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(54) **Title**: MULTI-PURPOSE GAS TURBINE SEAL SUPPORT AND ASSEMBLY

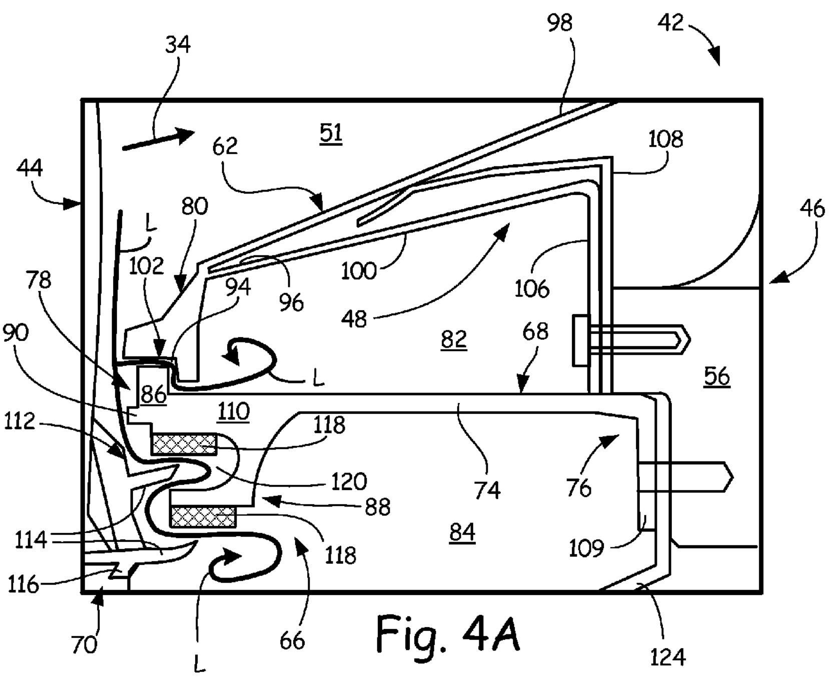

Fig. 4A

(57) **Abstract**: A gas turbine engine assembly includes a first module, a second module rotatable about a center line of the gas turbine engine and fluidly coupled with the first module, and a multi-purpose seal support. The multi-purpose seal support includes an aft end secured to the first module, and a forward end disposed proximate the second module. The forward end has a discourager portion, a seal portion, and a meshing portion.

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MULTI-PURPOSE GAS TURBINE SEAL SUPPORT AND ASSEMBLY

BACKGROUND

The described subject matter relates to gas turbine engines, and more particularly to seals within gas turbine engines.

Gas turbine engines operate according to a continuous-flow, Brayton cycle. A compressor section pressurizes an ambient air stream, fuel is added and the mixture is burned in a central combustor section. The combustion products expand through a turbine section where bladed rotors convert thermal energy from the combustion products into mechanical energy for rotating one or more centrally mounted shafts. The shafts, in turn, drive the forward compressor section, thus continuing the cycle. Gas turbine engines are compact and powerful power plants, making them suitable for powering aircraft, heavy equipment, ships and electrical power generators. In power generating applications, the combustion products can also drive a separate power turbine attached to an electrical generator.

Seals are required in many locations within a gas turbine engine to regulate air flow to various portions of the engine. From time to time these seals may become damaged, fail or provide for inadequate sealing. This can result in the undesirable heating of engine components.

Flow management often requires a seal on one side of the module to prevent the hot air from the flow path entering and heating the steel frame. Furthermore, a seal land is also required nearby to provide sealing between a rotating disk and an adjacent cavity. A structural part is also useful to transfer meshing loads from the rotating disk to the frame in case of shaft failure. All these functional requirements normally would require multiple pieces of hardware with attendant complexity, leakage, and space considerations.

SUMMARY

A gas turbine engine assembly comprises a first module, a second module rotatable about a center line of the gas turbine engine and fluidly coupled with the first module, and a multi-purpose seal support. The multi-purpose seal support includes an aft end secured to the second module, and a forward end disposed proximate the first module. The forward end has a discourager portion, a seal portion, and a meshing portion.

A turbine exhaust case (TEC) assembly comprises a frame, a fairing, and a multi-purpose seal support. The fairing defines a main gas flow passage generally axially

through the frame. The multi-purpose seal support includes an aft end secured to the inner hub. A forward end has a discourager, a seal, and a meshing recess.

A multi-purpose seal support element for a gas turbine engine comprises a ring-shaped body, a flow inhibitor portion, a seal, and a bridging portion. The body includes an axially forward end and an axially aft end. The flow inhibitor portion is formed at the forward end of the body. The seal includes at least one seal land formed proximate the flow inhibitor portion. The bridge portion is disposed proximate the seal and includes at least one U-shaped recess.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically depicts an example gas turbine engine.

FIG. 2 is a detailed view of a turbine assembly portion of the engine shown in FIG. 1.

FIG. 3 isometrically shows a turbine exhaust case with a multi-purpose seal support.

FIG. 4A shows the example seal assembly and multi-purpose seal support depicted in FIG. 2.

FIG. 4B is an isometric view of the region shown in FIG. 4A.

FIG. 5A isometrically shows a first example embodiment of a multi-purpose seal support element.

FIG. 5B is a sectional view of the seal support shown in FIG. 5A.

FIG. 6 is a sectional view of a second example embodiment of a multi-purpose seal support.

DETAILED DESCRIPTION

A multi-purpose seal support element for a turbine exhaust case (TEC) assembly or other gas turbine module can incorporate at least three features or functions which have not previously been combined in a single component. (1) A discourager is positioned adjacent a corresponding recess on the hot gas path wall or fairing to maintain a tortuous path for hot working/combustion ingestion into a cavity defined in part between the fairing and the multi-purpose seal support. (2) A seal portion engages or receives a corresponding seal portion of an adjacent module to prevent leakage of working or combustion gas into an inner cavity. (3) A fail safe meshing portion can be formed between seal lands or incorporated with one or more fishmouth seals to engage a rotor and bridge the upstream module with the TEC assembly in the event of failure. The axially extending portion of the support assembly transfers failure loads axially through the support ring into the TEC frame. A mounting end of the multi-purpose seal support can be fastened directly to the completed TEC assembly or other module. The combination simplifies assembly of the engine, reduces leakage, and improves maintainability.

FIG. 1 shows industrial gas turbine engine 10, one example of a gas turbine engine. Engine 10 is circumferentially disposed about a central, longitudinal axis, or engine centerline axis 12, and includes in series order, low pressure compressor section 16, high pressure compressor section 18, combustor section 20, high pressure turbine section 22, and low pressure turbine section 24. In some examples, a free turbine section 26 is disposed aft of the low pressure turbine 24. Free turbine section 26 is often described as a “power turbine” and may rotationally drive one or more generators, centrifugal pumps, or other apparatus.

As is well known in the art of gas turbines, incoming ambient air 30 becomes pressurized air 32 in compressors 16, 18. Fuel mixes with pressurized air 32 in combustor section 20, where it is burned. Once burned, combustion gases 34 expand through turbine sections 22, 24 and power turbine 26. Turbine sections 22 and 24 drive high and low pressure rotor shafts 36 and 38 respectively, which rotate in response to the combustion products and thus the attached compressor sections 18, 16. Free turbine section 26 may, for example, drive an electrical generator, pump, or gearbox (not shown). Turbine exhaust case (TEC) assembly 42 is also shown in FIG. 1, disposed axially between low pressure turbine section 24 and power turbine 26. TEC assembly 42 is described in more detail below.

FIG. 1 provides a basic understanding and overview of the various sections and the basic operation of an industrial gas turbine engine. Although illustrated with reference to an industrial gas turbine engine, the described subject matter also extends to aero engines having a fan with or without a fan speed reduction gearbox, as well as those engines with more or fewer sections than illustrated. It will become apparent to those skilled in the art that the present application is applicable to all types of gas turbine engines, including those in aerospace applications. In this example, the subject matter is described with respect to TEC assembly 42 between turbine sections 24, 26 configured in a sequential flow arrangement for an industrial gas turbine engine. However, it will be appreciated that the teachings can be readily adapted to other turbine applications with fluidly coupled modules, such as but not limited to a mid-turbine frame, an interstage turbine frame, and/or a turbine exhaust case for an aircraft engine. In other alternative embodiments, TEC assembly 42 can be adapted into a case assembly or module for portions of compressor sections 16 and/or 18.

FIG. 2 shows engine assembly 40, and also includes TEC assembly 42, second module 44, and seal assembly 66 therebetween.

As described above, this illustrative example will be described with reference to turbine exhaust case (TEC) assembly 42 as a first turbine module, but the described subject matter can be readily adapted for several other gas turbine modules. TEC assembly 42 may be interconnected with a second upstream module 44 such as a low-pressure turbine module. TEC assembly 40 may also be connected to a downstream module 45 such as a power turbine module.

As seen in FIG. 2, TEC assembly 42 includes frame 46. Fairing assembly 48 extends generally axially through frame 46 to define main gas flow passage 51 for working/combustion gases 34 to flow during operation. The upstream module (e.g., low-pressure turbine 24 shown in FIG. 1) can include other components such as rotor blade 52 and/or an exit guide vane (not shown). These components are disposed upstream of frame 46 and fairing assembly 48 with respect to a conventional flow direction of working/combustion gases 34 through a conventional industrial gas turbine (IGT) system. The downstream module (e.g., power turbine 26 shown in FIG. 1) can include other components (not shown) such as a stator vane and rotor blade, which are disposed downstream of frame 46 and fairing assembly 48 with respect to the conventional flow direction of working/combustion gases 34.

Frame 46 includes outer case 54, inner hub 56, and a circumferentially distributed plurality of struts 58 (only one shown in FIG. 2) extending radially between outer case 54 and inner hub 56. Second module 44 is connected to first module (e.g., TEC assembly) 42 via fasteners 47 such that modules 42 and 44 abut along outer cases 54 and 55.

In this example, fairing assembly 48 includes outer fairing platform 60, inner fairing platform 62, and strut liners 64. In the embodiment shown, fairing assembly 48 is secured over annular surfaces of frame 46. In this example, fairing assembly 48 is adapted to have outer fairing platform 60 disposed radially inward of outer case 54 while inner fairing platform 62 may be disposed radially outward of inner frame hub 56. Strut liners 64 can also be adapted to be disposed around frame struts 58. Outer fairing platform 60 has a generally conical shape. Similarly, inner fairing platform 62 has a generally conical shape. Inner fairing platform 62 is spaced from outer platform 60 by strut liners 64. When assembled, outer fairing platform 60, inner fairing platform 62, and fairing strut liners 64 define a portion of main gas flow passage 51 for combustion gases 34 to pass through TEC assembly 42 during engine operation.

Main gas flow passage 51 can also be sealed between adjacent gas turbine modules, such as around the edges of fairing assembly 48, to prevent leakage and unwanted heating of frame 46 in TEC assembly 42. In one example, seal assembly 66 is secured to TEC assembly 42 and is adapted to perform multiple sealing and support functions at the interconnection between TEC assembly 42 and second module 44.

Similar to first module / TEC assembly 42, second module 44 includes various components such as rotor blade 52, outer radial case 55, blade platform 57, and rotor disk 70. Blade platform 57 is a rotating component which forms an inner radial edge of main engine gas flow passage 51. Seal assembly 66 is disposed generally radially inward from inner fairing platform 62, and axially between frame inner hub 56 and upstream rotor disk 70. Rotor disk 70 is disposed radially inward of main gas flow passage 51 and interfaces with adjacent portions of assembly 66 and multi-purpose seal support 68. As will be discussed subsequently, multi-purpose seal support 68 includes a discourager portion, a seal portion, and a meshing portion.

FIG. 3 shows an isometric view of turbine exhaust case assembly 42 with multi-purpose seal support 68 secured thereto. TEC assembly 42 includes aft case flange 72A and forward case flange 72B for interconnecting TEC assembly 42 with other modules into engine 10 (shown in FIG. 1). Multi-purpose seal support 68 includes ring shaped body 74 with aft end 76 (shown in FIGS. 4A–4B) secured to a forward facing side of TEC assembly 42, and forward end 78 adjacent to and facing an aft side of upstream module 44 (FIG. 2). As was also shown in FIG. 2, seal assembly 66 can be mounted to a forward recessed portion of inner frame hub 56 (not visible in FIG. 3).

FIG. 4A depicts a detailed sectional view of the area in and around seal assembly 66. FIG. 4B is an isometric view of the area shown in FIG. 4A.

Assembly 66 interacts with forward end 80 of inner fairing platform 62 to minimize leakage from main engine gas flow passage 51. Multi-purpose seal support 68 is disposed between first cavity 82 and second cavity 84. During combustion, seal assembly 66 acts to limit a hot leakage gas flow L from entering first cavity 82 and second cavity 84, either of which would result in excessive heating of frame inner hub 56. Similarly, seal assembly 66 allows for purging of first cavity 82 prior to or during an engine warmup cycle. Assembly 66 can also limit secondary flow between first cavity 82 and second cavity 84. Additionally, assembly 66 limits damage to the engine in case an upstream rotor becomes damaged or loses functionality. Seal assembly 66 can provide all of these functions in a single piece which is more durable and cost effective than other solutions known in the art.

Multi-purpose seal support forward end 78 generally includes discourager portion 86, seal portions 88, and meshing portion 90. Discourager portion 86 can be a flow inhibiting flange or other structure adapted to engage with recess 94 formed in a surface of inner fairing platform 62. This has the effect of preventing ingestion into cavity 82. Here, recess 94 is machined out of fairing Y-junction 96, which connects fairing platform wall 98 and fairing wall 100. This allows for thermal growth and contraction of fairing assembly 48, with a thermal barrier between fairing platform wall 98 and frame inner hub 56. Discourager gap 102, which can include axial gap 104A and radial gap 104R, is defined between inner fairing platform 62 and seal support discourager portion 80. First (seal support) cavity 82 can be defined annularly by Y-junction 96, fairing mounting wall 100, fairing mounting flange 106, and seal support element body 74. Second (rotor) cavity 84 can be defined radially inward of multi-purpose seal support 68. Fairing mounting flange 106 can also serve as a backing ring for heat shield segment 108 which operates as a thermal radiation barrier for fairing mounting wall 100 and fairing mounting flange 106.

Fairing assembly 48 thermally expands and contracts based on engine operating conditions. Thus dimensions of discourager gap 102 range between a first low temperature state in which discourager portion 86 is spaced apart from Y-junction 96, and a second heated state in which discourager portion 86 closely engages or briefly contacts Y-junction 96 of inner fairing platform 62. When closely engaged, leakage flow L must pass through a tortuous path and change directions to reach cavity 82. Dimensions of gap 102 are enlarged because fairing assembly 48 shrinks or contracts toward frame 46. This allows for purging of first seal support cavity 96 when working gases 34 are at an engine idle or cold soak temperature. As the engine approaches full operating temperature, fairing assembly 48 thermally expands such that the dimensions of axial and/or radial gaps 104A, 104R are reduced, forming an effective discourager seal between inner fairing platform 62 and seal support discourager portion 86 to minimize leakage flow L into first cavity 82.

Seal portion 88 of multi-purpose seal support 68 includes at least one axially projecting seal land 110 disposed adjacent to a corresponding seal portion 112 on upstream module 44. Abradable seal pads 118 are secured to each seal land 110 to form a labyrinth seal between main gas flow passage 51 and second (rotor) cavity 84. In the illustrated example, two abradable seal pads 118 each receive knife edges 114, which can be formed on an aft side of upstream rotor disk 70 (e.g., mini-disk 116). A generally U-shaped recess 120 is also formed between adjacent seal lands 110. In alternative embodiments, seal land(s) 110 can be adapted to create an additional or alternative type of seal. For example, FIG. 6 shows a receiving portion of a fishmouth seal in place of the labyrinth seal lands shown in FIGS. 2–4B.

Seal assembly 68 also can include a meshing feature for use as a failsafe feature in the event of an upstream rotor failure. In this example, multi-purpose seal support 68 includes meshing portion 90 in which axial loads from a failure of rotor disk 70 can be transmitted into and through multi-purpose seal support 68. Here, example meshing portion 90 consists of projection 92 with a forward-most surface distal from TEC assembly 42 and facing rotor disk 70. In ordinary operation, projection 92 is spaced axially apart from the first module and from rotor disk 70 as shown. In the event that one or more portions of upstream module 44 (e.g., rotor disk 70) fails, rotor disk 70 will move aftward into, and contact meshing portion 90. This has the effect of bridging rotor disk 70 and TEC assembly 42 so that axial and rotational forces of rotor disk 70 are transmitted into seal support body 74. In turn, forces are absorbed by frame inner hub 56 by way of aft seal support flange 109. In certain embodiments, flow divider ring 124 can be secured between aft seal support flange 109 and frame inner hub 56. Flow divider ring 124 partially defines a boundary for a frame cooling air passage (not shown).

FIG. 5A and 5B show multi-purpose seal support 68 independent of modules 42, 44. As was shown in FIGS. 4A–4B, multi-purpose seal support 68 includes ring-shaped body 74 extending axially between aft portion 76 and forward portion 78. Aft portion 76 includes aft seal support flange 109, which can be used to fasten multi-purpose seal support 68 to a turbine module (e.g., TEC assembly 42 shown in FIG. 2). Forward portion 78 includes three features integrated into one. Discourager portion 86 adapted to engage with a fairing assembly of a gas turbine engine. Discourager portion 86, for example, can comprise radial projection 130 and axial projection 132, or another shape adapted to engage with a corresponding portion of the fairing assembly. As shown in FIGS. 4A and 4B, a fairing assembly undergoes thermal growth and shrinkage depending on the operational state of the engine. Here, ring-shaped body 74 is sized so that axial projection 130 and radial projection 132 are disposed forward of the forward end of the fairing platform. This creates axial and radial discourager gaps 104A, 104R (shown in

FIGS. 4A and 4B) so that an effective seal can formed with a fairing Y-junction to prevent leakage flow out of the main working gas flow passage and into a cavity disposed radially outward of multi-purpose seal support 68.

At least one seal land 110 is also incorporated into seal support forward end 78 for engaging a corresponding seal portion of an adjacent rotating gas turbine module. In the example of FIGS. 4A–4B, seal lands 110 may be adapted to receive knife edges formed on a rotor disk, or knife edges formed on a separate rotor attachment such as a mini-disk secured to an aft side of the main rotor disk. Each seal land 110 can have at least one abradable seal pad 118. Forward contact face on seal support body 74 can serve as a meshing portion 90 to contact a face of rotor disk 70 in the event of a rotor failure.

FIG. 6 shows a cross-section of an alternative multi-purpose seal support 168. Multi-purpose seal support 168 operates similarly to multi-purpose seal support 68 shown in FIGS. 2–5. Discourager portion 186 is adapted to define a gap between seal support forward end 178 and a corresponding portion of fairing assembly 148 (shown in phantom). Projection 192 forms a first meshing portion similar to meshing portion 90 shown above. However, seal lands 110 and abradable pads 118 (in FIGS. 2–5) have been replaced with fish mouth recesses 210. Fish mouth recesses 210A, 210B each receive respective legs 214A, 214B (also shown in phantom) projecting from an upstream module (e.g., upstream rotor disk or mini-disk). In this example, in addition to fish mouth recess 210A and optional recess 210B operating as a sealing portion 188, there can be a second meshing portion 190. In the event of failure of the upstream module, one or both legs 214A, 214B would contact the surfaces of respective recesses 210A, 210B to transfer additional meshing loads through body 174 to aft support flange 209.

Multi-purpose seal support 68 and 168 allow three important functions of a gas turbine engine to be incorporated into a relatively small space. The meshing feature can be incorporated adjacent to the sealing portion so that a knife edge, fishmouth leg or other seal projection on the rotor can create a failsafe bridging relationship proximate the seal lands. The forward end of the seal support is also in close proximity to fairings defining the main gas flow passage. Thus a discourager such as a flow inhibiting flange or other projection can be located proximate the sealing and meshing portions.

In addition, multi-purpose seal supports 68,168 are also easily manufacturable and replaceable. They can be mounted directly to a completed gas turbine module (e.g., a turbine exhaust case), simplifying assembly and maintenance of the engine. For example, if one of the features fails or reaches the end of its useful life, a new multi-purpose seal support can be quickly removed and replaced during any maintenance activity requiring separation of the two adjacent modules.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS:

1. An assembly for a gas turbine engine, comprising:

a first module;

a second module rotatable about a center line of the gas turbine engine and fluidly coupled with the first module; and

a multi-purpose seal support including an aft end secured to the first module, and a forward end disposed proximate the second module, the forward end having a discourager portion, a seal portion, and a meshing portion.

2. The assembly of claim 1, wherein the discourager portion engages a recess formed in an outer surface of a fairing defining a main gas flow passage extending generally axially through the first module.

3. The assembly of claim 2, wherein the discourager portion is spaced apart from the recess to define a discourager gap therebetween, and wherein dimensions of the discourager gap range between a first temperature state in which the discourager portion is spaced apart from the fairing, and a second temperature state in which the discourager portion closely engages the fairing to form a discourager seal.

4. The assembly of claim 1, wherein the seal portion of the multi-purpose seal support includes at least one labyrinth seal land disposed axially adjacent to a corresponding knife edge of the second module.

5. The assembly of claim 1, wherein the seal portion of the multi-purpose seal support includes at least one fishmouth seal recess receiving a corresponding leg of the second module.

6. The assembly of claim 1, further comprising a U-shaped recess formed between two adjacent seal lands of the first module.

7. The assembly of claim 1, wherein the first module comprises a turbine exhaust case, and the second module comprises a turbine rotor module.

8. The assembly of claim 7, wherein the turbine exhaust case is fluidly coupled with a power turbine assembly.

9. A turbine exhaust case (TEC) assembly comprising:

a frame including an outer case, an inner hub, and a circumferentially distributed plurality of struts extending radially between the outer case and the inner hub;

a fairing defining a main gas flow passage generally axially through the frame; and a multi-purpose seal support including an aft end secured to the inner hub, and a forward end having a discourager, a seal, and a meshing projection.

10. The TEC assembly of claim 9, wherein the discourager portion engages a recess formed into a Y-junction disposed on a forward side of the fairing.

11. The TEC assembly of claim 10, wherein the discourager portion is spaced apart from the recess to define a discourager gap therebetween, and wherein dimensions of the discourager gap range between a first state in which the discourager portion is spaced apart from the fairing, and a second state in which the discourager portion closely engages the fairing to form a discourager seal.

12. The TEC assembly of claim 9, wherein the seal portion of the multi-purpose seal support element includes at least one seal land.

13. The TEC assembly of claim 12, wherein the at least one seal land comprises an abradable pad.

14. The TEC assembly of claim 12, wherein the at least one seal land is a recess adapted to receive a corresponding leg for a fishmouth seal.

15. The TEC assembly of claim 9, wherein the meshing projection includes a forward-most surface distal from the remainder of the TEC assembly.

16. A multi-purpose seal support for a gas turbine engine, the assembly comprising:

a ring-shaped body including a axially forward end and an axially aft end;

a flow inhibitor formed at the forward end of the body;

a seal including at least one seal land formed proximate the flow inhibitor portion; and

a bridge portion disposed proximate the seal, the bridge portion including a projection extending distally from the axially aft end.

17. The multi-purpose seal support element of claim 16, wherein the discourager portion has both an axial projection and a radial projection.

18. The multi-purpose seal support element of claim 16, wherein the at least one seal land comprises an abradable seal pad.

19. The multi-purpose seal support element of claim 16, wherein the at least one seal land comprises a recess adapted to receive a corresponding leg for a fishmouth seal.

20. The multi-purpose seal support element of claim 16, further comprising a mounting flange at the aft end of the support ring for securing the seal support element to a stationary gas turbine module.

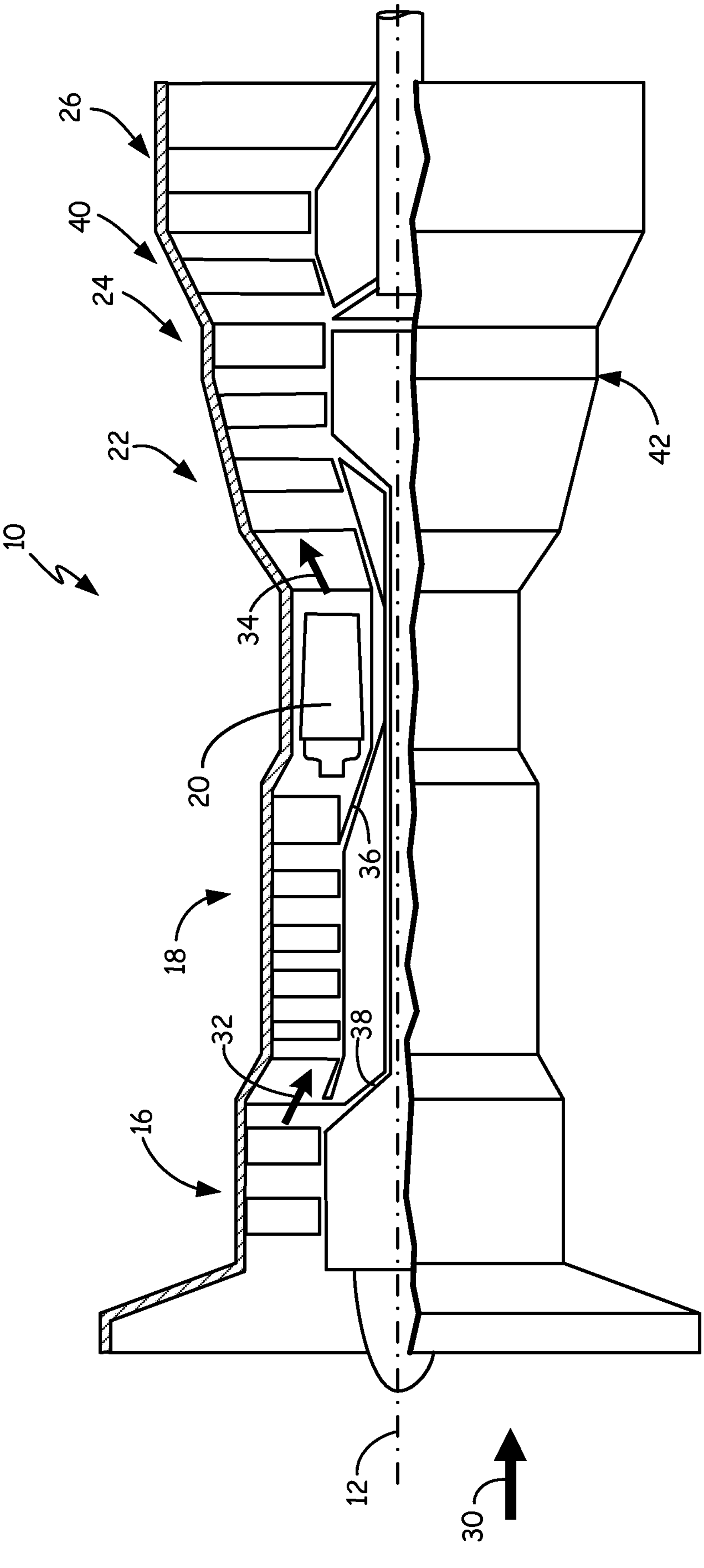

Fig. 1

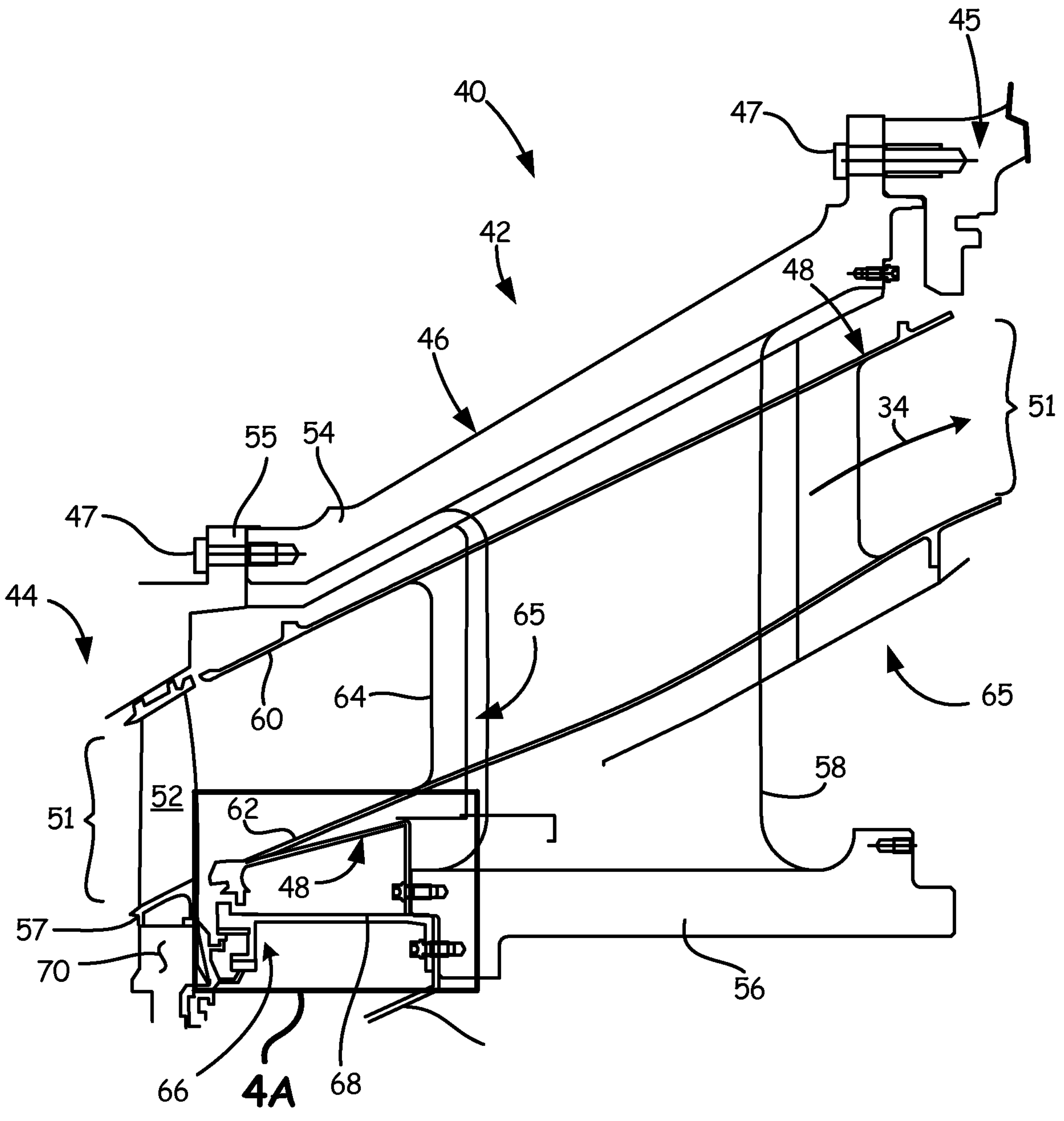
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Fig. 2

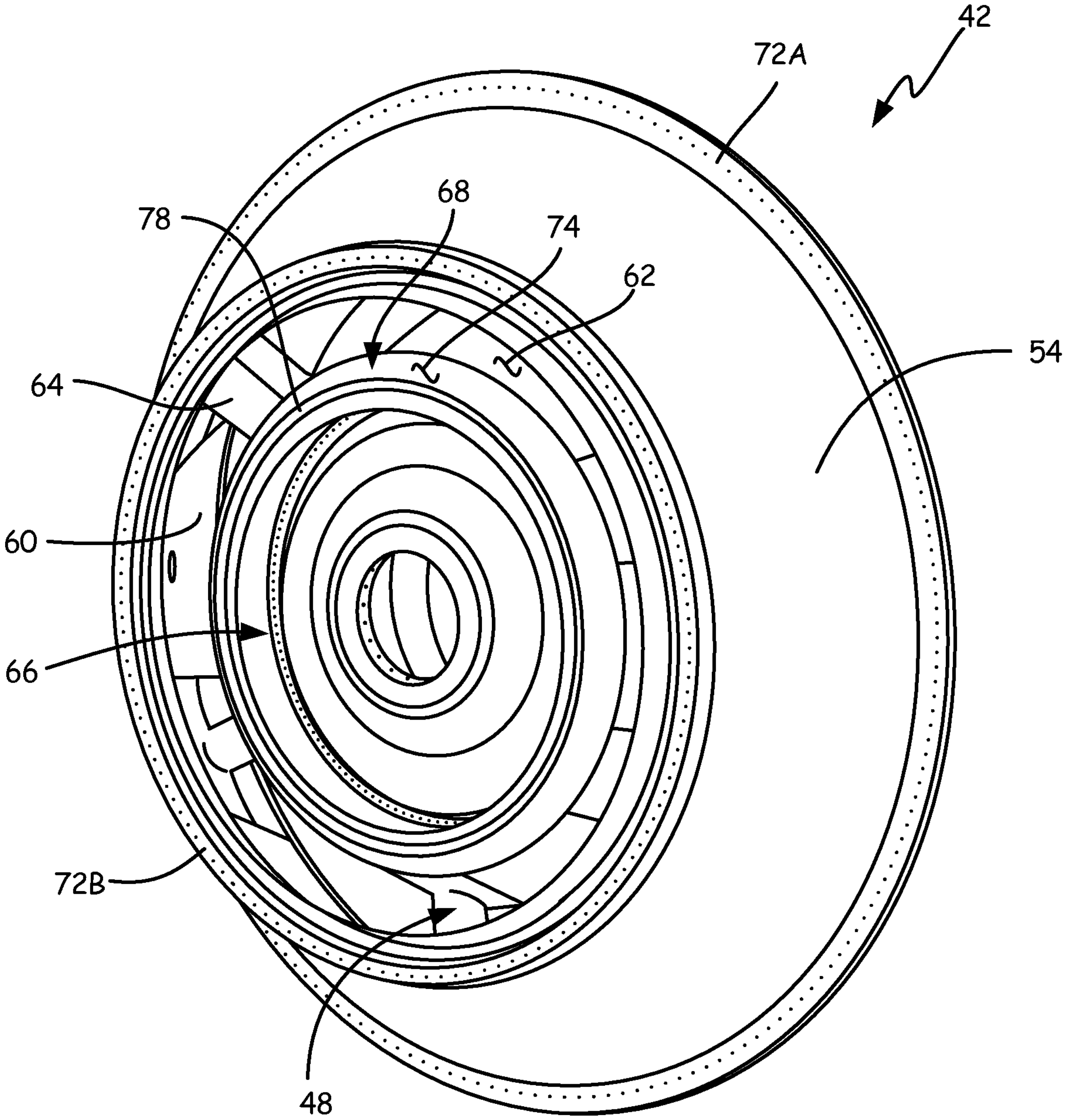

Fig. 3

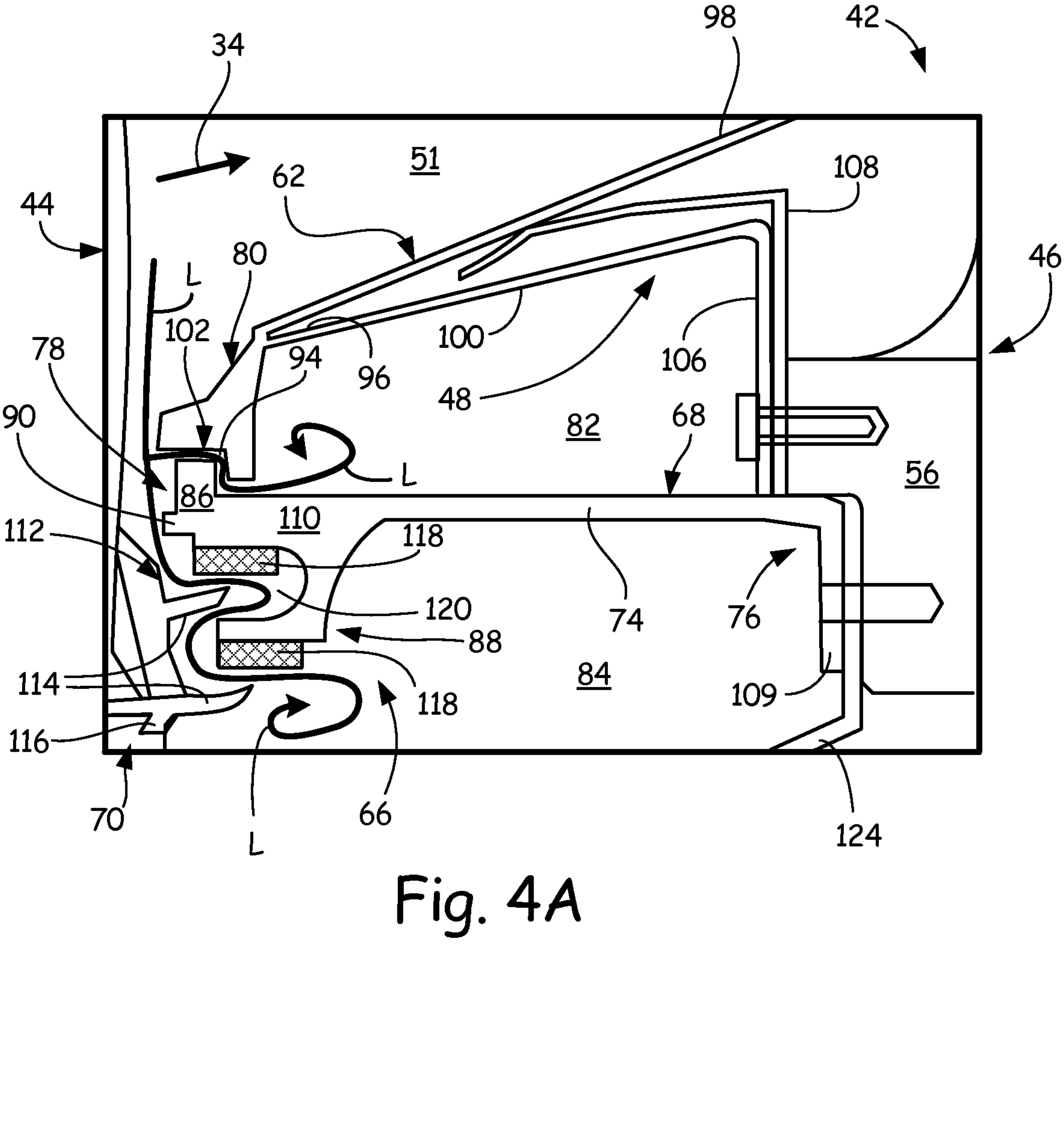
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Fig. 4A

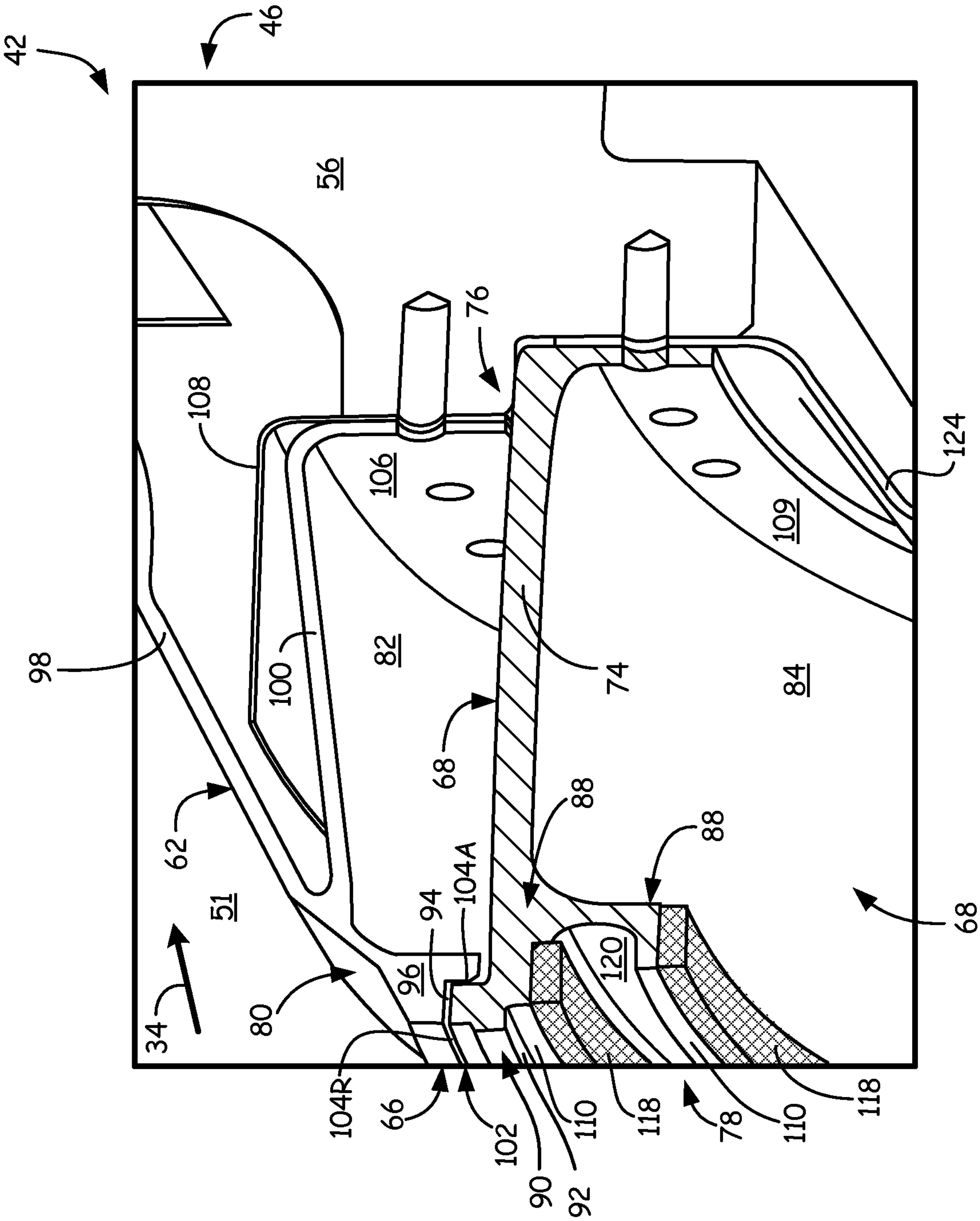
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Fig. 4B

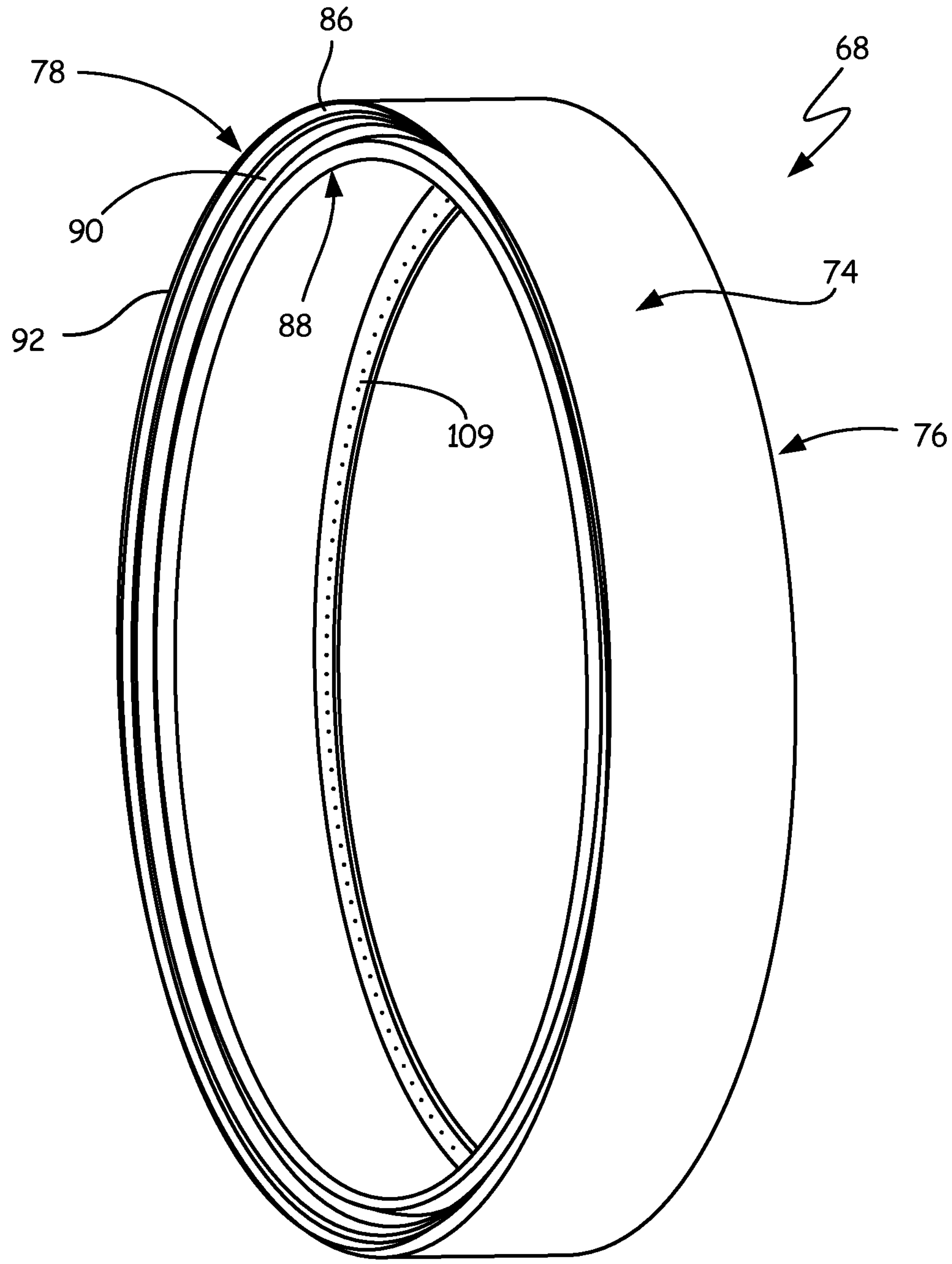
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Fig. 5A

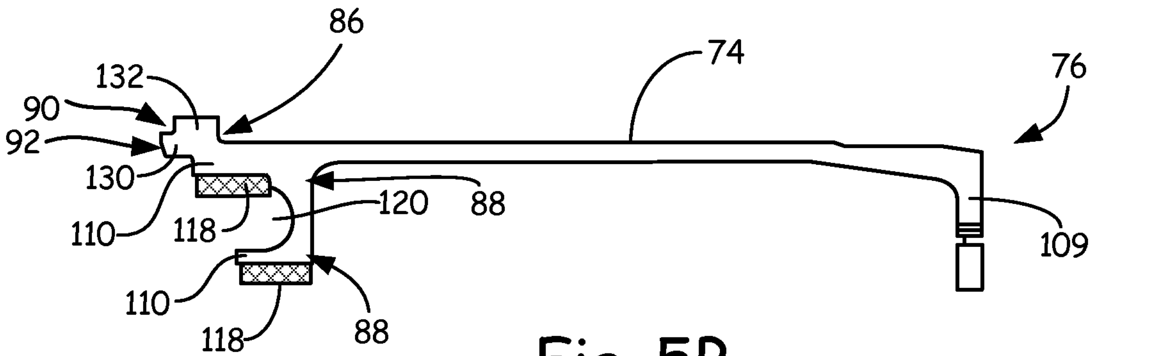
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Fig. 5B

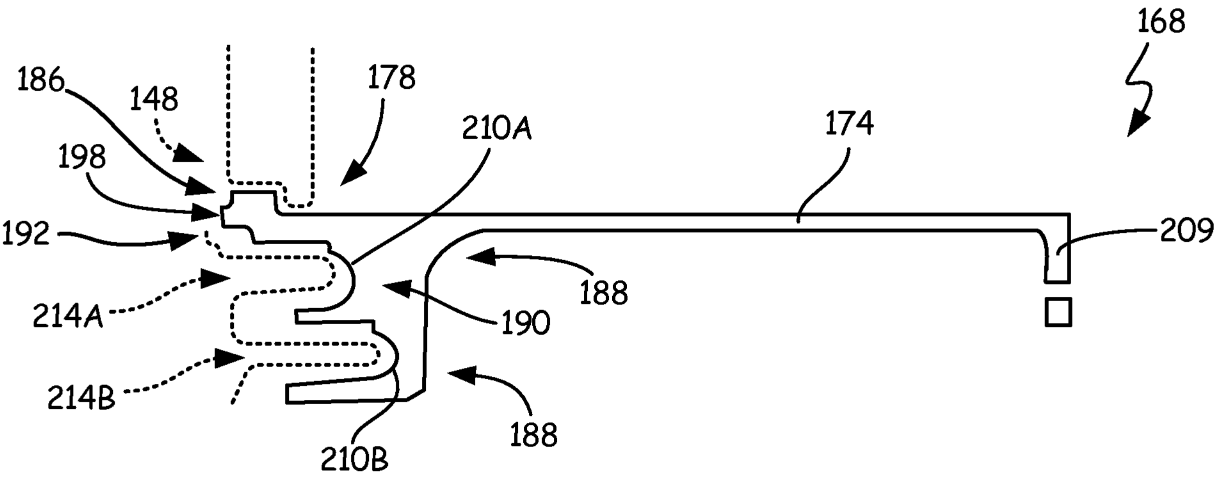

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/077397

A. CLASSIFICATION OF SUBJECT MATTER

F01D 11/02(2006.01)i, F01D 25/24(2006.01)i, F02C 7/28(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D 11/02; F01D 25/16; F02C 7/28; F16J 15/447; F01D 11/08; F01D 5/00; F01D 25/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: gas turbine, seal, discourager, land, mesh, case, module, turbine exhaust case, and fairing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2011-0081237 A1 (DUROCHER et al.) 07 April 2011 See abstract; paragraphs [0020],[0021],[0030],[0038]; claim 10; and figures 2,6,9.	1-8,16-20 9-15
Y	US 6062813 A (HALLIWELL et al.) 16 May 2000 See abstract; column 5, lines 22-27, lines 59-63; and figure 2.	1-8,16-20
A	US 2009-0142182 A1 (KAPUSTKA, THEODORE W.) 04 June 2009 See abstract; paragraphs [0025],[0028]; and figure 2.	1-20
A	US 2004-0213666 A1 (GIEG et al.) 28 October 2004 See abstract; paragraph [0014]; claim 9; and figure.	1-20
A	US 2012-0017594 A1 (KOWALSKI et al.) 26 January 2012 See abstract; paragraph [0014]; claim 1; and figures 2,3,4A.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 April 2014 (09.04.2014)	**14 April 2014 (14.04.2014)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/077397

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0081237 A1	07/04/2011	CA 2715227 A1	01/04/2011
		US 8500392 B2	06/08/2013
US 6062813 A	16/05/2000	None	
US 2009-0142182 A1	04/06/2009	US 8215901 B2	10/07/2012
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		DE 50209543 D1	05/04/2007
		EP 1389265 A1	18/02/2004
		EP 1389265 B1	21/02/2007
		US 6966752 B2	22/11/2005
		WO 02-090724 A1	14/11/2002
US 2012-0017594 A1	26/01/2012	EP 2596215 A1	29/05/2013
		WO 2012-012330 A1	26/01/2012