream area within the turbine while a left side of FIG. 3 corresponds to a downstream area within the turbine. Flow C, made up of compression discharge air which is cooler than combusted hot gas, originates from the compressor but approaches the transition piece 120 in the flow annulus 124 from a downstream area of the turbine and moves upstream as is typical in a can-annular, reverse flow combustor. Flow I, also made up of compressor discharge air, moves upstream in the exterior space 302 from a downstream area of the turbine and enters the flow annulus 124 through the first apertures 400. Flow H, made up of hot gas, originates from the combustion chamber and is directed downstream in the interior space 304 of the transition piece 120.

[0016] As shown in FIG. 3, the second apertures 200 extend from the outer surface 300a to the inner surface 300b of the wall 300. The present invention encompasses

es second apertures 200 formed to be normal to the wall 300 and formed at an angle θ to the wall 300. In FIG. 3, the apertures 200 are shown at the angle θ such that exit portions 200b of the apertures 200 are downstream or rearward relative to entry portions 200a of the apertures 200. In one embodiment, the angle θ formed by the longitudinal axes 200c of the apertures 200 and a direction 202 that is tangential to the wall 300 and is pointed downstream may be acute at 30 degrees and may range from 20 to 35 degrees. However, other smaller and larger angles are also contemplated. In FIG.3, the downstream tangent points to the left. Although the second apertures 200 are substantially cylindrical, the entry portions 200a and the exit portions 200b will have elliptical shapes if the apertures 200 are not normal to the wall 300. However, the apertures 200, 400 may have a cross section that is not circular and, for example, is polygonal.

[0017] Another variation of the apertures 200 is that the angular position of the entry portion 200a may be different from the angular position of the exit portion 200b on the circumference of the transition piece 120. Moreover, the exit portion 200b of the apertures 200 may be upstream or forward relative to the entry portion 200a of the apertures 200 thereby creating an obtuse angle between the longitudinal axes of the apertures 200 and the direction 202.

[0018] In FIG. 3, the second apertures 200 have a substantially cylindrical geometry with a constant diameter from the entry portion to the exit portion. In one embodiment, the diameter may be 0.03 inch and alternatively may range from 0.02 inch to 0.04 inch. However, other dimensions for the apertures 200 are also contemplated.

[0019] The first apertures 400 also have a substantially cylindrical geometry with a constant diameter. In one embodiment, the diameter may range from 0.1 inch to 1.0 inch. However, other dimensions for the apertures 400 are also contemplated.

[0020] Also, the apertures 200, 400 may gradually increase or decrease in diameter through the walls 300, 500 respectively.

[0021] The second apertures 200 may be formed on the wall 300 of the transition piece 120 by laser drilling or other machining methods selected based on factors such as cost and precision. The larger dimensions of the first apertures 400 allow for more tolerance and thus similar or more cost-effective machining methods may be used to form the apertures 400.

[0022] In FIG. 3, flow I caused by the first apertures or holes 400 cools the transition piece 120 by forming jets of air that do not strike or directly impinge on the outer surface 300a. Flow C in the flow annulus provides convective cooling of the transition piece 120 by removing heat while traveling along the outer surface 300a. Flow E created by the second apertures or effusion holes 200 provides jets of air at all or selected areas of the transition piece 120 that cool the transition piece 120 as the cooling air passes through the apertures 200 contacting internal surfaces therein. Effusion cooling is a form of transpira-

tion cooling. An aperture that is angled to the wall will have a larger internal surface area compared to an aperture normal to the wall due to increased length so that heat transfer is prolonged and greater cooling of the transition piece 120 can be achieved. Moreover, after the cool air exits the exit portion 200b of the apertures 200, a layer or film of cooling air is formed adjacent the inner surface 300b of the wall 300 of the transition piece 120. Formation of such a layer of cooling air on the inner surface 300b further cools the transition piece 120. The formation of such a layer is facilitated by an angled aperture compared to a normal aperture since the degree of change required in direction by the cool air is reduced. However, the present invention encompasses the two variations of normal and angled apertures. Cooling by the film formed on the inner surface can improve as the hole sizes and angles are decreased. However, smaller holes are more prone to blockage from impurities. In comparison, larger holes can cause excessive penetration of the hot gas stream by the cool air jets and reduce the efficiency of the turbine. Therefore, such benefits and drawbacks must therefore be collectively considered when determining the geometry of the effusion holes.

[0023] The invention has been described with reference to the example embodiments described above. Modifications and alterations will occur to others upon a reading and understanding of this specification. Example embodiments incorporating one or more aspects of the invention are intended to include all such modifications and alterations insofar as they come within the scope of the appended claims.

Claims

1. A turbine engine comprising:

a combustion section;
 an air discharge section downstream of the combustion section;
 a transition region between the combustion section and air discharge section;
 a combustor transition piece (120) defining the combustion section and transition region, said transition piece (120) adapted to carry combusted gas flow (H) to a first stage of the turbine engine (16) corresponding to the air discharge section, the transition piece (120) defining an interior space (304) for combusted gas flow (H); and
 a sleeve (129) surrounding the combustor transition piece (120) so as to form a flow annulus (124) between the sleeve (129) and the transition piece (120), said sleeve (129) including a first set of apertures (400) for directing cooling air (I) from compressor discharge air into the flow annulus (124),

wherein the transition piece (120) includes an outer surface (300a) bounding the flow annulus (124) and an inner surface (300b) bounding the interior space (304), the transition piece (120) includes a second set of apertures (200) for directing cooling air in the flow annulus (124) to the interior space (304), and each of the second set of apertures (200) extends from an entry portion (200a) on the outer surface (300a) to an exit portion (200b) on the inner surface (300b).

2. The turbine engine of claim 1, wherein the first set of apertures (400) are normal to the sleeve (129).
3. The turbine engine of claim 1 or 2, wherein the first set of apertures (400) has a constant diameter ranging from 0.1 inch to 1.0 inch.
4. The turbine engine of any of the preceding claims, wherein one of the entry portion (200a) and the exit portion (200b) is located further downstream than the other of the entry portion (200a) and the exit portion (200b).
5. The turbine engine of claim 4, wherein the combustor transition piece (120) is a can-annular, reverse-flow type such that combusted gas flow (H) and compressor discharge air flow (C) are configured to be in opposing directions such that longitudinal axes through the second set of apertures (200) form an acute angle with a direction of combusted gas flow (H) and an obtuse angle with a direction of compressor discharge air flow (C).
6. The turbine engine of any of the preceding claims, wherein longitudinal axes through the second set of apertures (200) are oriented to form an acute angle with a downstream tangent to the outer surface (300a).
7. The turbine engine of claim 6, wherein the acute angle ranges from 20° to 35°.
8. The turbine engine of any of the preceding claims, wherein the second set of apertures (200) have a constant diameter from the entry portion (200a) to the exit portion (200b) ranging from 0.02 inch to 0.04 inch.
9. The turbine engine of any of the preceding claims, wherein the second set of apertures (200) are substantially normal to the outer surface (300a).

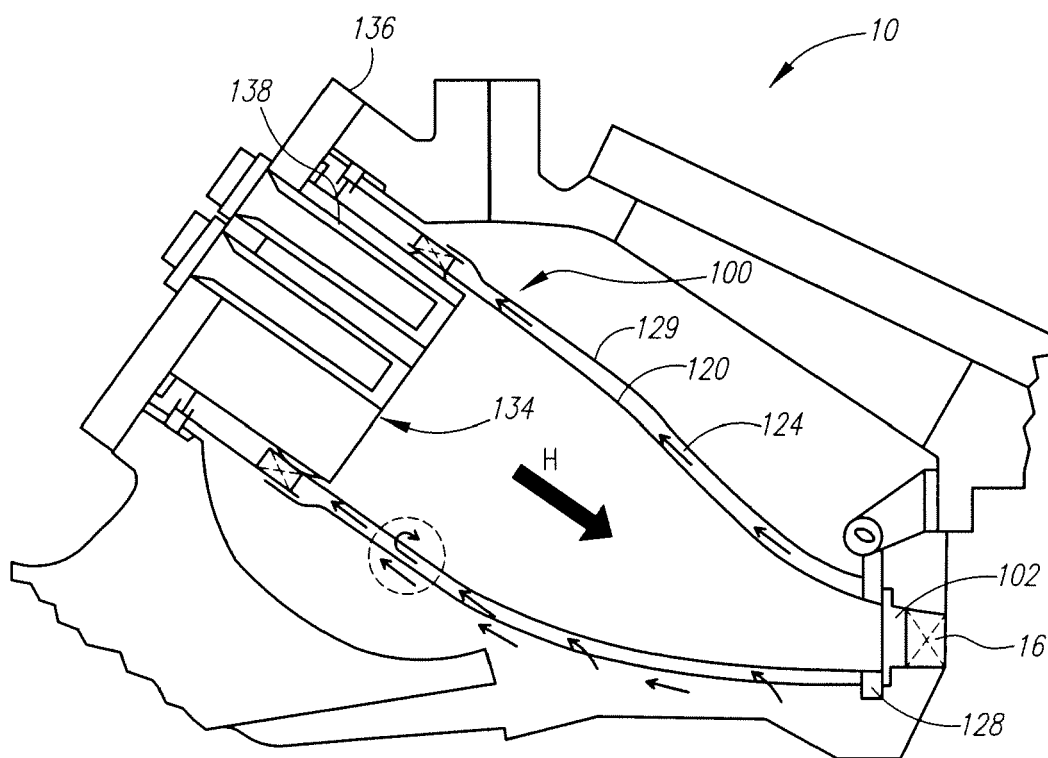


Fig. 1

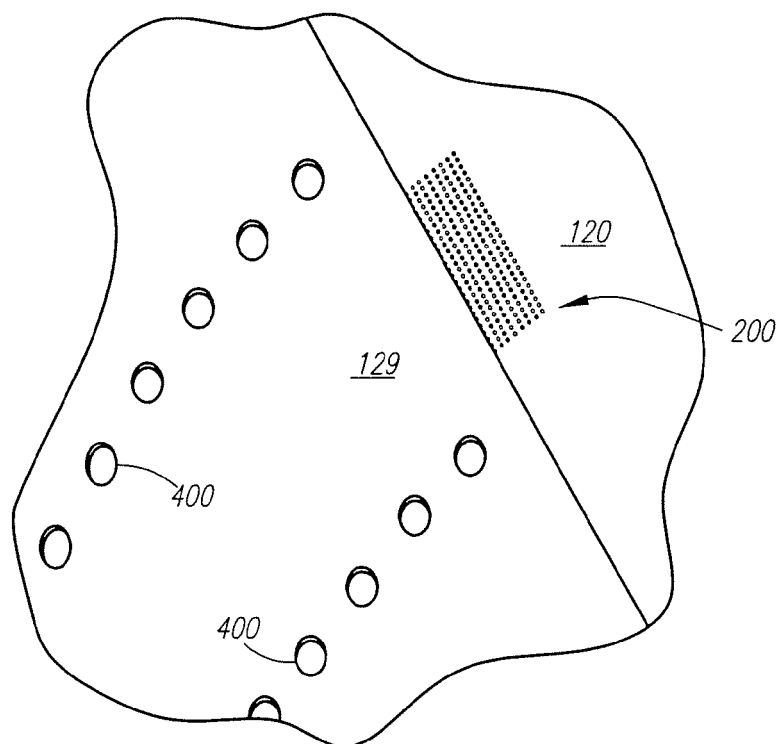


Fig. 2

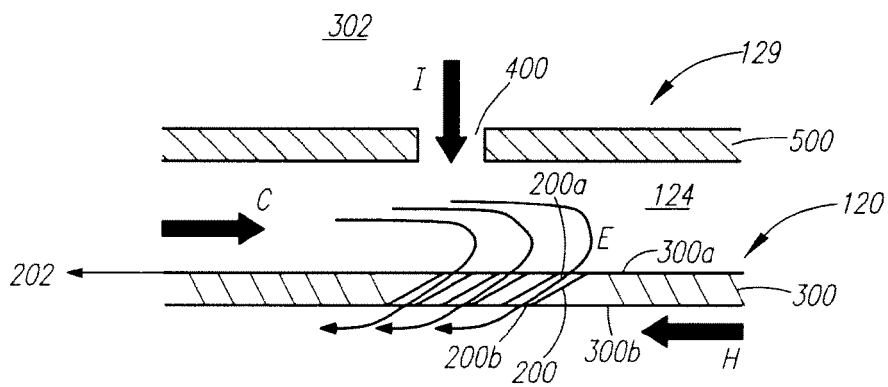


Fig. 3