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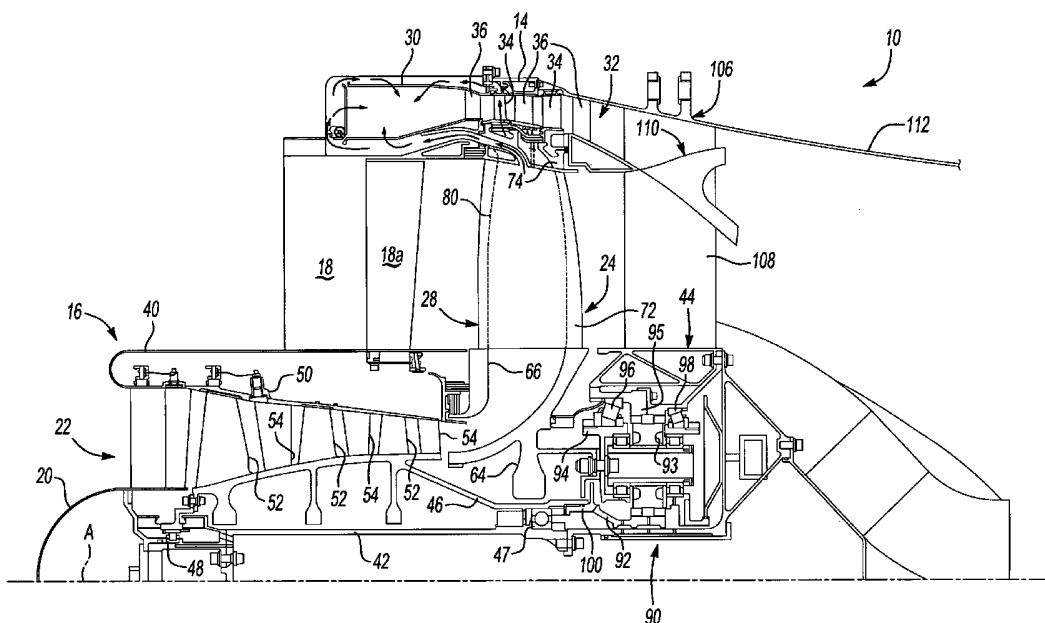
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(54) Title: VECTORING TRANSITION DUCT FOR TURBINE ENGINE



(57) Abstract: A transition duct is provided at the outlet of a turbine engine. The transition duct transitions the outlet of the tip turbine engine from round to rectangular. The transition duct also provides a plurality of variable vanes at the outlet of the transition duct. The transition duct incorporates a perimeter slot providing cooling to the duct outer wall and attached components. The variable vanes are installed to vector the exhaust gases. This allows the aircraft to decelerate, hover or accelerate in the forward direction by commanding the position of the variable vanes. One potential application of the tip turbine engine is for vertical installations in aircraft.

## VECTORIZING TRANSITION DUCT FOR TURBINE ENGINE

This invention was conceived in performance of U.S. Air Force contract F33657-03-C-2044. The government may have rights in this invention.

5

### BACKGROUND OF THE INVENTION

The present invention relates to turbine engines, and more particularly to a vectoring transition duct particularly useful for, but not limited to, vertical lift installations of a turbine engine, such as a tip turbine engine.

10       An aircraft gas turbine engine of the conventional turbofan type generally includes a forward bypass fan, a low pressure compressor, a middle core engine, and an aft low pressure turbine, all located along a common longitudinal axis. A high pressure compressor and a high pressure turbine of the core engine are interconnected by a high spool shaft. The high pressure compressor is rotatably  
15 driven to compress air entering the core engine to a relatively high pressure. This high pressure air is then mixed with fuel in a combustor, where it is ignited to form a high energy gas stream. The gas stream flows axially aft to rotatably drive the high pressure turbine, which rotatably drives the high pressure compressor via the high spool shaft. The gas stream leaving the high pressure turbine is expanded through  
20 the low pressure turbine, which rotatably drives the bypass fan and low pressure compressor via a low spool shaft. As a result of this architecture, conventional turbofans have an exhaust temperature profile which tends to be hotter towards the engine centerline (turbine discharge) with the cooler fan bypass air outboard.

25       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 length relative to the engine diameter. This elongated shape may complicate or prevent packaging of the engine into particular applications.

30       A recent development in gas turbine engines is the tip turbine engine. Tip turbine engines may include a low pressure axial compressor directing core airflow into hollow fan blades. The hollow fan blades operate as a centrifugal compressor when rotating. Compressed core airflow from the hollow fan blades is mixed with

fuel in an annular combustor, where it is ignited to form a high energy gas stream which drives the turbine that is 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. The tip turbine engine architecture generates a radial temperature profile with cooler, fan bypass discharge air towards the centerline, and hotter turbine discharge outboard (opposite of conventional turbofans). The tip turbine engine provides a thrust-to-weight ratio equivalent to or greater than conventional turbofan engines of the same class, but within a package of significantly shorter length.

10

### SUMMARY OF THE INVENTION

One potential application of the tip turbine engine is for vertical installations. Because the tip turbine engine is significantly shorter than conventional turbine engines, the tip turbine engine can more easily be installed vertically in aircraft to provide vertical lift. In the tip turbine engine of the present invention, a transition duct is provided for use especially (but not exclusively) in vertical installations. The transition duct transitions the outlet of the tip turbine engine from round to rectangular. The transition duct also provides a plurality of variable vanes at the outlet of the transition duct. The variable vanes are installed to vector the exhaust gases. This allows the aircraft to decelerate, hover or accelerate in the forward direction by commanding the position of the variable vanes.

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### BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the present invention can be understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

25

Figure 1 is a longitudinal sectional view of the tip turbine engine along an engine centerline.

30

Figure 2 illustrates the tip turbine engine of Figure 1 installed vertically with a transition duct mounted below the tip turbine engine.

Figure 2A is an enlarged view of the area 2A of Figure 2.

Figure 3 is a sectional view taken along lines 3-3 of Figure 2.

Figure 4 is a sectional view taken along lines 4-4 of Figure 2.

Figure 5 is a sectional view taken along lines 5-5 of Figure 2.

Figure 6 illustrates the tip turbine engine installed in a vertical orientation in an aircraft.

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### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates a partial sectional view of a tip turbine engine (TTE) type gas turbine engine 10. The engine 10 includes a rotationally fixed static outer support structure 14 and a rotationally fixed static inner support structure 16. A plurality 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 nosecone 20 is preferably located along the engine centerline A to improve airflow into an axial compressor 22, which is mounted about the engine centerline A behind the nosecone 20.

15 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 plurality 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 rotationally fixed static outer support structure 14.

20 A turbine 32 includes a plurality of tip turbine blades 34 (two stages shown) which rotatably drive the hollow fan blades 28 relative a plurality of tip turbine stators 36 which extend radially inwardly from the rotationally fixed static outer support structure 14. The annular combustor 30 is disposed axially forward of the turbine 32 and communicates with the turbine 32.

25 The rotationally fixed 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, which is mounted for rotation upon the static inner support housing 42 through an aft bearing assembly 47 and a forward bearing assembly 48. A plurality of compressor blades 52 extend radially outwardly from the axial compressor rotor 46. A fixed compressor case 50 is fixedly mounted to the splitter

30

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 fan-turbine rotor assembly 24 includes a fan hub 64 that supports a plurality 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 diffused and turned once again by the diffuser section 74 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.

The tip turbine engine 10 may optionally include a gearbox assembly 90 aft of the fan-turbine rotor assembly 24, such that the fan-turbine rotor assembly 24 rotatably drives the axial compressor 22 via the gearbox assembly 90. In the embodiment shown, the gearbox assembly 90 provides a speed increase at a 3.34-to-one ratio. The gearbox assembly 90 may be an epicyclic gearbox, such as a planetary gearbox as shown, that 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 92, which rotates the axial compressor rotor 46, and a planet carrier 94, which rotates with the fan-turbine rotor assembly 24. A plurality of planet gears 93 each engage the sun gear 92 and a rotationally fixed ring gear 95. The planet gears 93 are mounted to the planet carrier 94. The gearbox assembly 90 is mounted for rotation between the sun gear 92 and the static outer support housing 44 through a gearbox forward bearing 96 and a gearbox rearbearing 98. The gearbox assembly 90 may alternatively, or additionally, reverse the direction of rotation and/or may provide a decrease in rotation speed.

A plurality of exit guide vanes 108 are located between the static outer support housing 44 and the rotationally fixed exhaust case 106 to guide the combined airflow out of the engine 10. An exhaust mixer 110 mixes the airflow from the turbine blades 34 with the bypass airflow through the fan blades 28.

5 As shown in Figure 2, a transition duct 112 is mounted to the outer support structure 14 aft of the exit guide vanes 108. The transition duct 112 includes a wall 113 defining an interior passageway 114 that transitions the flow out of the tip turbine engine 10 from round near the exit guide vanes 108 to rectangular at the outlet 115 of the transition duct 112. The transition duct 112 also provides a  
10 plurality of variable vanes 120 at the outlet 115 of the transition duct 112. The variable vanes 120 are pivotable on shafts 122 to vector the exhaust gases. The shafts 122 are generally transverse, and in this embodiment, substantially perpendicular, to the airflow through the interior passageway 114 of the transition duct 112. A full perimeter vent slot 124 provides cooling of the variable vanes 120  
15 using a portion of vent air that is passed along the outside of the transition duct 112 and the tip turbine engine 10. This air could be nacelle ventilation flow used to minimize the heating of surrounding aircraft structure. Due to the unique radial temperature profile of the tip turbine exhaust (higher temperatures radially outward of the cooler temperatures), the perimeter slot is beneficial in that it promotes the  
20 evacuation of the nacelle ventilation flow while simultaneously providing cooling to the duct 112 in areas where bearings and other support for articulated vanes 120 mounted to shaft 122 reside.

Figure 2A is an enlarged view of the area 2A of Figure 2. As shown, the vent slot 124 extends through overlapping portions 113a, 113b of the transition duct  
25 outer wall 113. A peripheral seal 130 is formed between the attachment structure 132 for the variable vanes 120 (not shown in Figure 2A) and the surrounding airframe structure 136.

Referring to Figure 3, an actuator 126, such as a linear hydraulic actuator, is connected via linkage 128 to all of the shafts 122 of the variable vanes 120. More  
30 than one actuator 126 could also be used. The linkage 128 include cams, levers, gears, and/or other mechanisms so that the variable vanes 120 are varied differently. The asymmetric vane kinematics are utilized for constant area and required thrust-

post positioning. In particular, the variable vanes 120 near the side of the transition duct 112 opposite the direction of desired travel are angled away from their middle position more than the vanes 120 on the side of the transition duct 112 in the direction of desired travel. For example, the variable vane 120a is shown angled  
5 away from its middle position more than the next variable vane 120b, which in turn is angled more than the next variable vane 120c, and so on. This allows the aircraft to decelerate, hover or accelerate in the forward direction by commanding the position of the variable vanes 120.

Figures 4 and 5 illustrate two progressive sections of the transition duct 112.  
10 As shown, the transition duct 112 transitions from a substantially round opening (Figure 4) at the outlet of the tip turbine engine 10, to a rounded rectangular section (Figure 5) to a substantially rectangular section (Figure 3).

Figure 6 schematically illustrates the tip turbine engine 10 installed vertically in an aircraft 200. The aircraft 200 may optionally include at least one other turbine  
15 engine 210, mounted horizontally, which may be a tip turbine engine or a conventional turbine engine.

Referring to Figure 2, in operation, core airflow enters the axial compressor 22, where it is compressed by the compressor blades 52. The compressed air from the axial compressor 22 enters the inducer section 66 in a direction generally parallel  
20 to the engine centerline A, and is then 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 hollow fan blades 28 by rotation of the hollow fan blades 28. From the core airflow passage 80, the airflow is turned and diffused axially forward in the engine 10 by the diffuser section 74 into the  
25 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 plurality of tip turbine blades 34 mounted about the outer periphery of the fan-turbine rotor assembly 24 to  
30 drive the fan-turbine rotor assembly 24, which in turn rotatably drives the axial compressor 22 either directly or via the optional gearbox assembly 90. The fan-turbine rotor assembly 24 discharges fan bypass air axially aft to merge with the

core airflow from the turbine 32 in the exhaust case 106. Again, it should be noted that in the tip turbine engine 10, the higher temperature air is radially outward of the cooler bypass air. The transition duct 112 transitions the outlet of the tip turbine engine 10 from round to rectangular. The variable vanes 120 vector the exhaust  
5 gases to allow the aircraft to decelerate, hover or accelerate in the forward direction by commanding the position of the variable vanes 120.

In accordance with the provisions of the patent statutes and jurisprudence, exemplary configurations described above are considered to represent a preferred embodiment of the invention. However, it should be noted that the invention can be  
10 practiced otherwise than as specifically illustrated and described without departing from its spirit or scope. For example, although the tip turbine engine 10 is shown in a purely vertical orientation, it could also be used horizontally. Also, the variable vanes 120 of the present invention would provide benefits to installations mounted only substantially vertically or even anywhere between purely horizontal and purely  
15 vertical. Whatever the installed orientation of the turbine engine 10, the transition duct 112 provides the ability to vector the air flow from the turbine engine 10 to maneuver the aircraft 200.



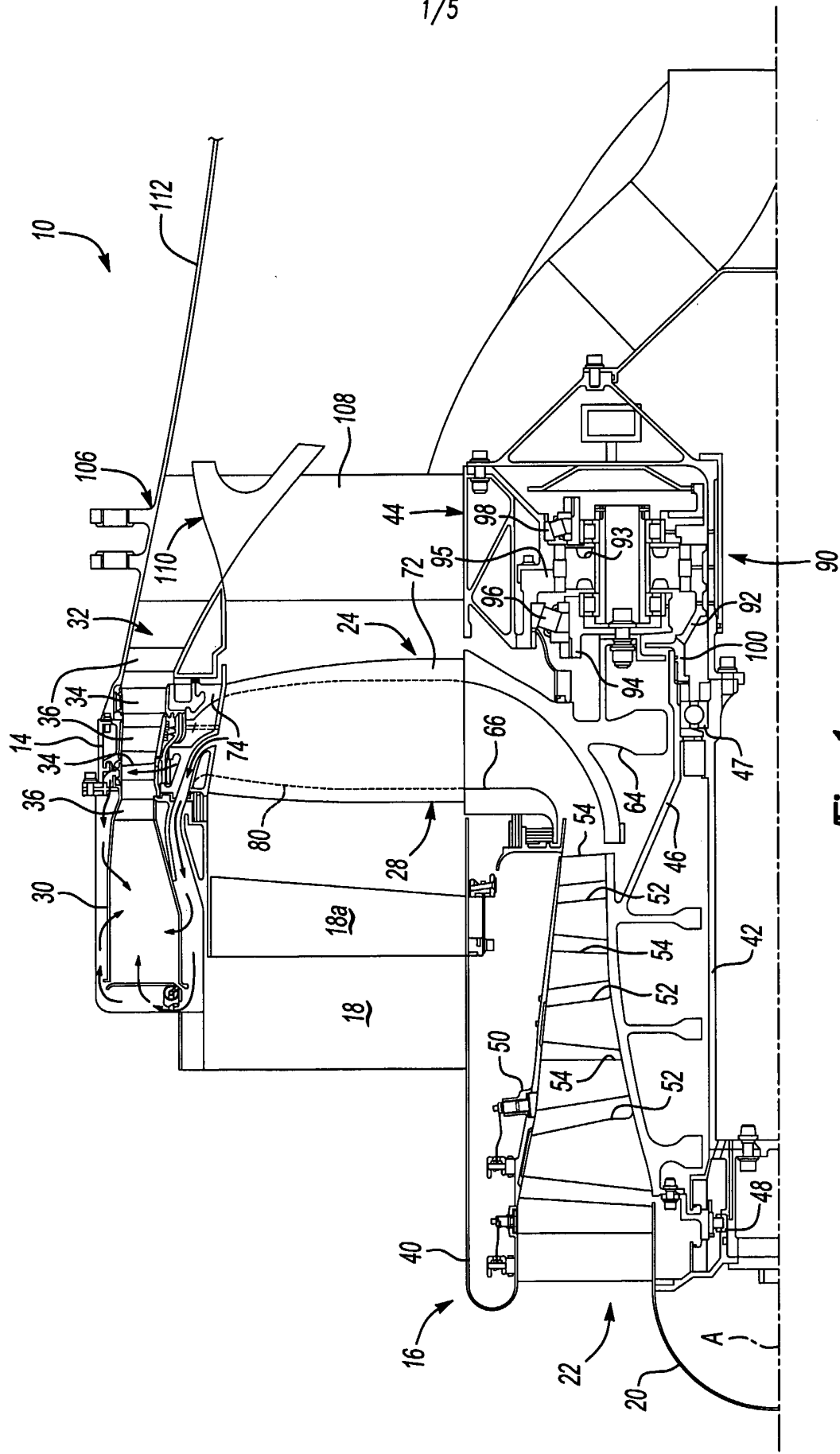
**CLAIMS**

1. A turbine engine assembly comprising:  
a fan including a plurality of fan blades;  
5 a combustor burning fuel to generate a high-energy gas stream;  
a turbine downstream from the combustor, the turbine rotatably drivable by  
the high-energy gas stream; and  
a transition duct downstream from the turbine and the fan, the transition duct  
including a plurality of variable vanes for vectoring airflow from the fan and the  
10 combustor.
2. The assembly claim 1 wherein the fan draws bypass air through a bypass air  
flow path, the assembly further including an axial compressor radially inward of the  
bypass air flow path.  
15
3. The assembly of claim 1 wherein an interior of the transition duct transitions  
from a generally round cross-section to a generally rectangular cross-section.
4. The assembly of claim 1 wherein the variable vanes are pivoted different  
20 amounts based upon the location of the variable vanes and based upon a desired  
direction of travel.
5. The assembly of claim 1 further including an actuator for pivoting the  
variable vanes about axes generally perpendicular to the air flow through the  
25 transition duct.
6. An aircraft including the turbine assembly of claim 1, wherein the fan is  
rotatable about a generally vertical axis.
- 30 7. The assembly of claim 1 wherein the plurality of vanes are each pivotable  
about an axis generally transverse to air flow through the engine.

8. The assembly of claim 1 wherein at least one of the plurality of fan blades defines a centrifugal compressor chamber therein for compressing core airflow therein and guiding the compressed core airflow toward the combustor.
- 5 9. A turbine engine and controller comprising:
- a bypass fan including a plurality of fan blades, at least one of the fan blades defining a centrifugal compressor chamber therein for centrifugally compressing core airflow;
- a combustor burning fuel mixed with the compressed core airflow from the
- 10 centrifugal compressor chamber to generate a high-energy gas stream;
- a turbine downstream from the combustor, the turbine rotatably driven by the high-energy gas stream, the turbine rotatably driving the bypass fan; and
- a transition duct downstream from at least one of the turbine and the fan, the transition duct transitioning air flow through the transition duct from a generally
- 15 round cross-section to a generally rectangular cross-section
10. The assembly claim 9 wherein the fan draws bypass air through a bypass air flow path, the assembly further including an axial compressor radially inward of the bypass air flow path, the axial compressor compressing core airflow prior to the
- 20 centrifugal compressor chamber.
11. The assembly of claim 9 including a plurality of variable vanes for vectoring airflow from the fan and the combustor.
- 25 12. The assembly of claim 11 wherein the variable vanes are pivoted different amounts based upon the location of the variable vanes and based upon a desired direction of travel.
13. The assembly of claim 11 further including an actuator for pivoting the
- 30 variable vanes about axes generally perpendicular to the air flow through the transition duct.

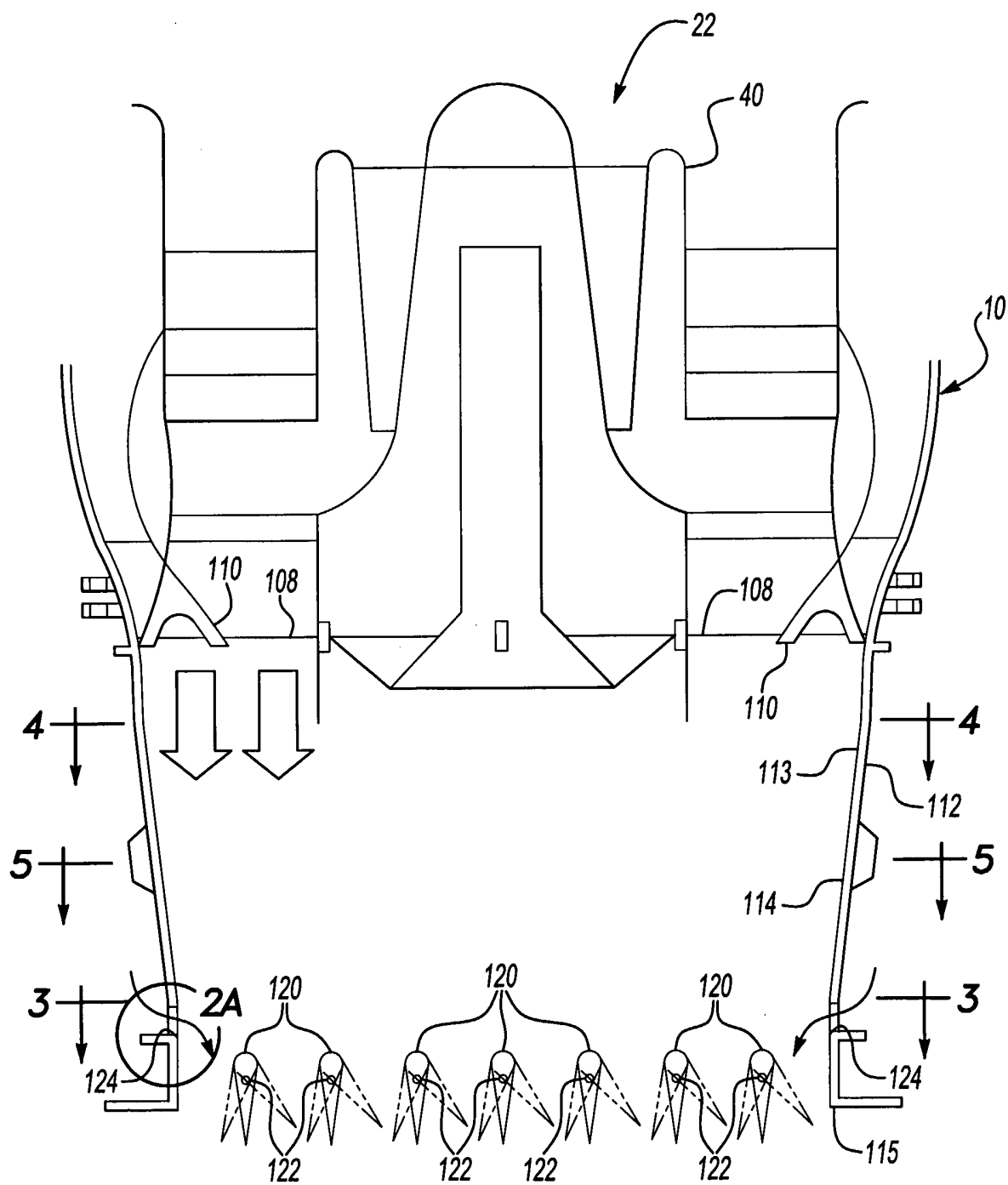
14. An aircraft including the turbine assembly of claim 9, wherein the fan is rotatable about a generally vertical axis.
15. The assembly of claim 1 wherein the plurality of vanes are each pivotable  
5 about an axis generally transverse to air flow through the engine.
16. A transition duct for a turbine engine comprising:  
an outer wall defining an interior having a generally round cross-section proximate an inlet and a generally rectangular cross-section proximate an outlet; and  
10 a plurality of variable vanes proximate the outlet for vectoring airflow through the interior.
17. The transition duct of claim 16 wherein the variable vanes are pivoted different amounts from one another based upon a desired direction of travel.  
15
18. The transition duct of claim 17 wherein at least a first one of the variable vanes proximate a side of the transition duct in the desired direction of travel are pivoted less than a second one of the variable vanes proximate a side of the transition duct away from the direction of travel.  
20
19. The transition duct of claim 17 further including an actuator for pivoting the variable vanes about axes generally perpendicular to the airflow through the interior.
20. The transition duct of claim 16 wherein the plurality of vanes are each  
25 pivotable about an axis generally transverse to air flow through the interior.
21. A transition duct for a turbine engine comprising:  
an outer wall defining an interior between an inlet and an outlet;  
a plurality of variable vanes pivotably mounted to the outer wall proximate  
30 the outlet for vectoring airflow through the interior; and  
a vent through the outer wall between the inlet and the plurality of variable vanes.

22. The transition duct of claim 21 wherein the outer wall has a generally round cross-section proximate the inlet and a generally rectangular cross-section proximate the outlet.
- 5 23. The transition duct of claim 21 mounted proximate an outlet of a turbine engine.
24. The transition duct and turbine engine of claim 23 wherein the turbine engine includes a fan having a plurality of fan blades including at least one hollow fan blade
- 10 having a core airflow compressor chamber defined therein.

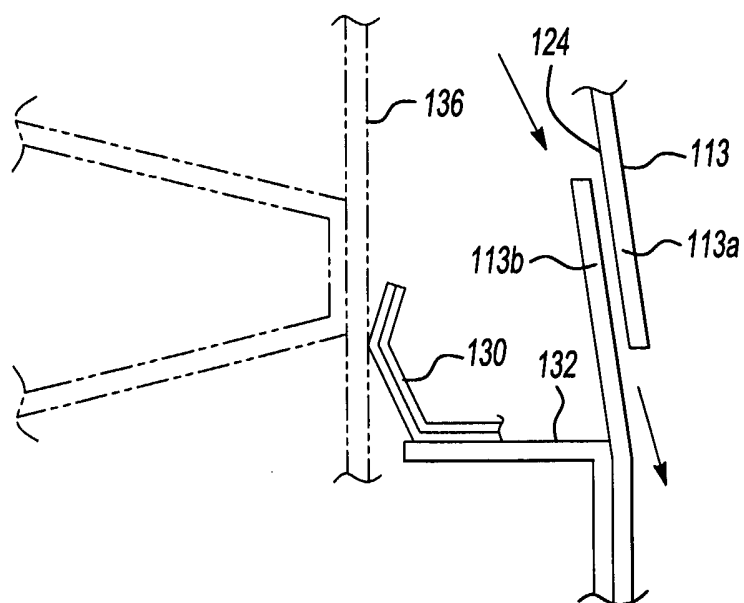
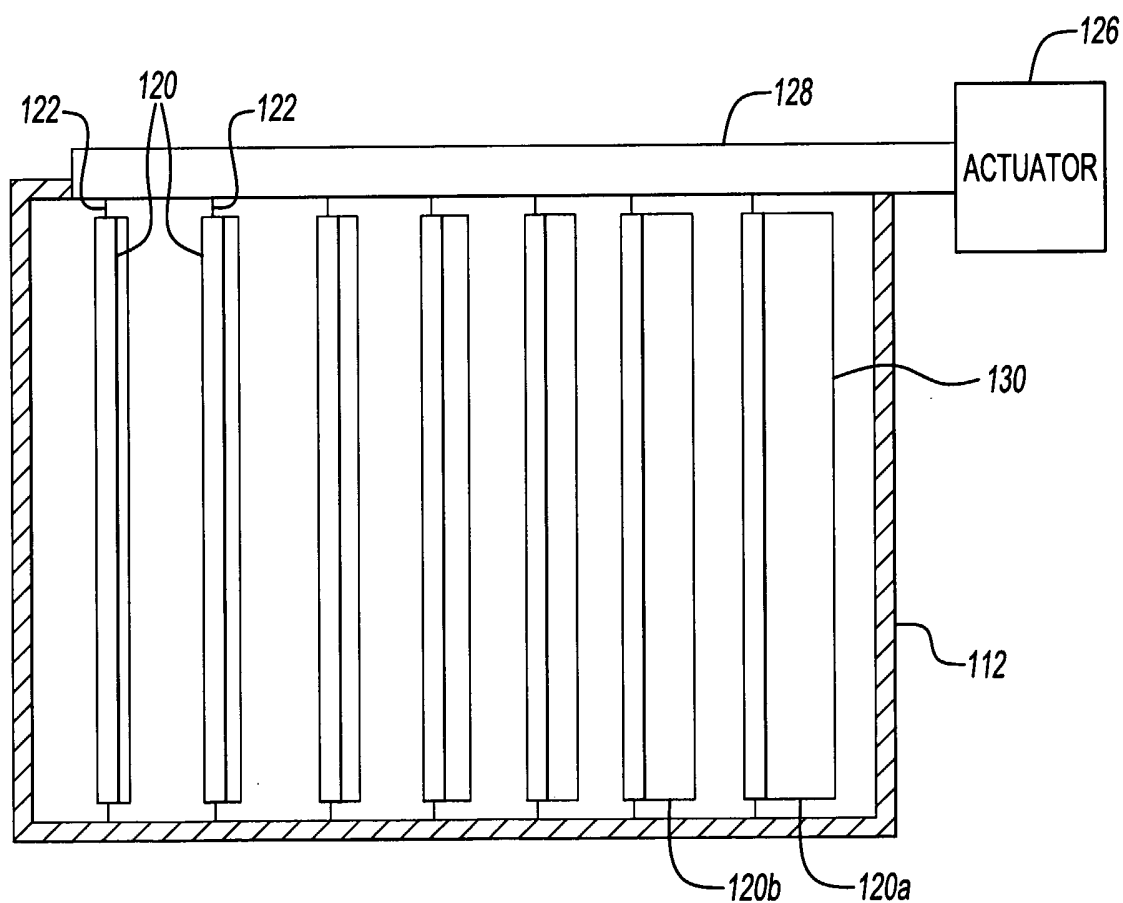


**Fig-1**

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**Fig-2**

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**Fig-2A****Fig-3**

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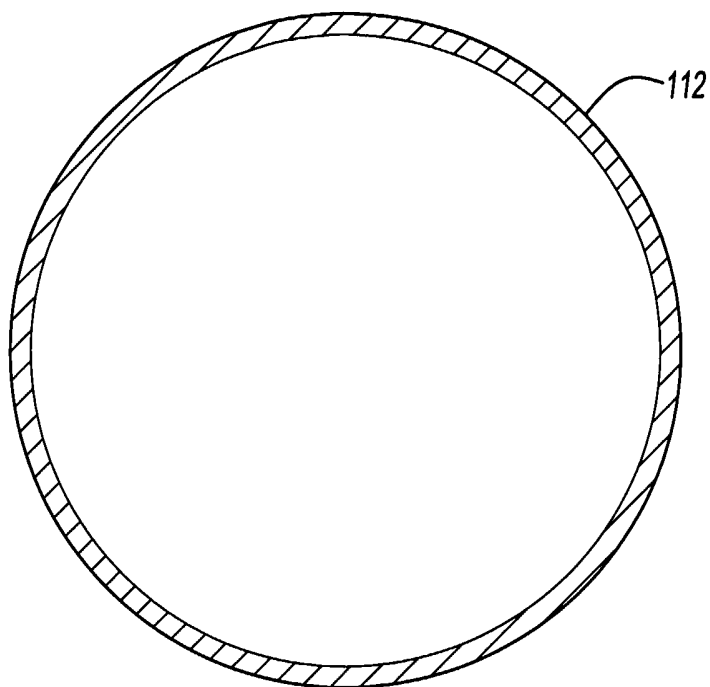


Fig-4

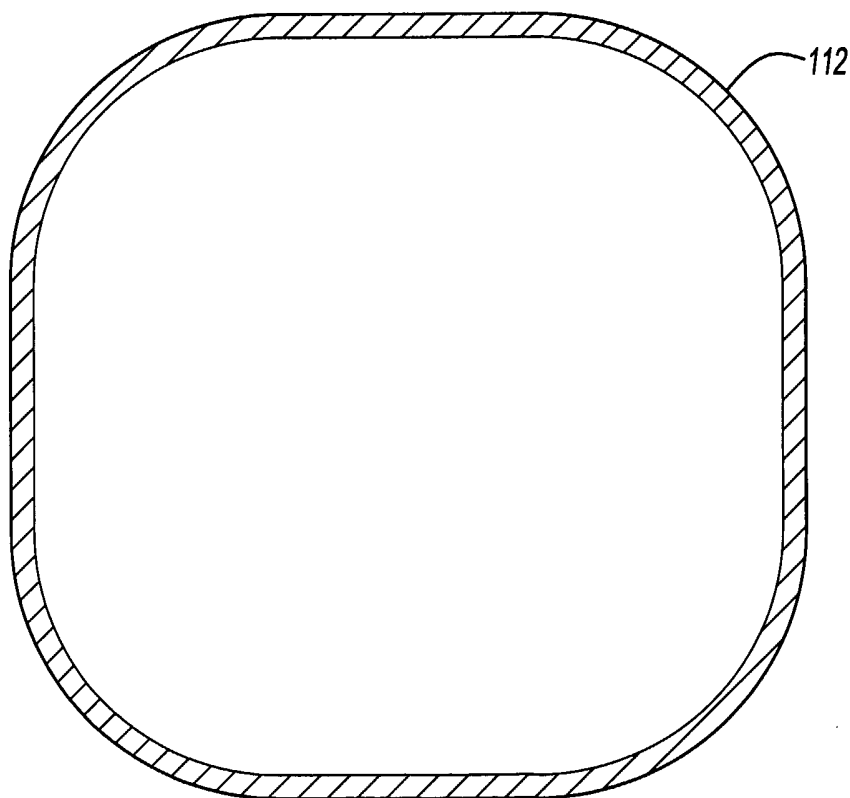


Fig-5



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