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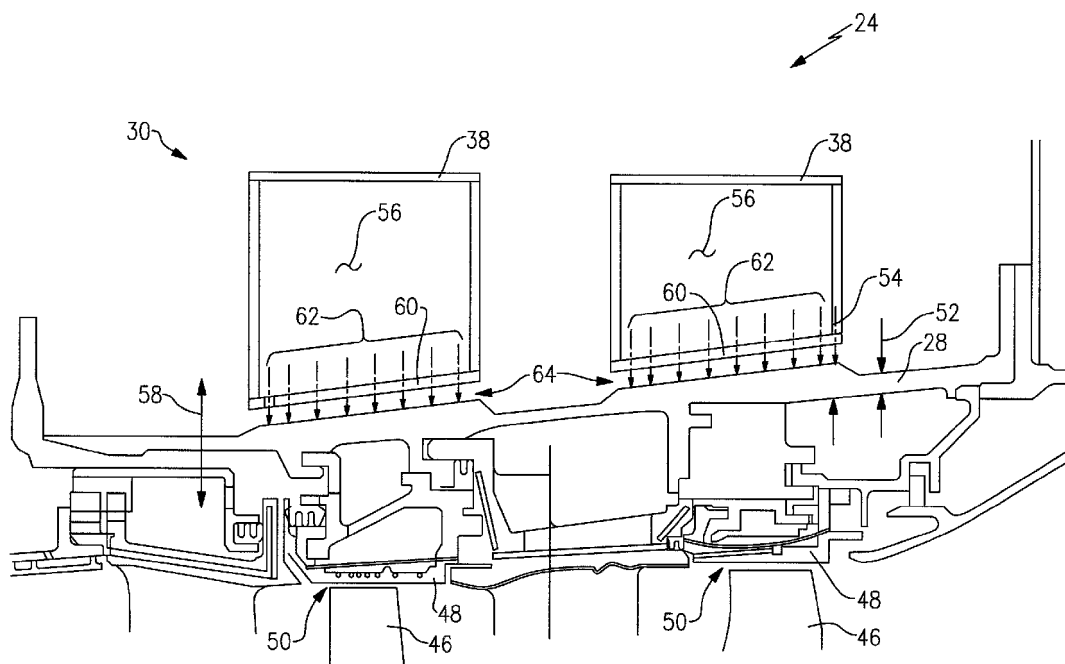
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BA ME(30) Priority: **26.07.2011 US 201113190674**(71) Applicant: **United Technologies Corporation****Hartford, CT 06101 (US)**(72) Inventor: **Lagueux, Ken****Berlin, CT Connecticut 06037 (US)**(74) Representative: **Leckey, David Herbert****Dehns****10 Salisbury Square****London****Greater London EC4Y 8JD (GB)**(54) **Gas turbine engine active clearance control system and corresponding method**

(57) An active clearance control system (30) utilizes a working fluid stream to control radial thermal growth and thereby a clearance between turbine blades (46) and a corresponding shroud (48) of a gas turbine engine (10). Conduits (38) disposed about a turbine case (28) and proximate to pads (44) defined within the turbine case include a flow surface (60) parallel to the pads (44). The pads (44) are an area of increased thickness in the tur-

bine case (28) that receives impingement flow from the conduits (38). Grooves (66) within the pads (44) further increase impingement cooling flow effectiveness. The increased thickness of the pads (44) provides the thermal mass desired to effect thermal expansion and contraction responsive to the cooling airflow. A method of actively controlling clearances within a gas turbine engine is also provided.

**FIG. 4**

Description**BACKGROUND**

[0001] This disclosure generally relates to an active clearance control system for controlling clearances within a gas turbine engine. More particularly, this disclosure relates to an active clearance control system that provides improved impingement cooling for a turbine casing.

[0002] An active clearance control system for a gas turbine engine is commonly utilized to maintain a desired clearance between a rotating turbine blade and a shroud. It is desired to minimize the clearance between a tip of the turbine blade and the shroud to minimize the amount of working fluid that escapes past the turbine blade. Active clearance control systems control a temperature of a turbine case with impingement airflow to control relative thermal expansion between the shroud and the turbine blade tip. Known systems include annular ribs at the locations where control is desired. The conduits providing impingement flow must therefore be tailored to the annular ribs to provide the desired uniform cooling or heating. This configuration results in corresponding curved surfaces that must be matched within exacting tolerances that increase assembly and manufacture costs and reduces effectiveness.

SUMMARY

[0003] A disclosed example active clearance control system utilizes a working fluid stream to control radial thermal growth and thereby a clearance between turbine blades and a corresponding shroud of a gas turbine engine.

[0004] The disclosed example active clearance control system includes conduits disposed about a turbine case and proximate to pads defined within the turbine case. The pads are an area of increased thickness in the turbine case that receives impingement flow from the conduits. The increased thickness of the pads provides the thermal mass desired to effect thermal expansion and contraction responsive to the cooling airflow. Axial grooves within the pads further enhance impingement cooling of the turbine case. Each of the pads includes an axial width and extends entirely about the circumference of the turbine case.

[0005] The example conduits include a flow surface that is substantially parallel to a surface of the pads. A radial spacing between the flow surface and the pad is uniform about the circumference of the turbine case to provide a uniform thermal contraction or expansion of the turbine case. The pads are also substantially parallel to the turbine case and the axis of the gas turbine engine.

[0006] These and other features disclosed herein can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS**[0007]**

Figure 1 is a schematic representation of an example of a gas turbine engine.

Figure 2 is an external view of a turbine section of the example gas turbine engine.

Figure 3 is a sectional view of the turbine section of a gas turbine engine.

Figure 4 is an enlarged sectional view of an example active clearance control system.

Figure 5 is an external view of the pads of the active clearance control system.

Figure 6A is a sectional view illustrating conduit portions of the example sample clearance control system.

Figure 6B is a side view of the conduit portions of the example clearance control system.

Figure 7 is a schematic representation of the impingement openings defined in the conduits of the active clearance control system.

Figure 8 is another schematic representation of another configuration of openings within a conduit for the active clearance control system.

Figure 9 is another example conduit configuration for the example active clearance control system.

Figure 10 is yet another schematic representation of a conduit for the active clearance control system.

DETAILED DESCRIPTION

[0008] Referring to Figure 1, an example gas turbine engine 10 includes a fan section 12 and a compressor section 14. The compressor section 14 includes a low pressure compressor 18 and a high pressure compressor 16. Compressed air from the compressor section 14 is directed to a combustor 20 where the compressed air is mixed with fuel and ignited. The ignited fuel generates a high speed flow stream that drives a turbine section 22. The example turbine section 22 includes a high pressure turbine 24 and a low pressure turbine 26. The high pressure turbine 24 drives a high spool 40 that in turn drives the high pressure compressor 16. The low pressure turbine 26 drives a low spool 42 that in turn drives a low pressure compressor 18.

[0009] The example gas turbine engine 10 is disposed concentrically about an axis A and includes an active clearance control system 30. The active clearance control system 30 controls clearances between turbine blades within the high pressure turbine section 24 and corresponding blade shrouds to minimize the leaking of the flow stream past the turbine blades.

[0010] Referring to Figure 2, the turbine section 22 includes the active clearance control system 30 that utilizes a working fluid stream to control radial thermal growth and thereby a clearance between turbine blades 46 and a corresponding shroud 48 (Figure 3). The example ac-

tive clearance control system 30 locally regulates the temperature of a portion of the turbine case 28 to control thermal contraction of expansion. The working fluid stream is modulated responsive to detected operating parameters to reduce the blade tip to shroud clearance.

[0011] The example active clearance control system 30 includes conduits 38 that receive airflow through inlet 32 from a supply 34. Airflow is modulated to regulate a temperature of a select portion of the turbine case 28 radially outward of a corresponding turbine blade 46. The airflow is supplied through the inlet 32 and manifold 36 in communication with the conduits 38 to provide uniform airflow about the circumference of the turbine case 28.

[0012] The active clearance control system 30 produces impingement airflow that circulates within the conduits 38 and impinges against specific portions of the turbine case 28. The airflow impinging against the case 28 is then circulated along a corresponding pad 44 (Figure 3) and exhausted axially.

[0013] Airflow utilized and communicated to impinge against the case 28 may be introduced from the atmosphere, for example, through ram air or through one of the compressor stages of the gas turbine engine 10. Airflow communicated from an early portion of the compressor section 14 or atmosphere is not yet subjected to the extreme operating conditions present within the gas turbine engine 10. Accordingly, the cooling airflow is at temperature lower than the operating temperature of the engine 10 and can provide a cooling affect. The airflow is channeled through the manifold 36 and enters the conduits 38 where the airflow is directed against specific portions of the case 28 to affect the desired clearance control.

[0014] The cooling airflow cools the outer turbine case 28 and causes a thermal contraction in a radial direction. Uniform thermal control about the entire circumference of the turbine case 28 is desired to maintain a uniform clearance circumferentially between the blades 46 and shrouds 48.

[0015] Referring to Figure 3 with continued reference to Figure 2, the conduits 38 are disposed about the turbine case 28 and proximate to pads 44. The pads 44 are an area of increased thickness in the turbine case 28 that receive impingement flow produced by the conduits 38. The pads 44 include axial grooves 66 (Figure 5) that further enhance impingement cooling of the turbine case 28. The increased thickness of the pads 44 provides the thermal mass desired to effect thermal expansion and contraction responsive to the cooling airflow. Each of the pads 44 include an axial width and extend entirely about the circumference of the turbine case 28. The axial width of each of the pads 44 is determined to provide the desired thermal movement of the turbine case 28 that provides for the desired control over a clearance 50 between each of the blades 46 and shrouds 48.

[0016] Hot combustion gases exhausted from the combustor 20 and directed against the turbine blades 46 increase temperatures within the turbine section 22. The increased temperatures generate thermal expansion of

the turbine blades 46 and shrouds 48. The shrouds 48 are supported by the turbine case 28 and are exposed to the same hot gases encountered by the turbine blades 46. Differences in material composition and structure can result in differences in thermal expansion that can result in increases in the clearance 50 between the turbine blade 46 and the shroud 48.

[0017] The example active clearance control system 30 provides a cooling airflow to the pads 44 of the turbine case 28 to cause a relative radial contraction that regulates the clearance 50 between the turbine blade 44 and corresponding shroud 48. The clearance 50 is minimized such that minimal amounts of hot gases generated within the combustor 20 bypass each of the turbine blades 46. Bypass flow past the turbine blades is essentially wasted energy that cannot be utilized for driving the high spool 40 and thereby the high pressure compressor section 16. However, the turbine blades must maintain a minimum clearance such that contact is not made between moving and stationary parts of the turbine section 22.

[0018] Referring to Figure 4, an enlarged sectional view of the example active clearance control system 30 is illustrated within the high pressure turbine section 24. It should be understood that although the disclosed sample is utilized with the high pressure turbine section 24, it is within the contemplation of this disclosure that the example active clearance control system may also be utilized for low pressure turbine sections, or in other parts of the gas turbine engine 10 where clearance control is desired.

[0019] The conduits 38 are substantially rectangular in shape and define an internal flow area 56. The internal flow area 56 directs the cooling airflow about the circumference of the turbine case 28 (best shown in Figures 2 and 6). Each of the conduits 38 includes a flow surface 60 having a plurality of impingement openings 62. The openings 62 direct impingement airflow 64 against pads 44 defined on the turbine case 28. Each of the pads 44 includes a thickness 54 greater than the thickness 52 of other portions of the turbine case 28. The additional material provided in the pad areas 44 provide the desired mass of material that can be affected by the impingement flow 64.

[0020] The pads 44 are disposed radially outward of the interface between the corresponding turbine blade 46 and shroud 48. In this example, a separate pad 44 is provided for controlling the clearance 50 between each separate turbine blade 46. Accordingly, control of clearances between each individual turbine blade 46 and 48 may be controlled separately if desired.

[0021] During operation of the example active clearance control system 30 impingement airflow 64 against the pads 44 is utilized to effect radial thermal contraction or expansion of the turbine case 28 in a direction indicated by arrows 58. As appreciated cooling of the turbine case 28 causes an accompanying thermal shrinking of the turbine case 28. Alternatively warmer or reduced cooling impingement airflow on the pads 44 provides cir-

cumferential expansion of the turbine case 28. Thermal movement caused by the impingement flow 64 controls the clearance 50 between the turbine blade 46 and the shroud 48.

[0022] The example conduits 38 include a flow surface 60 that is substantially parallel to a surface of the pads 44. The substantial parallel relationship between the flow surface 60 and the pad surfaces 44 provides for the desired clearance between the flow surface 60 and the pad 44. A radial spacing between the flow surface 60 and the pad 44 is uniform about the circumference of the turbine case to provide a uniform thermal contraction or expansion of the turbine case 28.

[0023] The pads 44 are also substantially parallel to the turbine case 28 and the axis A. Accordingly the flow surface 60 and the pads 44 define corresponding parallel flat surfaces for the entire axial distance of each of the pads 44. Moreover, the corresponding parallel flat surfaces have uniform clearance at all axial positions along the axial length of each of the pads 44. The axial orientation or alignment between the conduits 38 and each of the pads 44 can be varied without changing the distance between the flow surface 60 and the pads 44. Slight relative axial variation of alignment between the conduit 38 and the pads 44 will not significantly affect impingement flow against the pads 44. It should be understood that deviations in a desired distance between a flow surface 60 and the pad surface 44 influences the degree of thermal growth and control provided by the active clearance control system 30. Accordingly, it is desired to provide a substantially uniform and consistent annular spacing between the flow surface 60 of the conduits 38 and the surface of the pads 44.

[0024] Referring to Figure 5 with continued reference to Figure 4, the pads 44 include the plurality of axial grooves 66. The axial grooves 66 increase surface area of the pads 44 to further enhance impingement cooling of the turbine casing 28. The grooves 66 extend from one axial side 43 of the pads 44 to a second axial side 45. The grooves 66 extend parallel to the axis A of the engine 10. The grooves 66 direct impingement flow 64 axially away from the pads 44 such that airflow is not trapped and is exhausted thereby providing that a uniform constant flow of cooling airflow circulates across the pads 44.

[0025] Referring to Figures 6A and 6B with continued reference to Figure 4, a schematic representation of the conduits perpendicular to the axis A is illustrated. The example conduits 38 are formed in sections. A first section 38A defines essentially half of the conduit 38 circumference about the turbine engine case 28. A second section 38B defines a second half that is connected to the first section 38A to define a complete circumferential flow path about the turbine case 28. Although the example conduit 38 is disclosed as including two sections 38A and 38B, more sections could also be utilized and are within the contemplation of this disclosure.

[0026] The inlet 32 and manifold 36 are provided at one end of the conduits 38. Accordingly, incoming airflow

enters at one circumferential location and flows towards a bottom location. It is desired to provide uniform impingement airflow about the entire circumference of the turbine engine case 28. This uniform airflow is provided by including a flow area 56 that eliminates potentially flow disrupting effects that may interrupt the desired uniform airflow through the impingement openings 62. Moreover, the flow area 56 is of such an area as to produce uniform pressure throughout the circumference of each of the conduits 38 thereby eliminating any deviations between impingement airflow at any portion about the circumferential distance of the turbine case 28.

[0027] Referring to Figure 7 with continued reference to Figures 6A-B, an example conduit 68A includes an alternate distribution of flow areas to provide uniform airflow about the circumference of the turbine case 28. In this example, the flow area provided by the impingement openings 62 increases in a direction away from an inlet 32. The increase in flow area is provided by a non-uniform distribution of impingement openings. The number of impingement openings for a defined area increases in a direction away from the inlet. In this example, a first section 70 includes the least amount of impingement openings. A middle or second section 72 includes a greater density of impingement openings than the first section 70. A last or third section 74 includes the greatest density of impingement openings. The number and density of impingement openings accommodate potential differences in pressure within the conduit 68A.

[0028] Referring to Figure 8, another example conduit 68B includes impingement openings 82, 84 and 86 that vary in size corresponding to a distance from the inlet 32. A first plurality of impingement openings 82 within a first section 76 are of a first size. A second section 78 spaced a distance greater than the first section 76 includes a second plurality of impingement openings 84 with an opening size greater than the first group 76. A last or third section 78 include impingement openings 86 spaced a furthest away from the inlet 32 that are larger than those in the previous sections 76, 78. Accordingly, the differences in hole sizes define a varying flow area based on a distance from the inlet 32 that provide a balanced and uniform impingement flow about the circumference of the turbine case 28. In other words, to maintain a uniform mass of air flow given the pressure drop in a direction away from the inlet, the holes are varied in size.

[0029] Referring to Figure 9, each of the example conduits 38 is substantially square or rectangular in cross-section. However it is within the contemplation of this disclosure that other cross-sectional shapes could also be utilized. In the example illustrated in Figure 9, the flow surface 60 is parallel with each of the pads 44 such that a uniform clearance is provided about the entire circumference of the case 28. However the conduit 88 includes a curved outer surface. Accordingly alternate shapes may be utilized that include the flat flow surface 60 disposed substantially parallel to the corresponding pad 44.

[0030] Referring to Figure 10, another example conduit

90 is shown and extends across two pads 44. Each of the pads 44 is substantially parallel to the axis A. Accordingly, the axial orientation or alignment between the conduit 90 and each of the pads 44 can be varied without changing the distance between the flow surface 60 and the pads 44. Slight relative axial variation of alignment between the conduit 90 and the pads 44 will not significantly affect impingement flow against the pads 44.

[0031] Moreover, because the pads 44 are aligned along the axis A and along the surface of case 28, a single conduit 90 can be utilized to reduce overall structure and provide a desired uniform impingement flow against the pads 44. In this example, the conduit 84 is substantially rectangular and includes flow surfaces 62 that are disposed proximate each of the corresponding pads 44. In this example, the conduit 90 extends across both of the pads 44. However, the areas in which impingement openings 62 are provided and the flow surfaces 60 remain only in the areas that are aligned with the corresponding pad 44.

[0032] Accordingly, the disclosed example active clearance control system 30 provides for the uniform impingement of cooling flow about the entire circumference of the turbine case 28 and eases alignment burdens during assembly and manufacture thereby improving the control provided by the example active clearance control system.

[0033] Although an example embodiment has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure. For that reason, the following claims should be studied to determine the scope and content of this invention.

Claims

1. An active clearance control system (30) for a gas turbine engine (10), the system (30) comprising:

a turbine case (28) disposed about an axis (A) and including at least one pad (44) encircling the turbine case (28), the at least one pad (44) substantially parallel to an outer surface of the turbine case (28); and
a conduit (38; 68; 88; 90) circumferentially encircling the turbine case (28) and the at least one pad (44), the conduit (38; 68; 88; 90) including a flow surface (60) parallel to and spaced apart from the at least one pad (44), the flow surface (60) including impingement openings (62; 82, 84, 86) for directing a flow stream onto the at least one pad (44) for controlling a clearance.

2. The active clearance control system as recited in claim 1, wherein the turbine case (28) includes a first thickness and the at least one pad (44) comprises a second thickness greater than the first thickness,

wherein, optionally, the second thickness extends for an axial distance equal to or less than the flow surface (60) of the conduit (38; 68; 88; 90).

3. The active clearance control system as recited in claim 1 or 2, wherein the at least one pad (44) includes axially orientated grooves (66) for guiding impingement airflow, the axially orientated grooves (66) optionally providing an increased area of the corresponding pad (44) to increase impingement cooling.
4. The active clearance control system as recited in any preceding claim, including an inlet (32) communicating the flow stream into the conduit (68B), wherein an opening area of the impingement openings (62; 82, 84, 86) increases in a direction away from the inlet (32).
5. The active clearance control system as recited in claim 4, wherein a size of each of the impingement openings (82, 84, 86) increases in a direction away from the inlet (32), or wherein a number of impingement openings for a defined area increases in a direction away from the inlet (32).
6. The active clearance control system as recited in any preceding claim, including at least one turbine rotor rotatable about the axis within the turbine case (28) and the at least one pad (44) comprises at least one pad (44) corresponding with each of the at least one turbine rotors.
7. The active clearance control system as recited in any preceding claim, wherein the conduit (38) comprises a substantially rectangular cross-section.
8. The active clearance control as recited in any preceding claim, wherein the conduit (38) comprises a first portion (38A) extending a first circumferential distance about the turbine case (28) and a second portion (38B) extending a second circumferential distance about the turbine case (28), and wherein, optionally, each of the first portion (38A) and second portion (38B) are in fluid communication with a common inlet (32).
9. The active clearance control as recited in any preceding claim, wherein the flow surface (60) of the conduit (38; 68; 88; 90) is spaced apart a fixed distance common over an entire axial distance of the at least one pad (44).
10. The active clearance control as recited in any preceding claim, including a blade shroud disposed radially outward of a turbine blade, wherein the controlled radial growth of the turbine case controls a clearance between the blade shroud and a tip of the

turbine blade.

11. The active clearance control as recited in any preceding claim, wherein the at least one pad (44) comprises at least two pads (44) and the conduit (90) includes an axial length that extends over the at least two pads (44). 5
12. The active clearance control as recited in any preceding claim, wherein the conduit (38; 68; 88; 90) defines a flow area determined to provide a substantially equal airflow through each of the impingement openings (62; 82, 84, 86). 10
13. A method of actively controlling clearances within a gas turbine engine comprising: 15
 providing a case (28) including a pad (44) of a thickness greater than surrounding portions of the case (28), the pad (44) encircling the case (28) and extending substantially parallel to a surface of the case (28); 20
 providing a conduit (38; 68; 88; 90) encircling the pad (44) and spaced circumferentially apart from the pad (44) a defined distance along an axial length of the conduit (38; 68; 88; 90); and 25
 flowing a working fluid through the conduit (38; 68; 88; 90) and a plurality of impingement openings (62; 82, 84, 86) onto the pad (44); and
 controlling thermal growth of the case by adjusting a temperature of the working fluid flowing onto the pad (44). 30
14. The method of actively controlling clearances within a gas turbine engine as recited in claim 13, wherein the case (28) comprises a turbine case (28) that supports a shroud (48) movable responsive to the controlled thermal growth of the turbine case (28) and defining a clearance between the shroud (48) and a tip of a turbine blade (46) by controlling thermal growth of the turbine case, and/or including uniformly controlling thermal growth about a circumference of the case. 35 40
15. The method of actively controlling clearances within a gas turbine engine as recited in claim 13 or 14, wherein the conduit (38; 68; 88; 90) includes a flow surface (60) that is substantially parallel to the case (28) and the pad (44), the impingement openings (62; 82; 84; 86) disposed within the flow surface (60). 45 50

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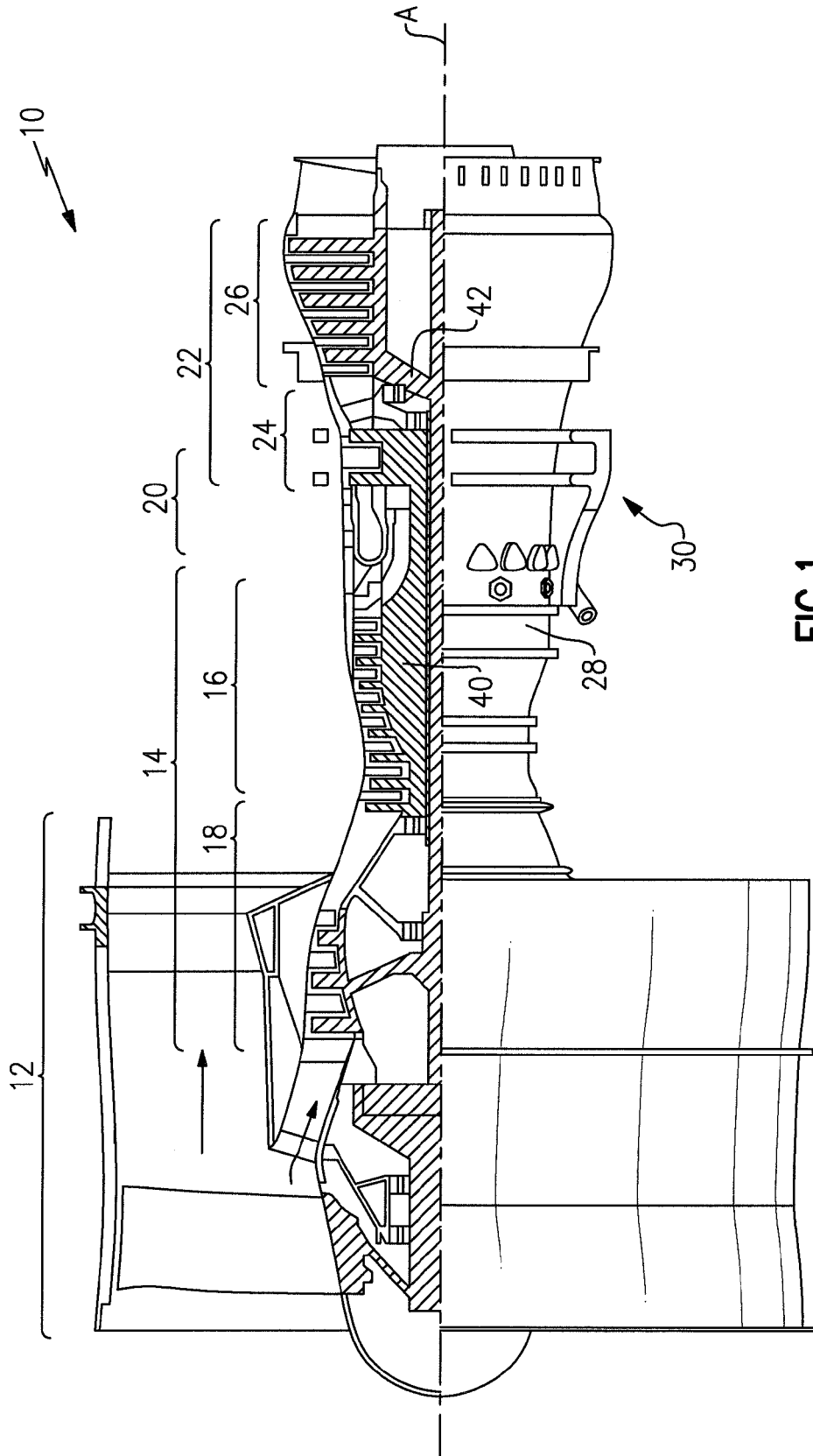


FIG.1

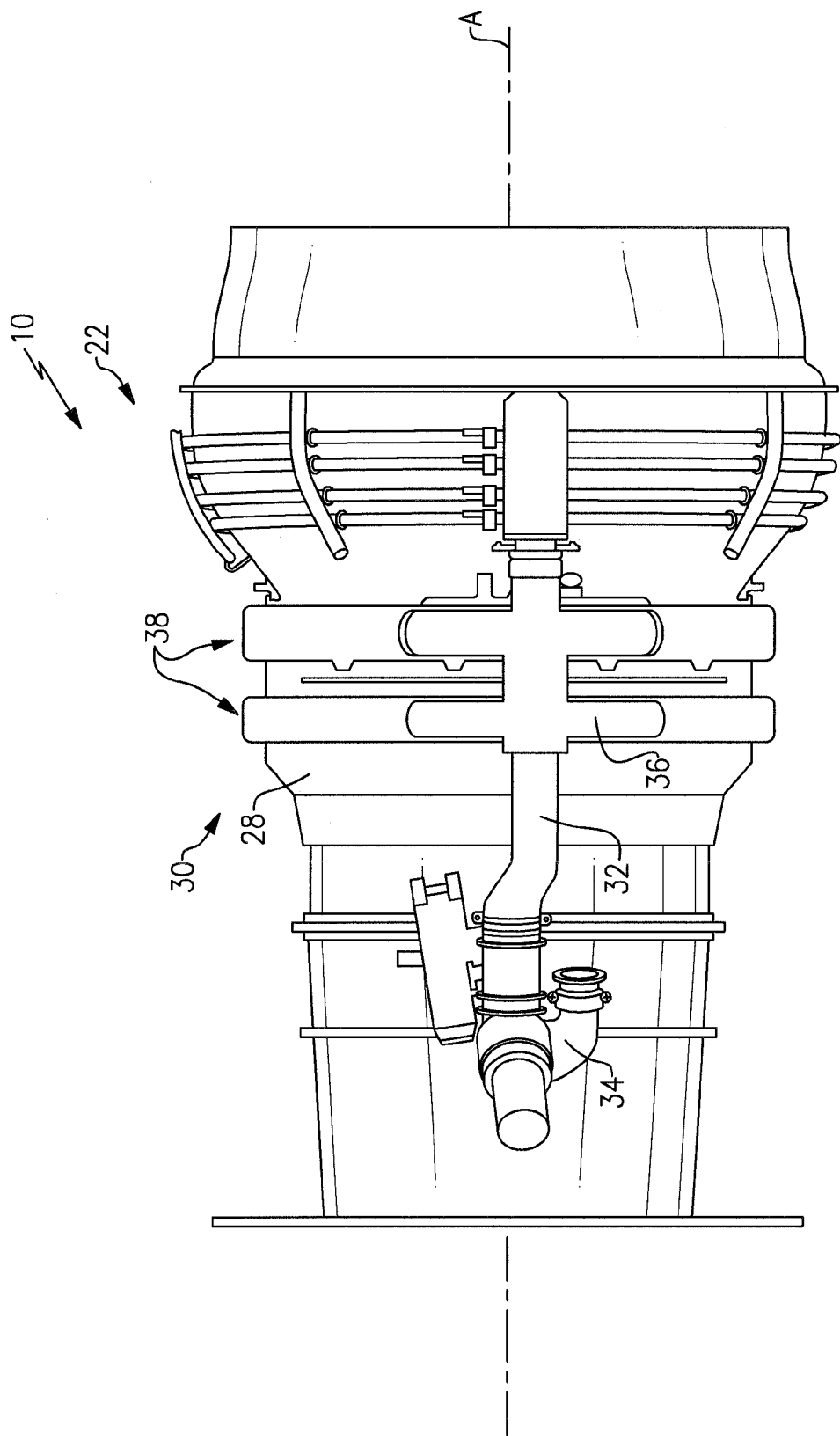


FIG. 2

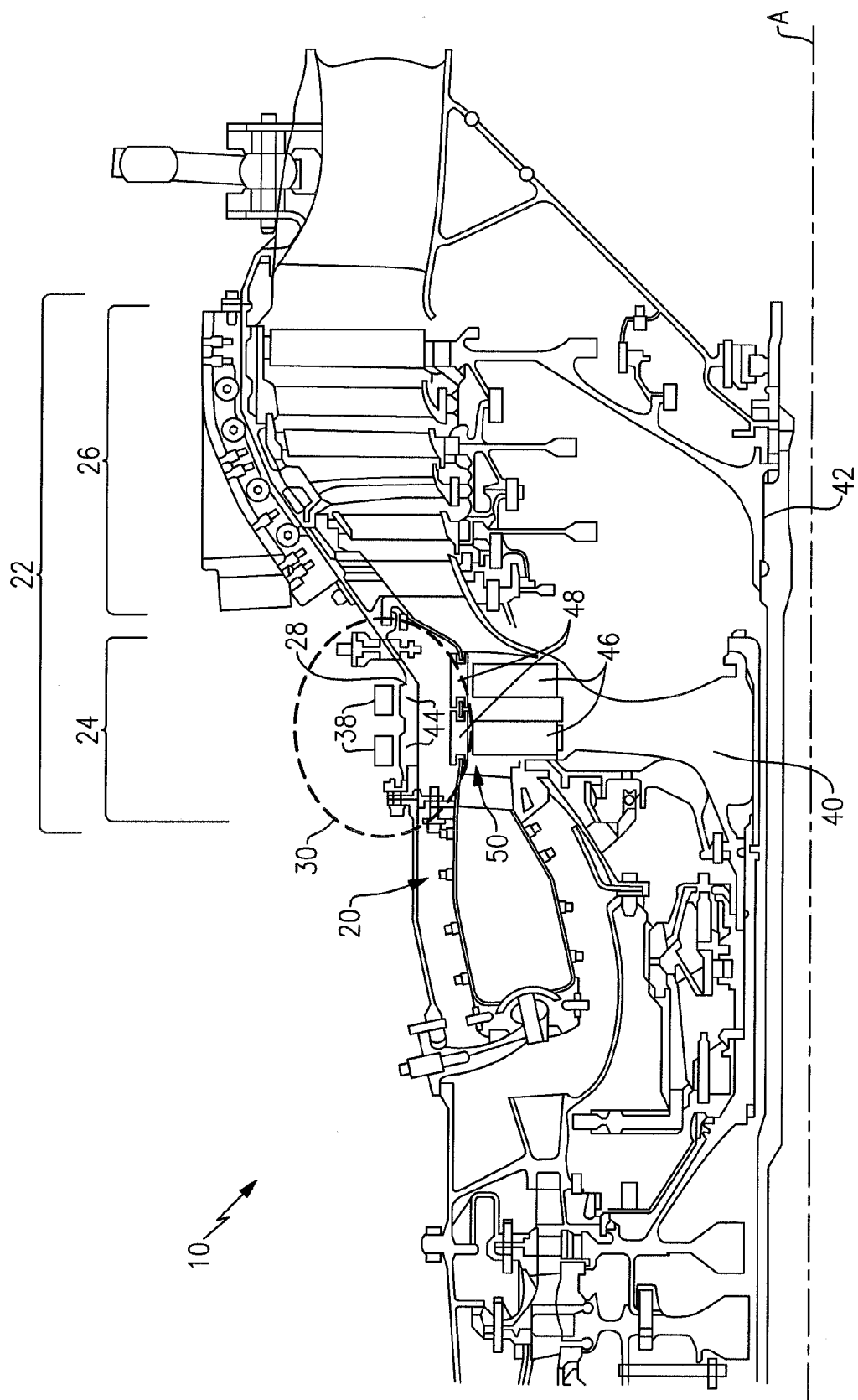


FIG. 3

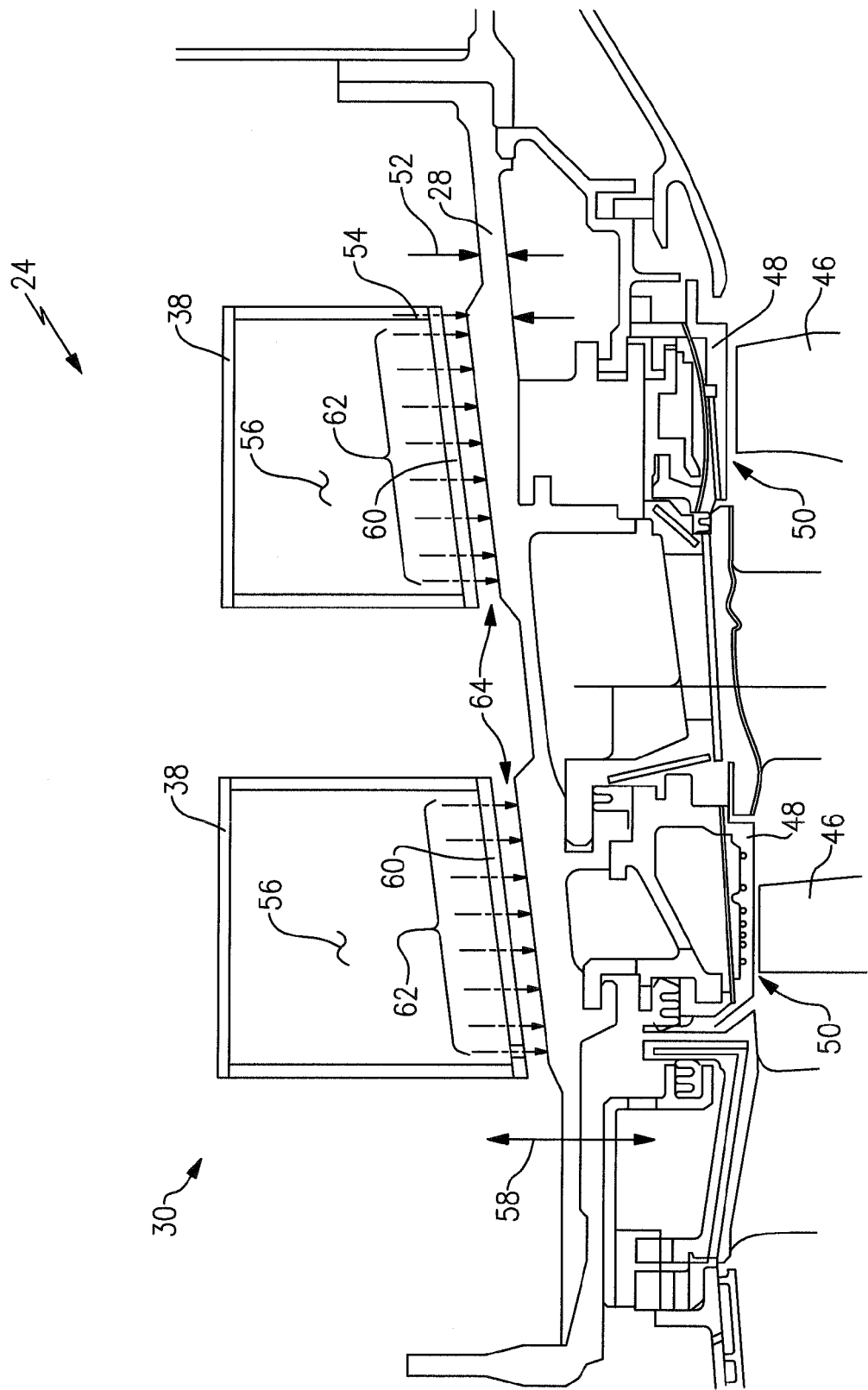


FIG. 4

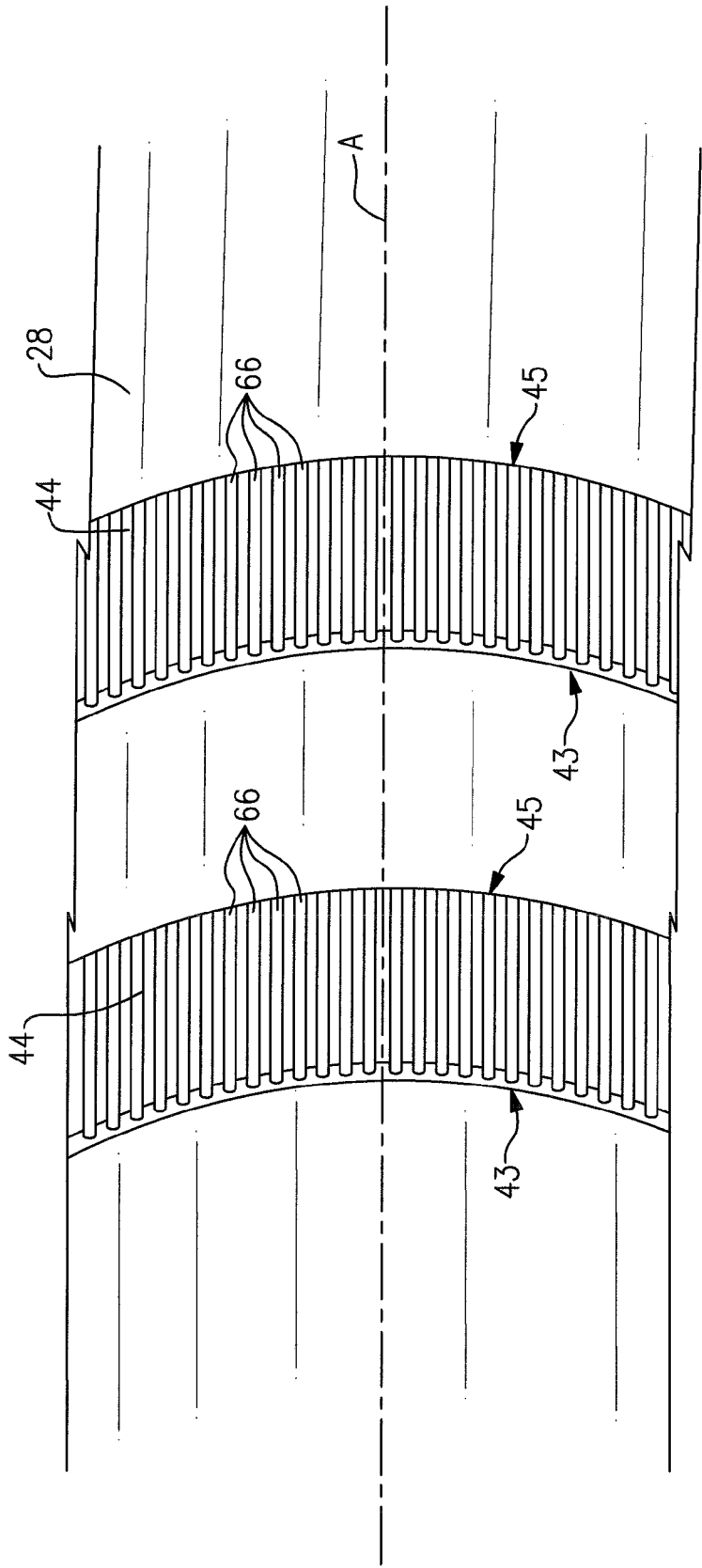


FIG. 5

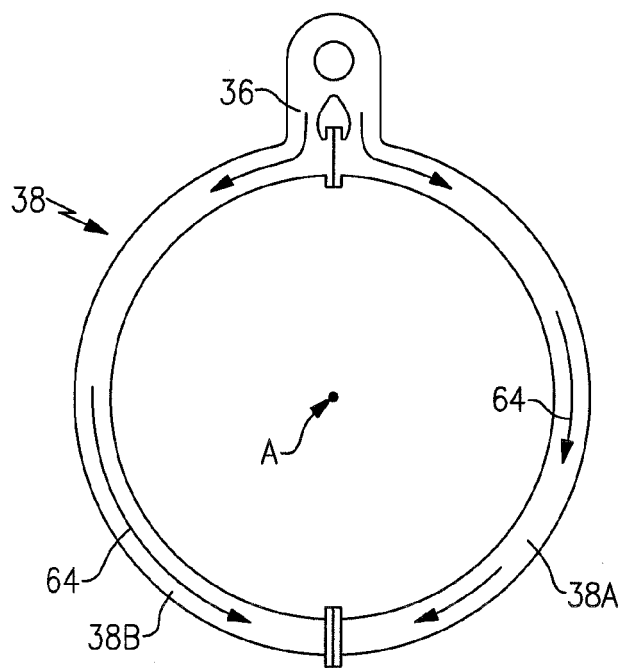


FIG. 6A

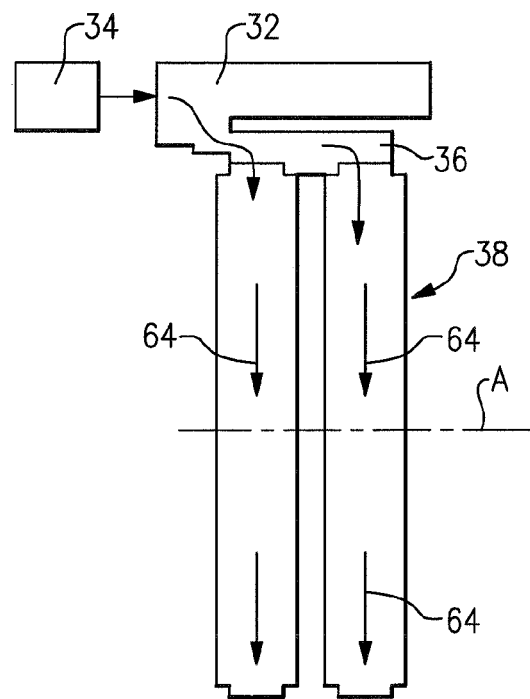


FIG. 6B

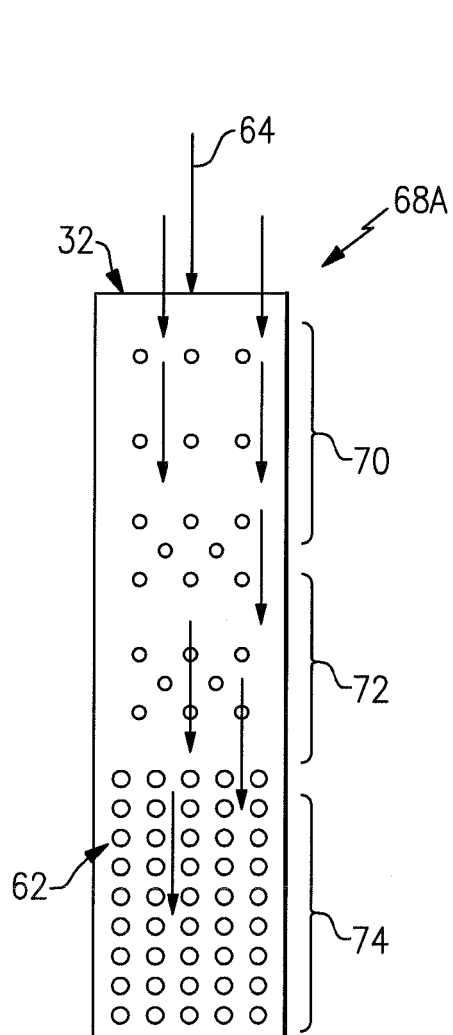


FIG. 7

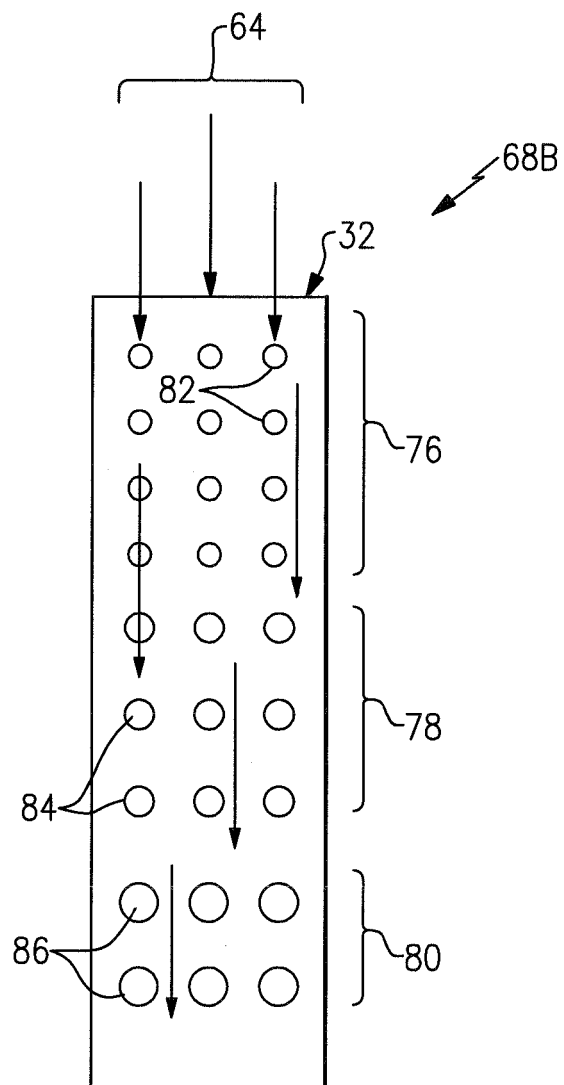


FIG. 8

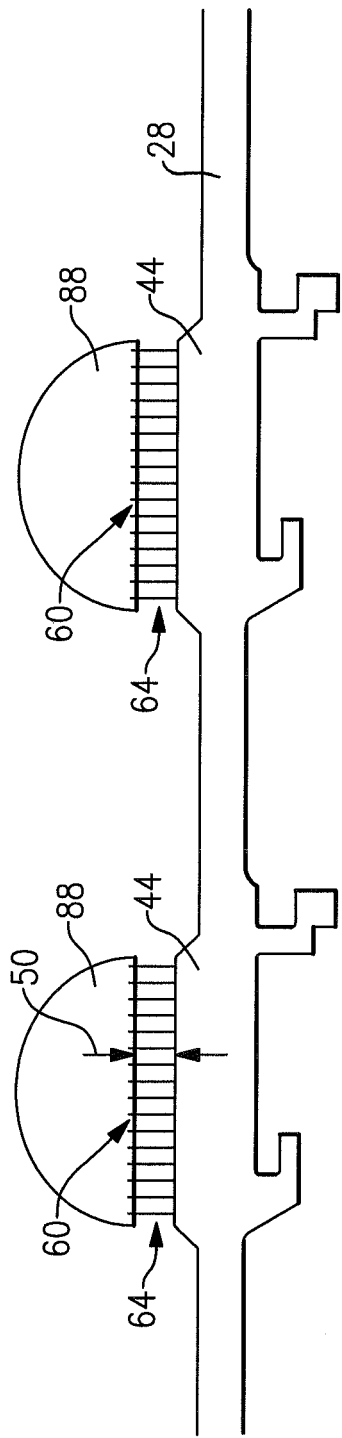


FIG. 9

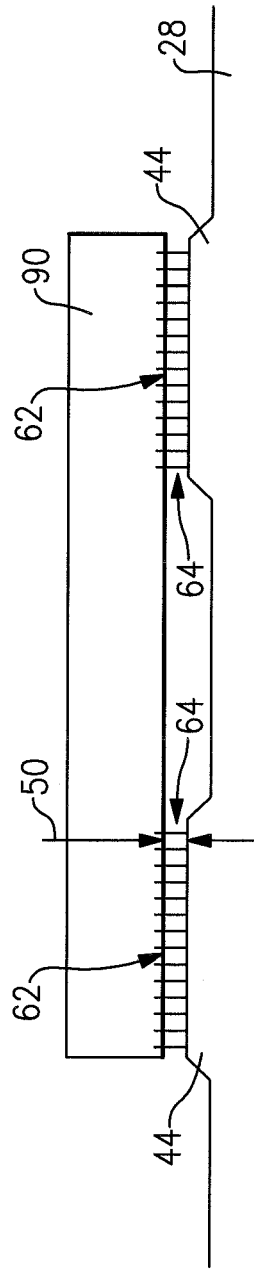


FIG. 10



EUROPEAN SEARCH REPORT

Application Number
EP 12 17 7516

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	US 2009/319150 A1 (PLUNKETT TIMOTHY T [US] ET AL) 24 December 2009 (2009-12-24) * figures 2, 3 * * page 2, paragraph 19 * * page 2, paragraph 21 * -----	1,2,4-15	INV. F01D11/24
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 3 December 2012	Examiner Lutoschkin, Eugen
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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