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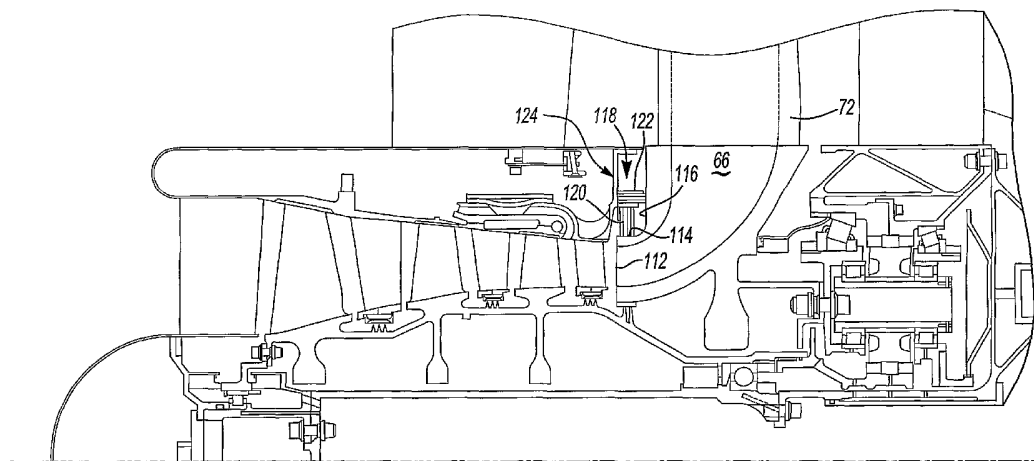
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(54) Title: SEAL ASSEMBLY FOR A FAN ROTOR OF A TIP TURBINE ENGINE



(57) Abstract: A seal assembly (118) mounted within a nonrotatable static inner support structure (16) for engagement with an axial seal face surface (114) and a radial seal face surface (116). The radial seal (120) engages the axial seal face surface and the axial seal (122) engages the radial seal face surface. The seal assembly provides minimal leakage of core airflow to increase the tip turbine engine operating efficiency.

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## SEAL ASSEMBLY FOR A FAN ROTOR OF A TIP TURBINE ENGINE

### BACKGROUND OF THE INVENTION

This invention was made with government support under Contract No.:  
5 F33657-03-C-2044. The government therefore has certain rights in this invention.

The present invention relates to a tip turbine engine, and more particularly to a fan-turbine rotor assembly which provides mechanical retention between a multitude of intricate rotational components.

An aircraft gas turbine engine of the conventional turbofan type generally  
10 includes a forward bypass fan, a compressor, a combustor, and an aft turbine all located along a common longitudinal axis. A compressor and a turbine of the engine are interconnected by a shaft. The compressor is rotatably driven to compress air entering the combustor to a relatively high pressure. This pressurized air is then mixed with fuel in a combustor and ignited to form a high energy gas stream. The  
15 gas stream flows axially aft to rotatably drive the turbine which rotatably drives the compressor through the shaft. The gas stream is also responsible for rotating the bypass fan. In some instances, there are multiple shafts or spools. In such instances, there is a separate turbine connected to a separate corresponding compressor through each shaft. In most instances, the lowest pressure turbine will drive the bypass fan.

20 Although highly efficient, conventional turbofan engines operate in an axial flow relationship. The axial flow relationship results in a relatively complicated elongated engine structure of considerable longitudinal length relative to the engine diameter. This elongated shape may complicate or prevent packaging of the engine into particular applications.

25 A recent development in gas turbine engines is the tip turbine engine. Tip turbine engines locate an axial compressor forward of a bypass fan which includes hollow fan blades that receive airflow from the axial compressor therethrough such that the hollow fan blades operate as a centrifugal compressor. Compressed core airflow from the hollow fan blades is mixed with fuel in an annular combustor and  
30 ignited to form a high energy gas stream which drives the turbine integrated onto the tips of the hollow bypass fan blades for rotation therewith as generally disclosed in

U.S. Patent Application Publication Nos.: **20030192303**; **20030192304**; and **20040025490**.

5 The tip turbine engine provides a thrust to weight ratio equivalent to conventional turbofan engines of the same class within a package of significantly shorter longitudinal length.

One significant rotational component of a tip turbine engine is the fan-turbine rotor assembly. The fan-turbine rotor assembly includes intricate components, which rotate at relatively high speeds to generate bypass airflow while communicating a core airflow through each of the multitude of hollow fan blades.  
10 Sealing of the communication path between the upstream axial compressor and the inducer section of the multitude of hollow fan blades presents design challenges due in part to the relatively large fan-turbine rotor assembly diameter.

Accordingly, it is desirable to provide a seal assembly which provides effective sealing between the axial compressor and the inducer to the fan-turbine  
15 rotor assembly.

### SUMMARY OF THE INVENTION

The fan-turbine rotor assembly for a tip turbine engine according to the present invention includes an inducer section in communication with a core airflow  
20 passage through the rotating fan blades. The inducer section includes an inducer inlet which defines an annular axial seal face surface and an annular radial seal face surface.

A seal assembly is mounted to a nonrotatable static inner support structure for engagement with the annular axial seal face surface and an annular radial seal  
25 face surface. The radial seal engages the annular axial seal face surface and the axial seal engages the annular radial seal face surface.

The present invention therefore provides a seal assembly which provides effective sealing between the axial compressor and the inducer to the fan-turbine rotor assembly.

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## BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

Figure 1 is a partial sectional perspective view of a tip turbine engine;

Figure 2 is a longitudinal sectional view of a tip turbine engine along an engine centerline;

Figure 3 is a partial perspective view of a fan-turbine rotor assembly;

Figure 4 is an expanded view of the seal assembly for the fan-turbine rotor assembly of Figure 2; and

Figure 5 is a schematic sectional view illustrating a seal assembly which seals a core airflow leakage path.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a general perspective partial sectional view of a tip turbine engine type gas turbine engine 10. The engine 10 includes an outer nacelle 12, a nonrotatable static outer support structure 14 and a nonrotatable static inner support structure 16. A multitude of fan inlet guide vanes 18 are mounted between the static outer support structure 14 and the static inner support structure 16. Each inlet guide vane preferably includes a variable trailing edge 18A.

A nose cone 20 is preferably located along the engine centerline A to smoothly direct airflow into an axial compressor 22 adjacent thereto. The axial compressor 22 is mounted about the engine centerline A behind the nose cone 20.

A fan-turbine rotor assembly 24 is mounted for rotation about the engine centerline A aft of the axial compressor 22. The fan-turbine rotor assembly 24 includes a multitude of hollow fan blades 28 to provide internal, centrifugal compression of the compressed airflow from the axial compressor 22 for distribution to an annular combustor 30 located within the nonrotatable static outer support structure 14.

A turbine 32 includes a multitude of tip turbine blades 34 (two stages shown), which rotatably drive the hollow fan blades 28 relative to a multitude of tip

turbine stators 36 which extend radially inwardly from the static outer support structure 14. The annular combustor 30 is axially forward of the turbine 32 and communicates with the turbine 32.

Referring to Figure 2, the nonrotatable static inner support structure 16 includes a splitter 40, a static inner support housing 42 and a static outer support housing 44 located coaxial to said engine centerline A.

The axial compressor 22 includes the axial compressor rotor 46 from which a plurality of compressor blades 52 extend radially outwardly and a compressor case 50 fixedly mounted to the splitter 40. A plurality of compressor vanes 54 extend radially inwardly from the compressor case 50 between stages of the compressor blades 52. The compressor blades 52 and compressor vanes 54 are arranged circumferentially about the axial compressor rotor 46 in stages (three stages of compressor blades 52 and compressor vanes 54 are shown in this example). The axial compressor rotor 46 is mounted for rotation upon the static inner support housing 42 through a forward bearing assembly 68 and an aft bearing assembly 62.

The fan-turbine rotor assembly 24 includes a fan hub 64 that supports a multitude of the hollow fan blades 28. Each fan blade 28 includes an inducer section 66, a hollow fan blade section 72 and a diffuser section 74. The inducer section 66 receives airflow from the axial compressor 22 generally parallel to the engine centerline A and turns the airflow from an axial airflow direction toward a radial airflow direction. The airflow is radially communicated through a core airflow passage 80 within the fan blade section 72 where the airflow is centrifugally compressed. From the core airflow passage 80, the airflow is turned and diffused toward an axial airflow direction toward the annular combustor 30. Preferably the airflow is diffused axially forward in the engine 10, however, the airflow may alternatively be communicated in another direction.

A gearbox assembly 90 aft of the fan-turbine rotor assembly 24 provides a speed increase between the fan-turbine rotor assembly 24 and the axial compressor 22. Alternatively, the gearbox assembly 90 could provide a speed decrease between the fan-turbine rotor assembly 24 and the axial compressor rotor 46. The gearbox assembly 90 is mounted for rotation between the static inner support housing 42 and the static outer support housing 44. The gearbox assembly 90 includes a sun gear

shaft 92 which rotates with the axial compressor 22 and a planet carrier 94 which rotates with the fan-turbine rotor assembly 24 to provide a speed differential therebetween. The gearbox assembly 90 is preferably a planetary gearbox that provides co-rotating or counter-rotating rotational engagement between the fan-turbine rotor assembly 24 and an axial compressor rotor 46. The gearbox assembly 90 is mounted for rotation between the sun gear shaft 92 and the static outer support housing 44 through a forward bearing 96 and a rear bearing 98. The forward bearing 96 and the rear bearing 98 are both tapered roller bearings and both handle radial loads. The forward bearing 96 handles the aft axial loads while the rear bearing 98 handles the forward axial loads. The sun gear shaft 92 is rotationally engaged with the axial compressor rotor 46 at a splined interconnection 100 or the like.

In operation, air enters the axial compressor 22, where it is compressed by the three stages of the compressor blades 52 and compressor vanes 54. The compressed air from the axial compressor 22 enters the inducer section 66 in a direction generally parallel to the engine centerline A and is turned by the inducer section 66 radially outwardly through the core airflow passage 80 of the hollow fan blades 28. The airflow is further compressed centrifugally in the core airflow passage 80 of the hollow fan blades 28 by rotation of the hollow fan blades 28. From the core airflow passage 80, the airflow is turned and diffused by the diffuser section 74 axially forward in the engine 10 into the annular combustor 30. The compressed core airflow from the hollow fan blades 28 is mixed with fuel in the annular combustor 30 and ignited to form a high-energy gas stream. The high-energy gas stream is expanded over the multitude of tip turbine blades 34 mounted about the outer periphery of the fan blades 28 to drive the fan-turbine rotor assembly 24, which in turn drives the axial compressor 22 through the gearbox assembly 90. Concurrent therewith, the fan-turbine rotor assembly 24 discharges fan bypass air axially aft to merge with the core airflow from the turbine 32 in an exhaust case 106. A multitude of exit guide vanes 108 are located between the static outer support housing 44 and the nonrotatable static outer support structure 14 to guide the combined airflow out of the engine 10 to provide forward thrust. An exhaust mixer

110 mixes the airflow from the turbine blades 34 with the bypass airflow through the fan blades 28.

The inducer section 66 of each fan blade 28 is mounted for rotation about the engine centerline A. The inducer section generally includes an inducer inlet 112 which defines an annular axial seal face surface 114 and an annular radial seal face surface 116 (also illustrated in Figure 3). That is, the inducer inlet 112 defines a contoured generally J-shaped intake which communicates with the core airflow passage 80 of the fan blade section 72.

A seal assembly 118 is mounted within the nonrotatable static inner support structure 16 for engagement with the annular axial seal face surface 114 and the annular radial seal face surface 116. The seal assembly 118 includes a radially oriented seal 120 and an axially oriented seal 122. A seal mount surface 124 extends axially from the nonrotatable static outer support structure 14 downstream of the axial compressor 22 to support the radial oriented seal 120 and the axial oriented seal 122. The radial oriented seal 120 engages the annular axial seal face surface 114 and the axial seal 122 engages the annular radial seal face surface 116 (also illustrated in Figure 4).

Preferably, the radial oriented seal 120 and the axial oriented seal 122 are brush seals. It should be understood that other seals will also be utilized by the present invention.

Referring to Figure 5, the seal assembly 118 location minimizes leakage potential for core airflow when the axial compressor airflow is communicated into the inducer inlet 112. Minimization of core airflow leakage increases the engine operating efficiency.

It should be understood that relative positional terms such as "forward," "aft," "upper," "lower," "above," "below," and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain

modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.



## CLAIMS

1. A fan assembly for a tip turbine engine comprising:  
a fan hub which rotates about an axis;  
5 an inducer section mounted to said fan hub, said inducer section defining an airflow passage which turns an airflow from an axial airflow direction to a radial airflow direction;  
a fan blade section mounted to the inducer section, the fan blade section defining a fan blade core airflow passage generally perpendicular to the axis; and  
10 a seal assembly between a nonrotatable support structure and said inducer section.
2. The fan assembly as recited in claim 1, wherein said seal assembly includes a brush seal.
- 15 3. The fan assembly as recited in claim 1, wherein said seal assembly includes a radially oriented seal and an axially oriented seal.
4. The fan assembly as recited in claim 3, wherein said inducer includes an axial inducer face and a radial inducer face, said axial inducer face engageable with  
20 said radial oriented seal and said radial inducer face engageable with said axial oriented seal.
5. The fan assembly as recited in claim 1, wherein said seal assembly includes  
25 an annular radial oriented brush seal and an annular axial oriented brush seal.
6. The fan assembly as recited in claim 5, wherein said inducer includes an axial seal face surface and a radial seal face surface, said axial seal face surface engageable with said radial oriented brush seal and said radial seal face surface  
30 engageable with said axial oriented brush seal.

7. A tip turbine engine comprising:  
a nonrotatable support structure mounted about an engine centerline;  
a gearbox mounted adjacent said nonrotatable support structure, said gearbox including a planet carrier rotatable about said engine centerline; and  
5 a fan hub mounted to said planet carrier for rotation therewith;  
an inducer section mounted to said fan hub, said inducer section having an axial seal face surface and a radial seal face surface which define an airflow passage which turns an airflow from an axial airflow direction to a radial airflow direction;  
a fan blade section mounted to the inducer section, the fan blade section  
10 defining a fan blade core airflow passage generally perpendicular to the axis; and  
a seal assembly mounted to said nonrotatable support structure, said seal assembly including a radial oriented seal and an axial oriented seal, said axial seal face surface engageable with said radial oriented seal and said radial seal face surface engageable with said axial oriented seal.
- 15 8. The tip turbine engine as recited in claim 7, wherein said nonrotatable support structure includes an inner static support housing and an outer static support housing located coaxial to said engine centerline.
- 20 9. The tip turbine engine as recited in claim 7, wherein said gearbox is mounted between said inner static support housing and said outer static support housing.
10. The tip turbine engine as recited in claim 9, further comprising a thrust bearing between said outer static support housing and said planet carrier.
- 25 11. The tip turbine engine as recited in claim 9, further comprising a radial bearing between said inner static support structure and a sun gear shaft.
12. The tip turbine engine as recited in claim 11, further comprising an axial  
30 compressor rotor mounted for rotation with said sun gear shaft about said engine centerline, said axial compressor upstream of said fan hub.

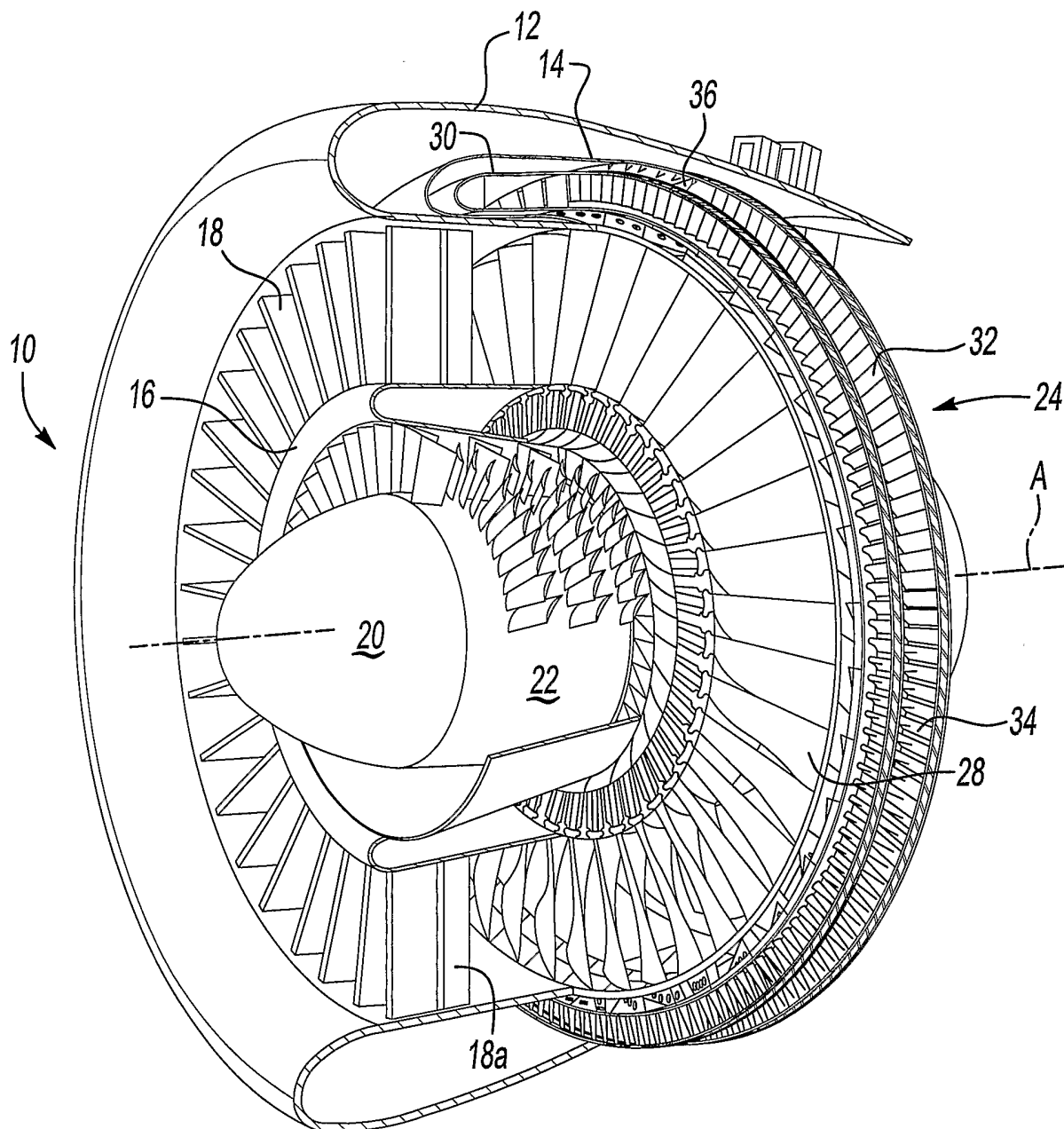
13. The tip turbine engine as recited in claim 12, wherein said nonrotatable support structure includes an axial compressor stator assembly.

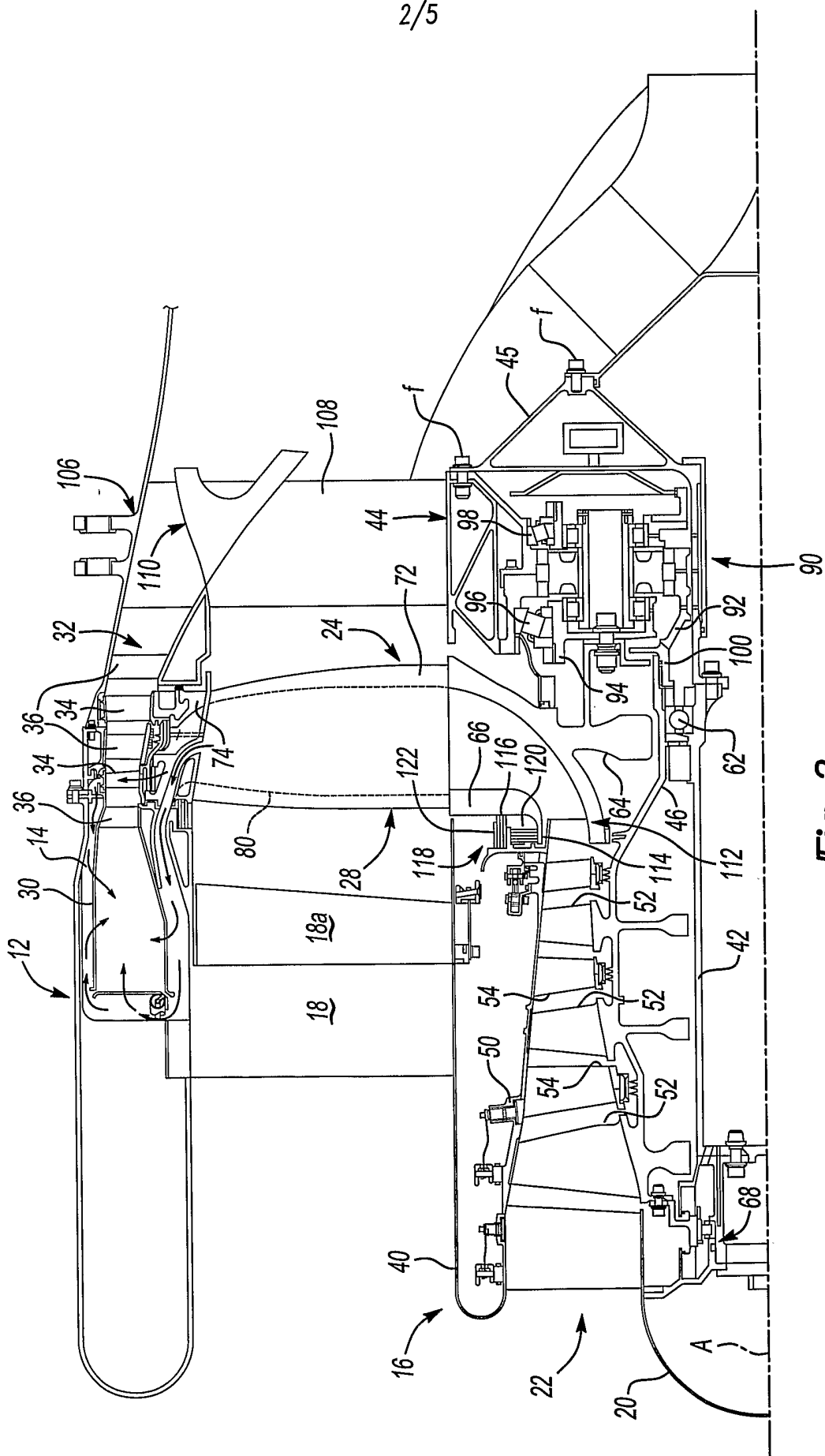
14. The tip turbine engine as recited in claim 13, wherein axial compressor stator assembly includes an exit stator support structure, said seal assembly mounted to said exit stator support structure.

15. The tip turbine engine as recited in claim 7, wherein said annular radial oriented seal and said annular axial oriented seal include brush seals.

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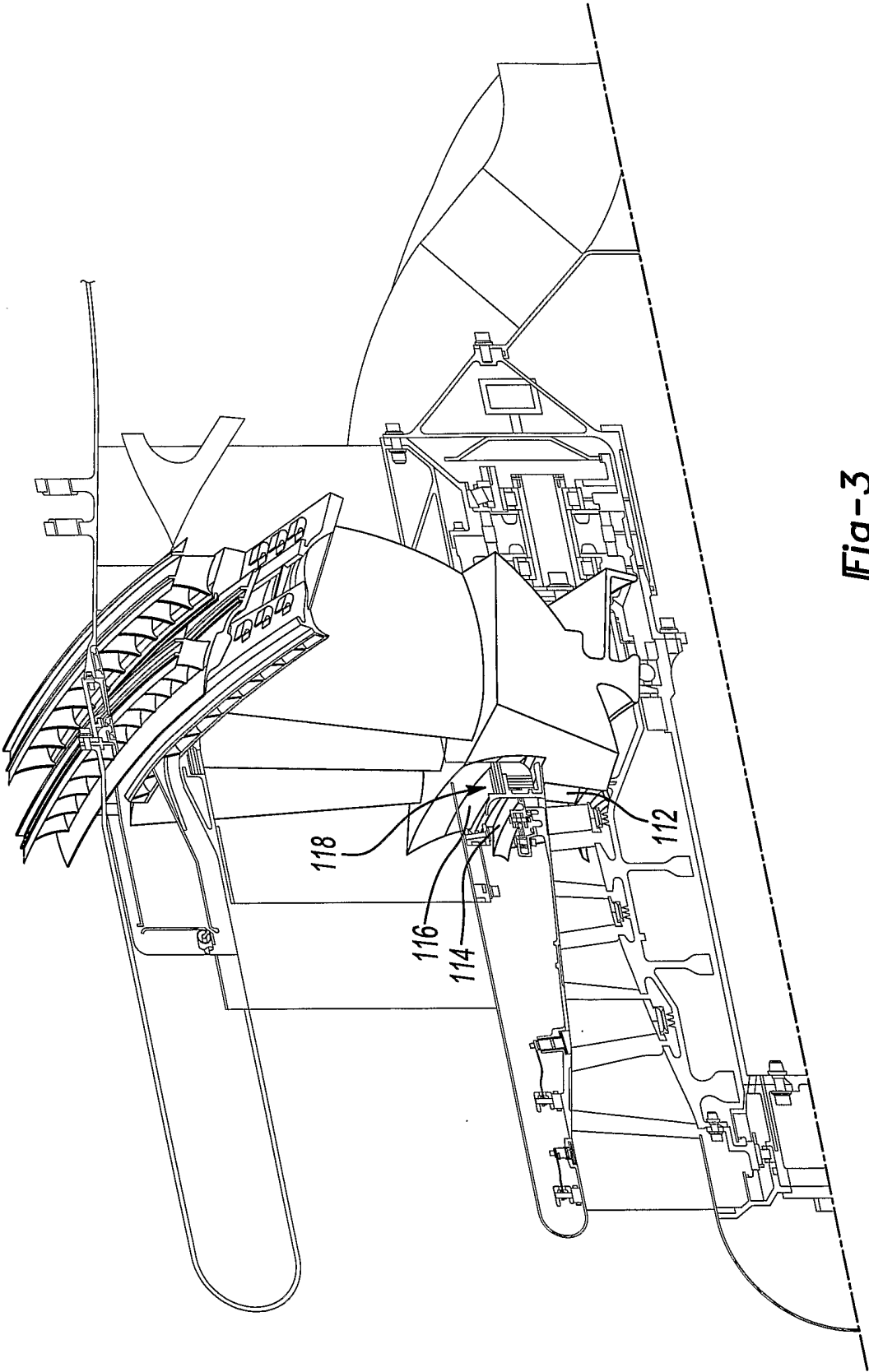
Fig-1



**Fig-2**

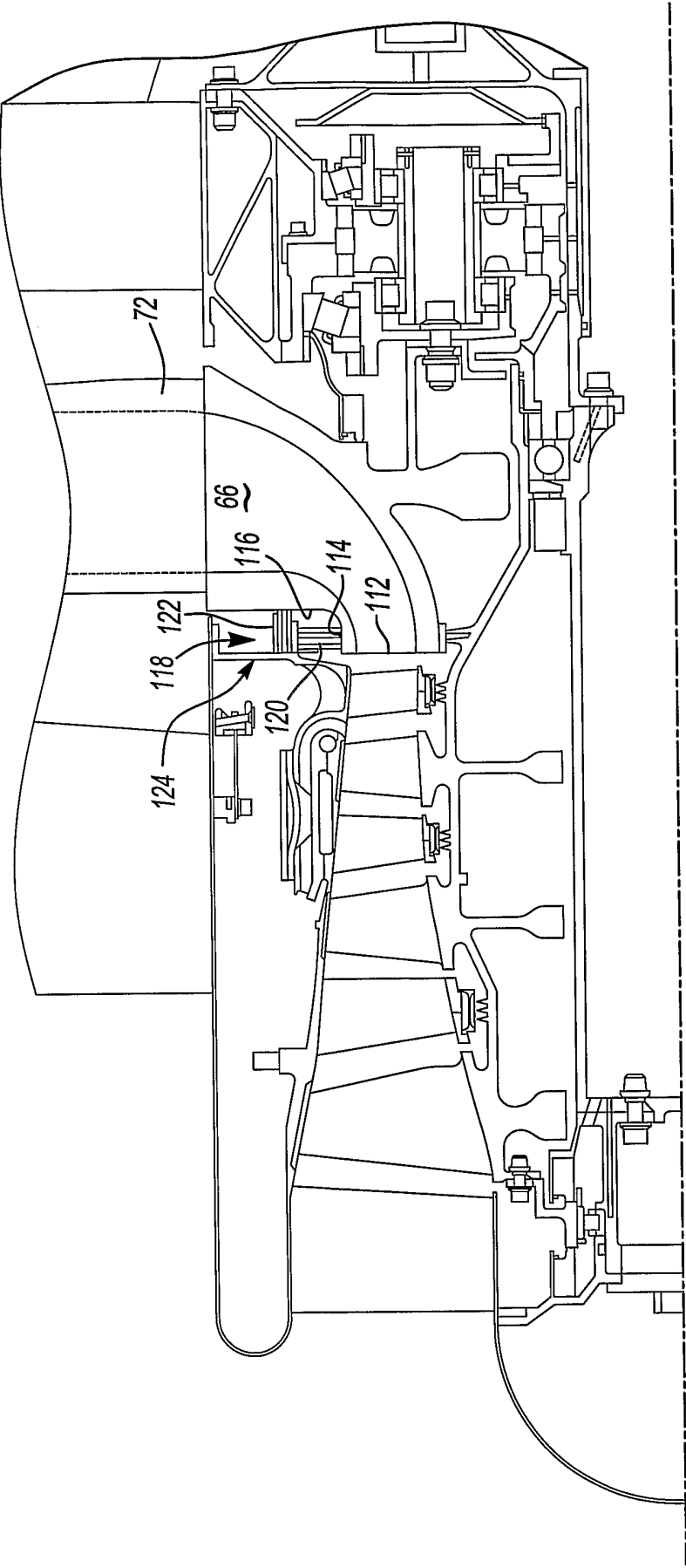
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**Fig-4**

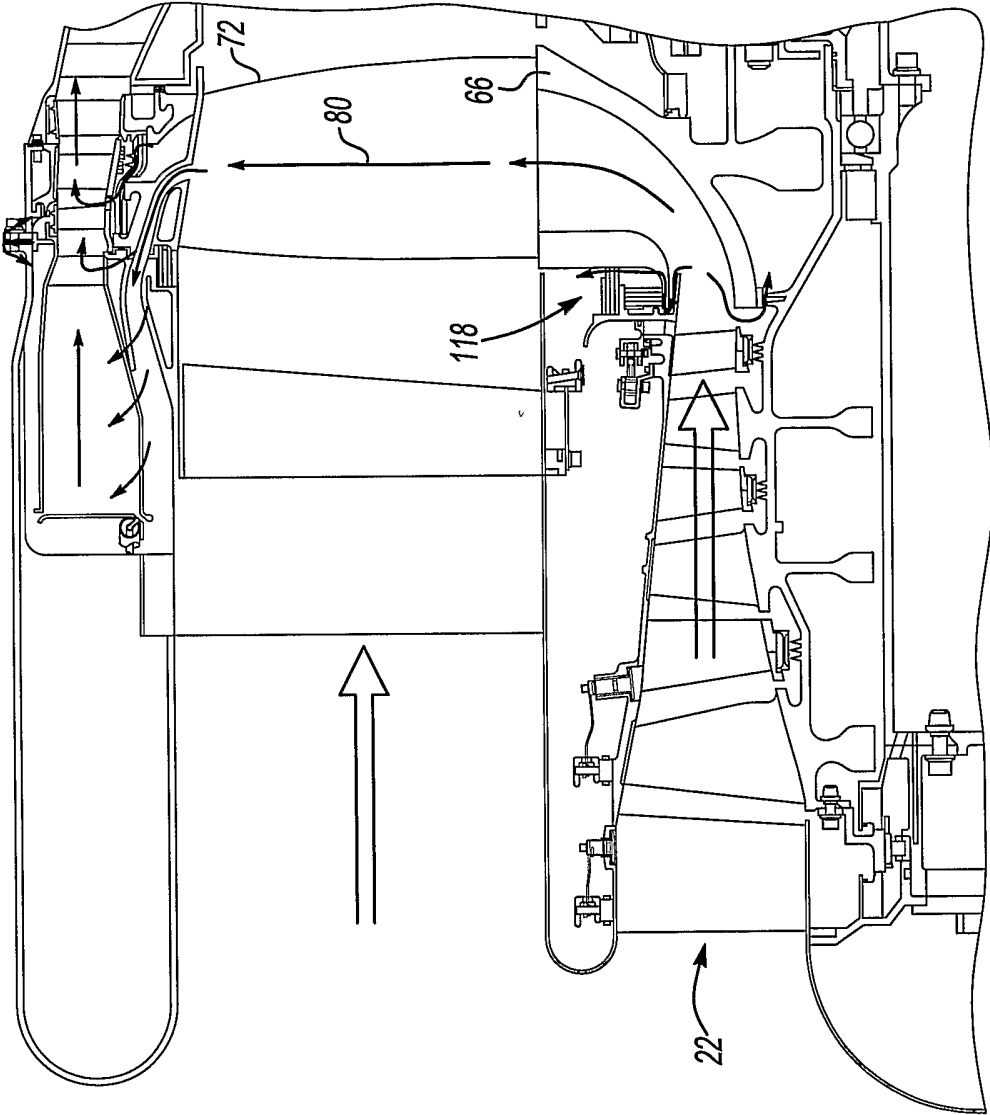


Fig-5



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US2004/040214

## A. CLASSIFICATION OF SUBJECT MATTER

F02K3/068 F02C3/073 F02C7/28 F01D11/00 F01D11/08  
F04D29/16 F04D29/16

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)

F02K F02C F01D F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2004/092567 A (MARIUS, PAUL, A) 28 October 2004 (2004-10-28) page 4 page 11 - page 12 page 15 - page 18 page 28 page 29 - page 30 abstract; figures 1,2,9,21,29,31,34	1-15
Y	DE 195 19 322 A1 (KSB AKTIENGESELLSCHAFT, 67227 FRANKENTHAL, DE) 28 November 1996 (1996-11-28) column 1, line 11 - column 2, line 13 column 2, line 48 - column 3, line 2 abstract; figures ----- -/--	1-15

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US2004/040214

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 5 232 333 A (GIRAULT ET AL)  3 August 1993 (1993-08-03)  column 7, line 36 - column 8, line 18  column 9, line 5 - line 14  column 9, line 67 - column 10, line 13  column 11, line 19 - line 44  abstract; figures 1,5-11  -----</p>	1,3,4,7, 8,10,11
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