US009896998B2

(12) United States Patent
Thomassin et al.

(10) **Patent No.: US 9,896,998 B2**

(45) **Date of Patent: *Feb. 20, 2018**

(54) **COMPOUND ENGINE ASSEMBLY WITH MODULATED FLOW**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 31 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/806,902**

(22) Filed: **Jul. 23, 2015**

(65) **Prior Publication Data**

US 2016/0245161 A1 Aug. 25, 2016

Related U.S. Application Data

(60) Provisional application No. 62/118,891, filed on Feb. 20, 2015.

(51) **Int. Cl.**
F02G 3/00 (2006.01)
F02G 1/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F02B 41/00*** (2013.01); ***B64D 33/10*** (2013.01); ***F01C 1/22*** (2013.01); ***F01C 11/008*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F02B 41/00; B64D 33/08; B64D 33/10; F01C 1/22; F01C 11/008; F01C 21/08;
(Continued)

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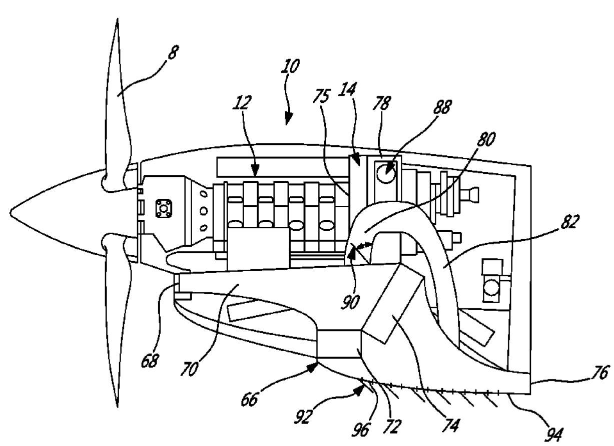
(57) **ABSTRACT**

A compound engine assembly including a compressor, an engine core including at least one rotary internal combustion engine and having an inlet in fluid communication with an outlet of the compressor, a turbine section having an inlet in fluid communication with an outlet of the engine core and configured to compound power with the engine core, and an air conduit having at least one heat exchanger extending thereacross. An outer wall of the air conduit has a plurality of openings defined therethrough downstream of the heat exchanger(s), each selectively closable by a pivotable flap movable between a retracted position where the opening is obstructed and an extended position away from the opening. Each opening defines a fluid communication between the air conduit and the ambient air when the respective flap is in the extended position. A method of directing flow through a compound engine assembly is also discussed.

19 Claims, 8 Drawing Sheets



(51) **Int. Cl.**

F02C 7/06	(2006.01)
F02C 7/10	(2006.01)
B64D 33/10	(2006.01)
B64D 41/00	(2006.01)
F02B 33/00	(2006.01)
F04C 18/00	(2006.01)
F01C 1/063	(2006.01)
F02B 41/00	(2006.01)
F02C 7/04	(2006.01)
F02C 7/042	(2006.01)
F02C 7/14	(2006.01)
F01C 1/22	(2006.01)
F01C 11/00	(2006.01)
F01C 21/06	(2006.01)
F01C 21/18	(2006.01)
F02C 3/04	(2006.01)
F02C 6/18	(2006.01)

(52) **U.S. Cl.**
CPC ***F01C 21/06*** (2013.01); ***F01C 21/18*** (2013.01); ***F02C 3/04*** (2013.01); ***F02C 6/18*** (2013.01); ***F02C 7/04*** (2013.01); ***F02C 7/042*** (2013.01); ***F02C 7/14*** (2013.01); *Y02T 50/675* (2013.01)

(58) **Field of Classification Search**
CPC F02C 3/04; F02C 6/18; F02C 7/04; F02C 7/042; F02C 7/14; F01P 5/08; F01P 7/023
USPC 60/614, 624, 39.08, 39.511; 244/57–58; 123/559.1; 418/61.2
See application file for complete search history.

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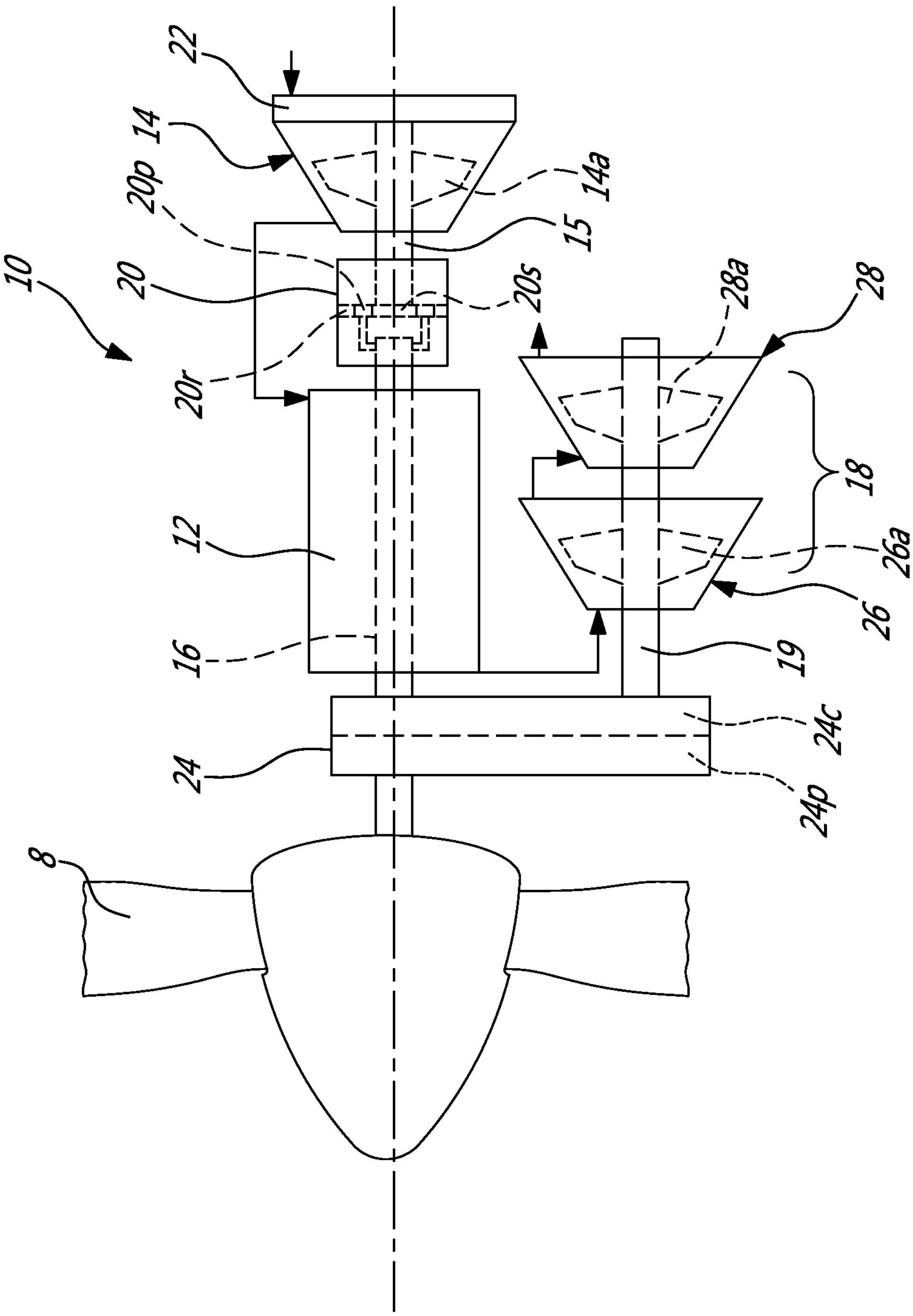

Fig-1

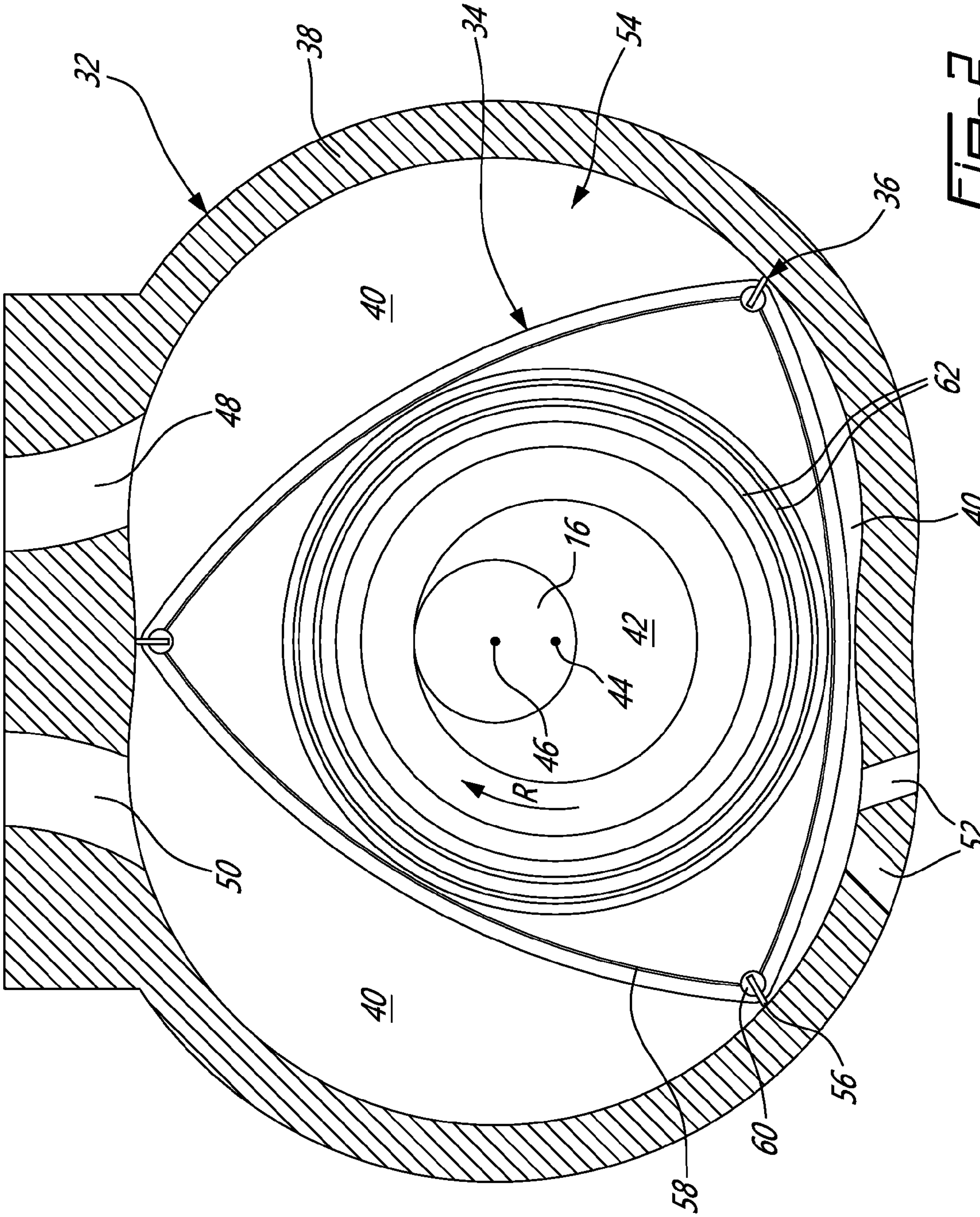

Fig-2

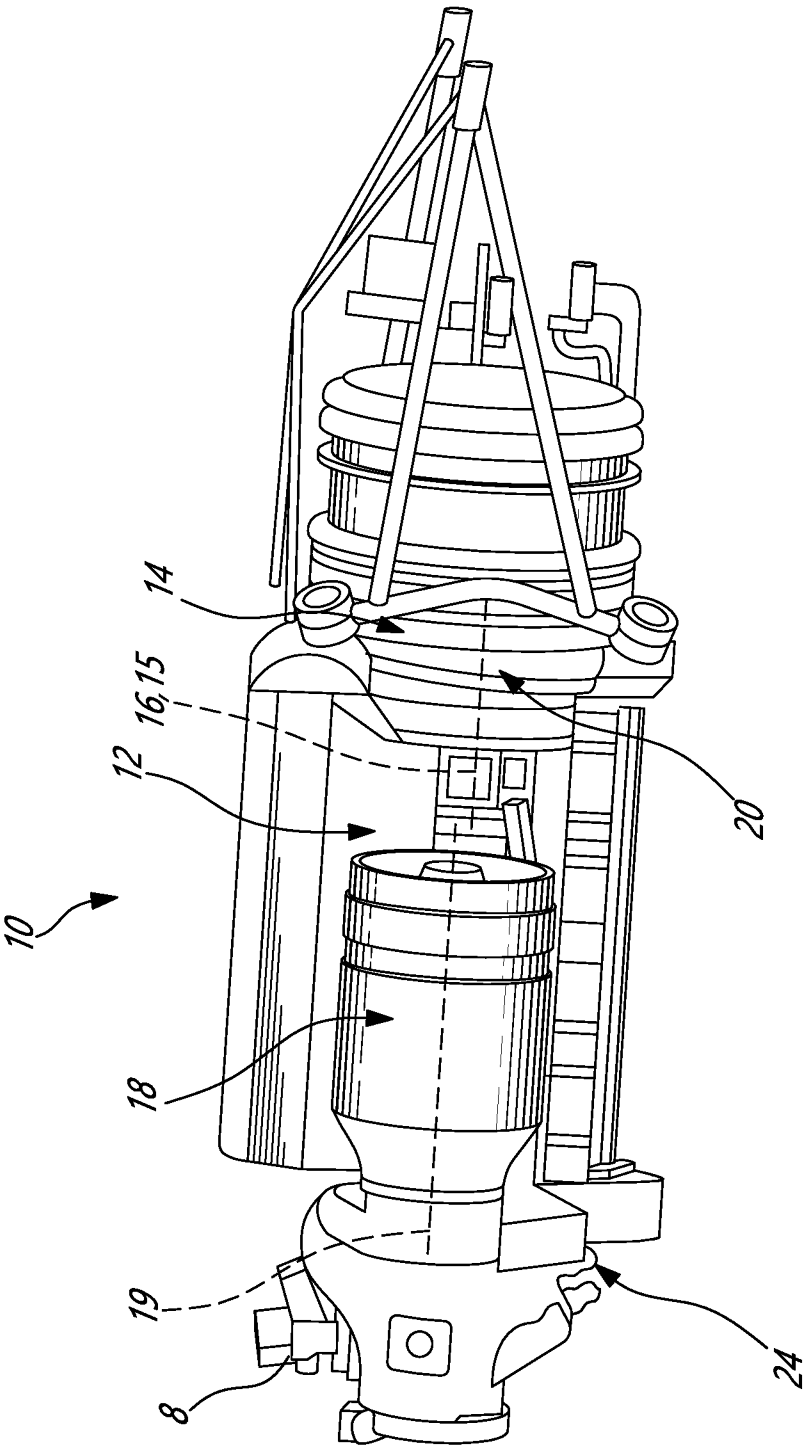

Fig-3

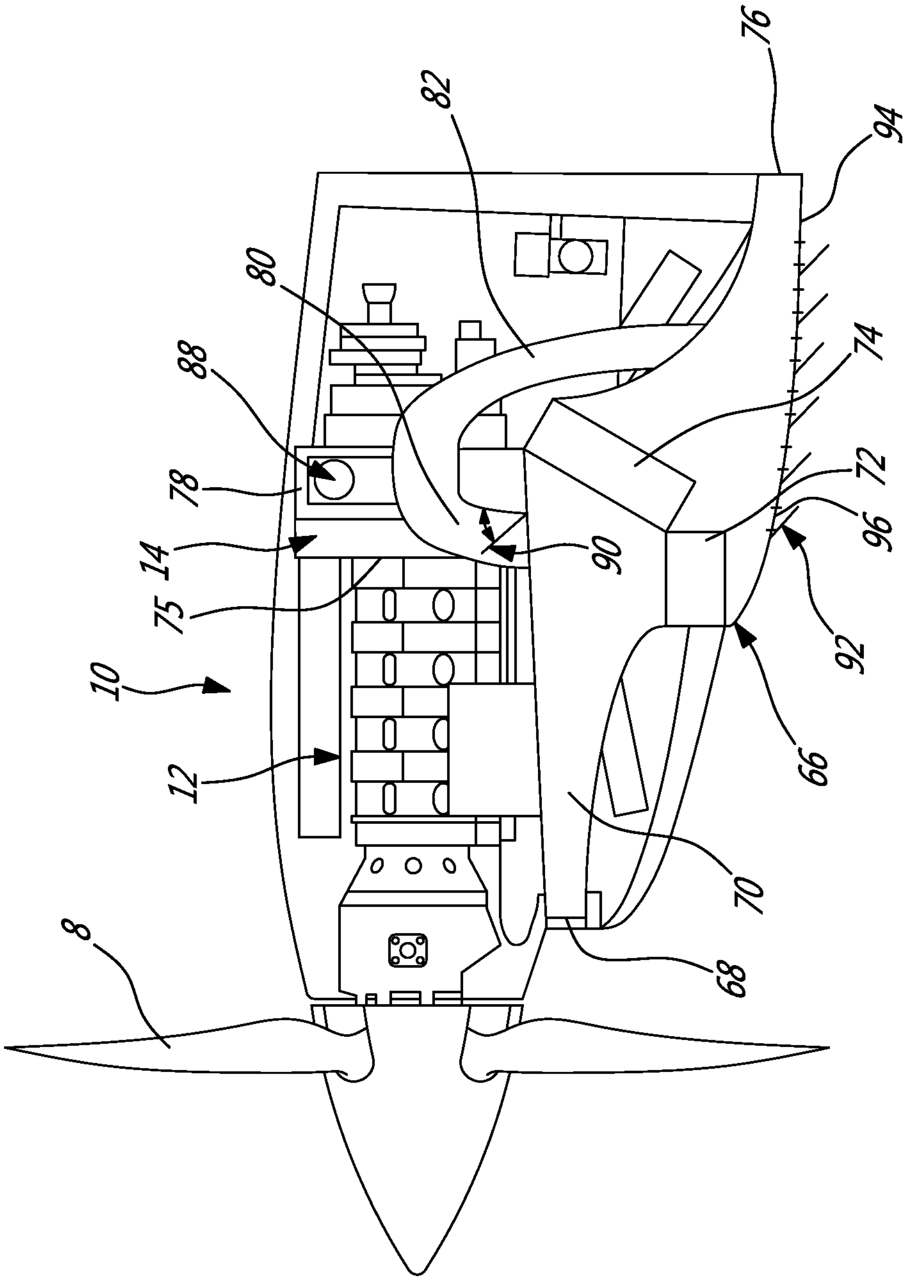

Fig-4

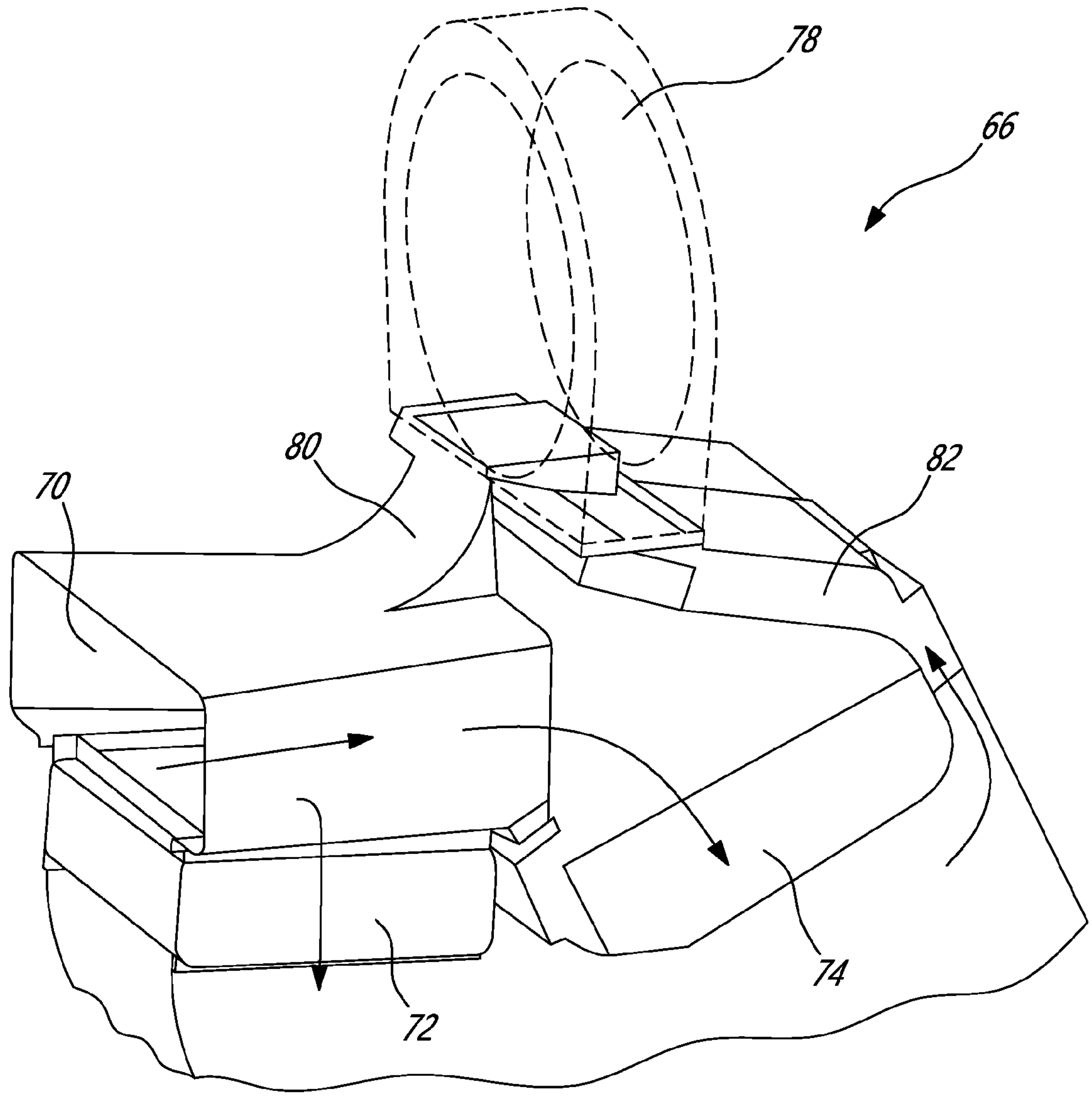

Fig-5

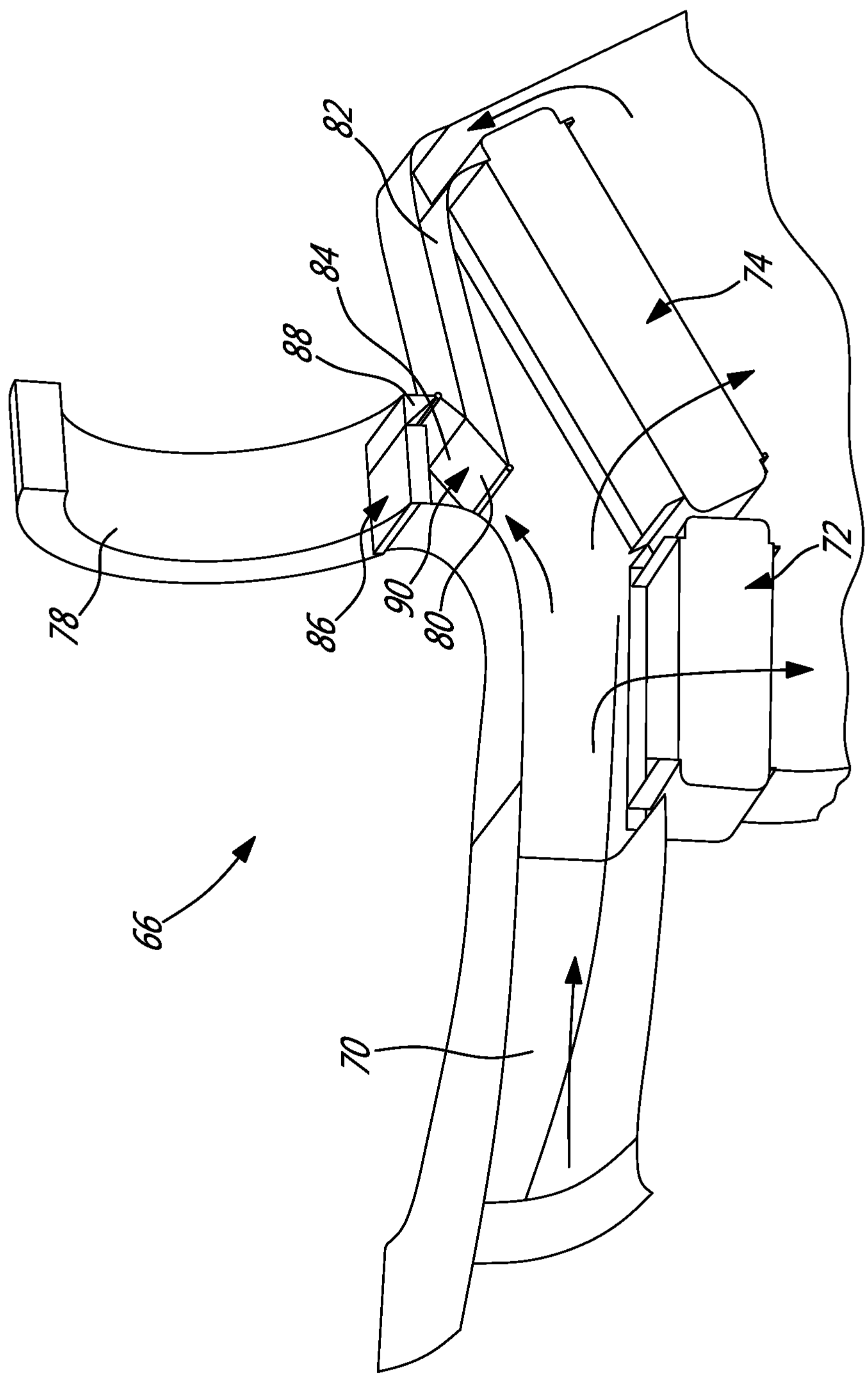

Fig-6A

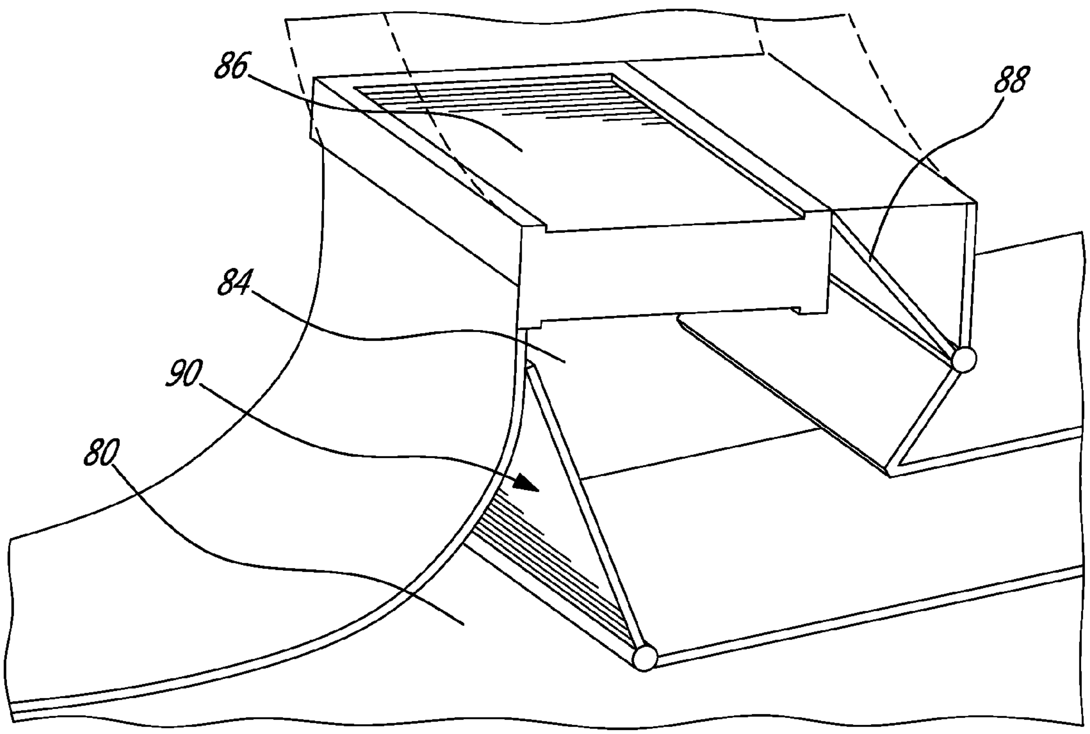

Fig. 6b

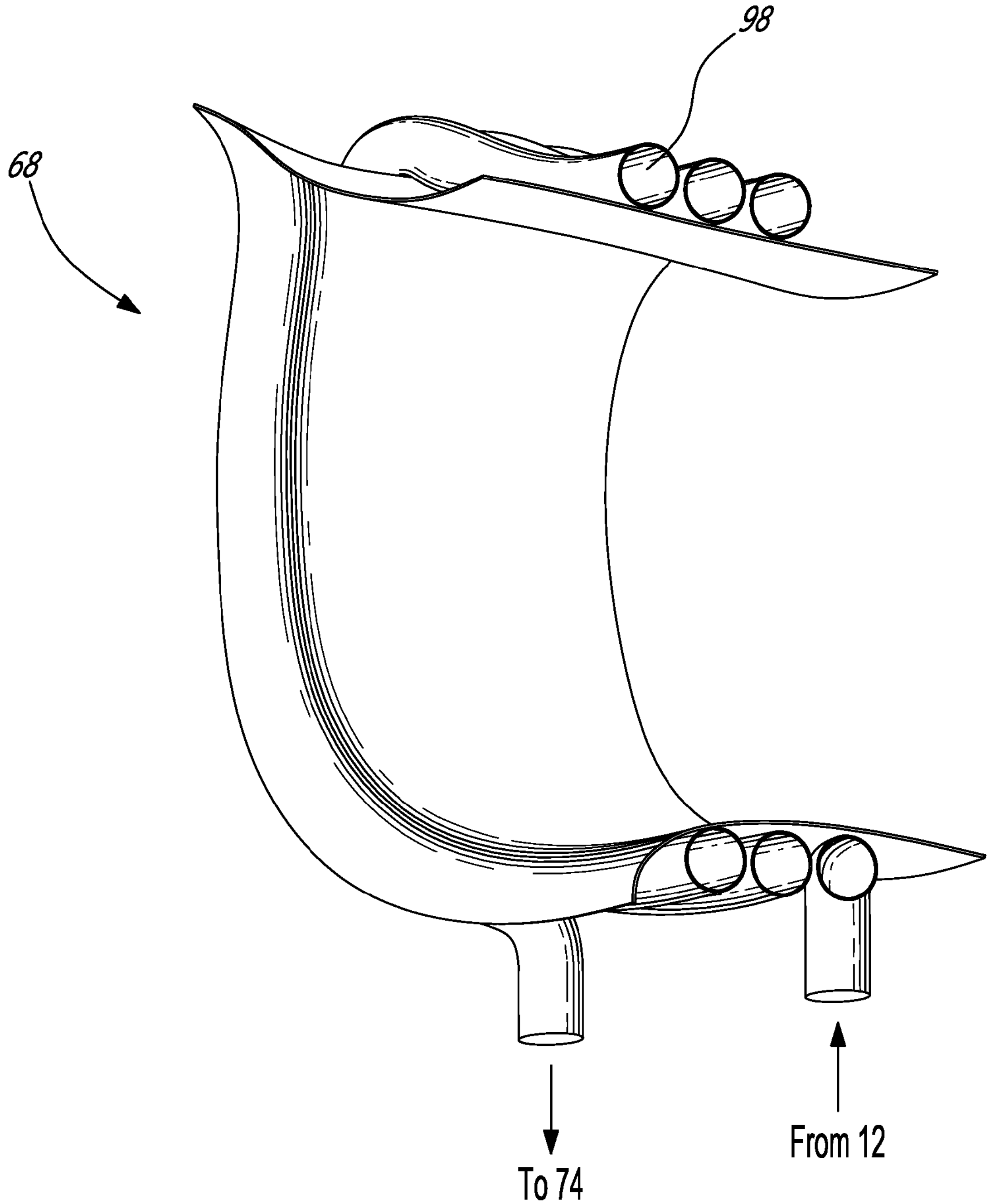

Fig-7

COMPOUND ENGINE ASSEMBLY WITH MODULATED FLOW

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. provisional application No. 62/118,891 filed Feb. 20, 2015, the entire contents of which are incorporated by reference herein.

TECHNICAL FIELD

The application relates generally to compound engine assemblies and, more particularly, to supercharged or turbocharged compound engine assemblies used in aircraft.

BACKGROUND OF THE ART

Compound engine assemblies including a compressor used as a supercharger or turbocharger may define a relatively bulky assembly which may be difficult to fit into existing aircraft nacelles, thus creating some difficulty in adapting them for aircraft applications.

SUMMARY

In one aspect, there is provided a compound engine assembly comprising: a compressor; an engine core including at least one internal combustion engine each having a rotor sealingly and rotationally received within a respective internal cavity to provide rotating chambers of variable volume in the respective internal cavity, the engine core having an inlet in fluid communication with an outlet of the compressor; a turbine section having an inlet in fluid communication with an outlet of the engine core, the turbine section configured to compound power with the engine core; and an air conduit having at least one heat exchanger extending thereacross such that an airflow through the air conduit circulates through the at least one heat exchanger, each of the at least one heat exchanger configured to circulate a fluid to be cooled in heat exchange relationship with the airflow circulating therethrough, the air conduit having opposed inlet and outlets in fluid communication with ambient air around the compound engine assembly; wherein an outer wall of the air conduit has a plurality of openings defined therethrough downstream of the at least one heat exchanger, each of the plurality of openings being selectively closable by a respective pivotable flap movable between a retracted position where the opening is obstructed and an extended position away from the opening, each of the plurality of openings defining a fluid communication between the air conduit and the ambient air around the compound engine assembly when the respective pivotable flap is in the extended position.

In another aspect, there is provided a compound engine assembly comprising: a compressor; an engine core including at least one rotary internal combustion engine in driving engagement with an engine shaft, the engine core having an inlet in fluid communication with an outlet of the compressor; a turbine section having an inlet in fluid communication with an outlet of the engine core, the turbine section including at least one turbine rotor engaged on a rotatable turbine shaft, the turbine shaft and the engine shaft being drivingly engaged to a same rotatable load; an air conduit having an inlet in fluid communication with ambient air around the compound engine assembly and an opposed outlet, the air conduit having at least one heat exchanger extending thereacross such that an airflow through the air conduit circulates through the at least one heat exchanger, each of the at least one heat exchanger configured to circulate a fluid to be cooled in heat exchange relationship with the airflow circulating therethrough, the air conduit having an outer wall including openings defined therethrough downstream of the at least one heat exchanger; and a plurality of pivotable flaps each attached to the outer wall adjacent a respective one of the openings and each movable between an extended position away from the opening and a retracted position closing the respective opening.

In a further aspect, there is provided a method of directing flow through a compound engine assembly, the method comprising: directing air into an inlet of a compressor of the compound engine assembly; directing compressed air from the compressor to an inlet of at least one rotary internal combustion engine of the compound engine assembly, the at least one rotary internal combustion engine driving rotation of an engine shaft; directing exhaust from the at least one rotary internal combustion engine on at least one turbine rotor of a turbine section of the compound engine assembly to drive rotation of a turbine shaft, the turbine shaft compounding power with the engine shaft to drive a rotatable load; and directing air through an air conduit containing at least one heat exchanger and through the at least one heat exchanger to cool a fluid of the compound engine assembly, including modulating a flow of the air through the at least one heat exchanger by selectively opening and closing a plurality of openings defined in an outer wall of the air conduit downstream of the at least one heat exchanger.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying figures in which:

FIG. **1** is a schematic view of a compound engine assembly in accordance with a particular embodiment;

FIG. **2** is a cross-sectional view of a Wankel engine which can be used in a compound engine assembly such as shown in FIG. **1**, in accordance with a particular embodiment;

FIG. **3** is a schematic tridimensional view of the compound engine assembly of FIG. **1** in accordance with a particular embodiment;

FIG. **4** is a schematic cross-sectional view of a nacelle installation of the compound engine assembly of FIG. **3**, in accordance with a particular embodiment;

FIG. **5** is a schematic tridimensional view of an intake assembly of the compound engine assembly of FIG. **4**, in accordance with a particular embodiment;

FIG. **6**A is a schematic side cross-sectional view of part of the intake assembly of FIG. **5**;

FIG. **6**B is an enlarged schematic side cross-sectional view of part of the intake assembly of FIG. **6**A; and

FIG. **7** is a schematic tridimensional view of an inlet lip of the intake assembly of FIG. **5**, in accordance with a particular embodiment.

DETAILED DESCRIPTION

Described herein are a compound engine assembly **10** and its installation for a propeller airplane. In the embodiment shown, the compound engine assembly **10** includes a liquid cooled heavy fueled multi-rotor rotary engine core **12** and a turbine section **18** used as an exhaust energy recovery system. As will be detailed below, other configurations for the engine core **12** are also possible.

Referring to FIG. **1**, the engine core **12** has an engine shaft **16** driven by the rotary engine(s) and driving a rotatable load, which is shown here as a propeller **8**. It is understood that the compound engine assembly **10** may alternately be configured to drive any other appropriate type of load, including, but not limited to, one or more generator(s), drive shaft(s), accessory(ies), rotor mast(s), compressor(s), or any other appropriate type of load or combination thereof. The compound engine assembly **10** further includes a compressor **14**, and a turbine section **18** compounding power with the engine core **12**.

The engine core **12** may include 2, 3, 4 or more rotary engines drivingly engaged to the shaft **16**. In another embodiment, the engine core **12** includes a single rotary engine. Each rotary engine has a rotor sealingly engaged in a respective housing, with each rotary engine having a near constant volume combustion phase for high cycle efficiency. The rotary engine(s) may be Wankel engine(s). Referring to FIG. **2**, an exemplary embodiment of a Wankel engine is shown. Each Wankel engine comprises a housing **32** defining an internal cavity with a profile defining two lobes, which is preferably an epitrochoid. A rotor **34** is received within the internal cavity. The rotor defines three circumferentially-spaced apex portions **36**, and a generally triangular profile with outwardly arched sides. The apex portions **36** are in sealing engagement with the inner surface of a peripheral wall **38** of the housing **32** to form three working chambers **40** between the rotor **34** and the housing **32**.

The rotor **34** is engaged to an eccentric portion **42** of the shaft **16** to perform orbital revolutions within the internal cavity. The shaft **16** performs three rotations for each orbital revolution of the rotor **34**. The geometrical axis **44** of the rotor **34** is offset from and parallel to the axis **46** of the housing **32**. During each orbital revolution, each chamber **40** varies in volume and moves around the internal cavity to undergo the four phases of intake, compression, expansion and exhaust.

An intake port **48** is provided through the peripheral wall **38** for successively admitting compressed air into each working chamber **40**. An exhaust port **50** is also provided through the peripheral wall **38** for successively discharging the exhaust gases from each working chamber **40**. Passages **52** for a glow plug, spark plug or other ignition element, as well as for one or more fuel injectors (not shown) are also provided through the peripheral wall **38**. Alternately, the intake port **48**, the exhaust port **50** and/or the passages **52** may be provided through an end or side wall **54** of the housing; and/or, the ignition element and a pilot fuel injector may communicate with a pilot subchamber (not shown) defined in the housing **32** and communicating with the internal cavity for providing a pilot injection. The pilot subchamber may be for example defined in an insert (not shown) received in the peripheral wall **38**.

In a particular embodiment the fuel injectors are common rail fuel injectors, and communicate with a source of Heavy fuel (e.g. diesel, kerosene (jet fuel), equivalent biofuel), and deliver the heavy fuel into the engine(s) such that the combustion chamber is stratified with a rich fuel-air mixture near the ignition source and a leaner mixture elsewhere.

For efficient operation the working chambers **40** are sealed, for example by spring-loaded apex seals **56** extending from the rotor **34** to engage the peripheral wall **38**, and spring-loaded face or gas seals **58** and end or corner seals **60** extending from the rotor **34** to engage the end walls **54**. The rotor **34** also includes at least one spring-loaded oil seal ring **62** biased against the end wall **54** around the bearing for the rotor **34** on the shaft eccentric portion **42**.

Each Wankel engine provides an exhaust flow in the form of a relatively long exhaust pulse; for example, in a particular embodiment, each Wankel engine has one explosion per 360° of rotation of the shaft, with the exhaust port remaining open for about 270° of that rotation, thus providing for a pulse duty cycle of about 75%. By contrast, a piston of a reciprocating 4-stroke piston engine typically has one explosion per 720° of rotation of the shaft with the exhaust port remaining open for about 180° of that rotation, thus providing a pulse duty cycle of 25%.

In a particular embodiment which may be particularly but not exclusively suitable for low altitude, each Wankel engine has a volumetric expansion ratio of from 5 to 9, and operates following the Miller cycle, with a volumetric compression ratio lower than the volumetric expansion ratio, for example by having the intake port located closer to the top dead center (TDC) than an engine where the volumetric compression and expansion ratios are equal or similar. Alternately, each Wankel engine operates with similar or equal volumetric compression and expansion ratios.

It is understood that other configurations are possible for the engine core **12**. The configuration of the engine(s) of the engine core **12**, e.g. placement of ports, number and placement of seals, etc., may vary from that of the embodiment shown. In addition, it is understood that each engine of the engine core **12** may be any other type of internal combustion engine including, but not limited to, any other type of rotary engine, and any other type of non-rotary internal combustion engine such as a reciprocating engine.

Referring back to FIG. **1**, the rotary engine core **12** is supercharged with the compressor **14** mounted in-line with the engine core, i.e. the compressor rotor(s) **14*a*** rotate co-axially with the engine shaft **16**. In the embodiment shown, the compressor rotor(s) **14*a*** are engaged on a compressor shaft **15**, and the engine shaft **16** is in driving engagement with the compressor shaft **15** through a step-up gearbox **20**. In a particular embodiment, the gearbox **20** is a planetary gear system. In a particular embodiment, the compressor shaft **15** includes a sun gear **20*s*** which is drivingly engaged to carrier-mounted planet gears **20*p***, which are drivingly engaged to a fixed ring gear **20*r***. The rotating carrier assembly is connected to the engine shaft **16**, for example through a splined connection. In a particular embodiment, the planetary gear system elements (sun gear, planet gears and ring gear) within the gearbox **20** are configured to define a speed ratio of about 7:1 between the compressor shaft **15** and engine core shaft **16**. It is understood that any other appropriate configuration and/or speed ratio for the gearbox **20** may alternately be used.

In the embodiment shown and referring particularly to FIG. **1**, the compressor **14** is a centrifugal compressor with a single rotor **14*a***. Other configurations are alternately possible. The compressor **14** may be single-stage device or a multiple-stage device and may include one or more rotors having radial, axial or mixed flow blades.

The outlet of the compressor **14** is in fluid communication with the inlet of the engine core **12**, which corresponds to or communicates with the inlet of each engine of the engine core **12**. Accordingly, air enters the compressor **14** and is compressed and circulated to the inlet of the engine core **12**. In a particular embodiment, the compressor **14** includes variable inlet guide vanes **22** through which the air circulates before reaching the compressor rotor(s) **14*a***.

The engine core **12** receives the pressurized air from the compressor **14** and burns fuel at high pressure to provide energy. Mechanical power produced by the engine core **12** drives the propeller **8**.

Each engine of the engine core **12** provides an exhaust flow in the form of exhaust pulses of high pressure hot gas exiting at high peak velocity. The outlet of the engine core **12** (i.e. the outlet of each engine of the engine core **12**) is in fluid communication with the inlet of the turbine section **18**, and accordingly the exhaust flow from the engine core **12** is supplied to the turbine section **18**.

The turbine section **18** includes at least one rotor engaged on a turbine shaft **19**. Mechanical energy recovered by the turbine section **18** is compounded with that of the engine shaft **16** to drive the propeller **8**. The turbine shaft **19** is mechanically linked to, and in driving engagement with, the engine shaft **16** through a reduction gearbox **24**, for example through an offset gear train with idler gear. In a particular embodiment, the elements of the reduction gearbox **24** (e.g. offset gear train) are configured to define a reduction ratio of approximately 5:1 between the turbine shaft **19** and the engine shaft **16**. The engine shaft **16** is also mechanically linked to, and in driving engagement with, the propeller **8** through the same reduction gearbox **24**. In a particular embodiment, the reduction gearbox **24** includes two gear train branches: a compounding branch **24***c* mechanically linking the turbine shaft **19** and the engine shaft **16** and a downstream planetary branch **24***p* mechanically linking the engine shaft **16** and propeller **8**. In another embodiment, the turbine shaft **19** and engine shaft **16** may be engaged to the propeller **8** through different gearboxes, or the turbine shaft **19** may be engaged to the engine shaft **16** separately from the engagement between the engine shaft **16** and the propeller **8**. In particular embodiment, the turbine shaft **19** is engaged to the compressor gearbox **20**.

As can be seen in FIGS. **1** and **3**, the turbine shaft **19** is parallel to and radially offset from (i.e., non-coaxial to) the engine shaft **16** and compressor shaft **15**. The compressor rotor(s) **14***a* and engine shaft **16** are thus rotatable about a common axis (central axis of the compressor and engine shafts **15**, **16**) which is parallel to and radially offset from the axis of rotation of the turbine rotor(s) **26***a*, **28***a* (central axis of the turbine shaft **19**). In a particular embodiment, the offset configuration of the turbine section **18** allows for the turbine section **18** to be enclosed in a casing separate from that of the engine core **12** and the compressor **14**, such that the turbine section **18** is modular and removable (e.g. removable on-wing) from the remainder of the compound engine assembly **10**.

Referring particularly to FIG. **1**, the turbine section **18** may include one or more turbine stages. In a particular embodiment, the turbine section **18** includes a first stage turbine **26** receiving the exhaust from the engine core **12**, and a second stage turbine **28** receiving the exhaust from the first stage turbine **26**. The first stage turbine **26** is configured as a velocity turbine, also known as an impulse turbine, and recovers the kinetic energy of the core exhaust gas while creating minimal or no back pressure to the exhaust of the engine core **12**. The second stage turbine **28** is configured as a pressure turbine, also known as a reaction turbine, and completes the recovery of available mechanical energy from the exhaust gas. Each turbine **26**, **28** may be a centrifugal or axial device with one or more rotors having radial, axial or mixed flow blades. In another embodiment, the turbine section **18** may include a single turbine, configured either as an impulse turbine or as a pressure turbine.

A pure impulse turbine works by changing the direction of the flow without accelerating the flow inside the rotor; the fluid is deflected without a significant pressure drop across the rotor blades. The blades of the pure impulse turbine are designed such that in a transverse plane perpendicular to the direction of flow, the area defined between the blades is the same at the leading edges of the blades and at the trailing edges of the blade: the flow area of the turbine is constant, and the blades are usually symmetrical about the plane of the rotating disc. The work of the pure impulse turbine is due only to the change of direction in the flow through the turbine blades. Typical pure impulse turbines include steam and hydraulic turbines.

In contrast, a reaction turbine accelerates the flow inside the rotor but needs a static pressure drop across the rotor to enable this flow acceleration. The blades of the reaction turbine are designed such that in a transverse plane perpendicular to the direction of flow, the area defined between the blades is larger at the leading edges of the blades than at the trailing edges of the blade: the flow area of the turbine reduces along the direction of flow, and the blades are usually not symmetrical about the plane of the rotating disc. The work of the pure reaction turbine is due mostly to the acceleration of the flow through the turbine blades.

Most aeronautical turbines are not "pure impulse" or "pure reaction", but rather operate following a mix of these two opposite but complementary principles—i.e. there is a pressure drop across the blades, there is some reduction of flow area of the turbine blades along the direction of flow, and the speed of rotation of the turbine is due to both the acceleration and the change of direction of the flow. The degree of reaction of a turbine can be determined using the temperature-based reaction ratio (equation 1) or the pressure-based reaction ratio (equation 2), which are typically close to one another in value for a same turbine:

$$\text{Reaction}(T) = \frac{(t_{S3} - t_{S5})}{(t_{S0} - t_{S5})} \quad (1)$$

$$\text{Reaction}(P) = \frac{(P_{S3} - P_{S5})}{(P_{S0} - P_{S5})} \quad (2)$$

where T is temperature and P is pressure, s refers to a static port, and the numbers refers to the location the temperature or pressure is measured: 0 for the inlet of the turbine vane (stator), 3 for the inlet of the turbine blade (rotor) and 5 for the exit of the turbine blade (rotor); and where a pure impulse turbine would have a ratio of 0 (0%) and a pure reaction turbine would have a ratio of 1 (100%).

In a particular embodiment, the first stage turbine **26** is configured to take benefit of the kinetic energy of the pulsating flow exiting the engine core **12** while stabilizing the flow and the second stage turbine **28** is configured to extract energy from the remaining pressure in the flow while expanding the flow. Accordingly, the first stage turbine **26** has a smaller reaction ratio than that of the second stage turbine **28**.

In a particular embodiment, the second stage turbine **28** has a reaction ratio higher than 0.25; in another particular embodiment, the second stage turbine **28** has a reaction ratio higher than 0.3; in another particular embodiment, the second stage turbine **28** has a reaction ratio of about 0.5; in another particular embodiment, the second stage turbine **28** has a reaction ratio higher than 0.5.

In a particular embodiment, the first stage turbine **26** has a reaction ratio of at most 0.2; in another particular embodiment, the first stage turbine **26** has a reaction ratio of at most 0.15; in another particular embodiment, the first stage turbine **26** has a reaction ratio of at most 0.1; in another particular embodiment, the first stage turbine **26** has a reaction ratio of at most 0.05.

It is understood that any appropriate reaction ratio for the second stage turbine **28** (included, but not limited to, any of the above-mentioned reaction ratios) can be combined with any appropriate reaction ratio for the first stage turbine **26** (included, but not limited to, any of the above-mentioned reaction ratios), and that these values can correspond to pressure-based or temperature-based ratios. Other values are also possible. For example, in a particular embodiment, the two turbines **26**, **28** may have a same or similar reaction ratio; in another embodiment, the first stage turbine **26** has a higher reaction ratio than that of the second stage turbine **28**. Both turbines **26**, **28** may be configured as impulse turbines, or both turbines **26**, **28** may be configured as pressure turbines.

In an embodiment where the engine core **12** includes one or more rotary engine(s) each operating with the Miller cycle, the compressor pressure ratio and the turbine section pressure ratio may be higher than a similar engine assembly where the engine core includes one or more rotary engine(s) having similar or equal volumetric compression and expansion ratios. The higher pressure ratio in the turbine section may be accommodated by additional axial turbine stage(s), an additional radial turbine, and/or a combination of axial and radial turbines suitable to accept the higher pressure ratio.

Referring to FIG. **4**, a nacelle installation of the compound engine assembly **10** according to a particular embodiment is shown. The installation includes an intake assembly **66** which features a common inlet **68** and air conduit **70** for the engine assembly (through the compressor **14**) and the oil and coolant heat exchangers **72**, **74**. The air conduit **70** extends from the inlet **68** to an opposed outlet **76**. The inlet **68** and outlet **76** of the air conduit **70** communicate with ambient air outside of or around the assembly **10**, for example ambient air outside of a nacelle receiving the assembly. In the embodiment shown, the ambient air penetrates the compound engine assembly **10** through the inlet **68** of the air conduit **70**—the inlet **68** of the air conduit **70** thus defines a nacelle inlet, i.e. an inlet of the assembly **10** as a whole.

It can be seen that the heat exchangers **72**, **74** extend across the air conduit **70**, such that the airflow through the air conduit **70** circulates through the heat exchangers **72**, **74**. In the embodiment shown, the heat exchangers **72**, **74** include an oil heat exchanger **72** which receives the oil from the engine assembly oil system and circulates it in heat exchange relationship with the airflow, such as to cool the oil; and a coolant heat exchanger **74** which receives the coolant from the engine core **12** (e.g. water, oil or other liquid coolant) and circulates it in heat exchange relationship with the airflow, such as to cool the coolant. Although two heat exchangers **72**, **74** are shown, it is understood that alternately a single heat exchanger or more than two heat exchangers may be provided in the air conduit **70**. The two heat exchangers **72**, **74** are shown as being placed in parallel, such that a portion of the airflow separately circulates through each heat exchanger. Alternately, the heat exchangers **72**, **74** may be placed in the air conduit **70** in series such that the same portion of the airflow circulates through one than through the other of the heat exchangers, although such a configuration may necessitate the use of larger heat exchangers. It is also understood that the angle of the heat exchangers **72**, **74** within the conduit **70** may be different from that shown. In a particular embodiment, the angle of the heat exchangers **72**, **74** with respect to the airflow within the conduit **70** is selected to obtain a desired balance between pressure losses and effectiveness of the heat exchangers, in consideration of the available space within the conduit **70**.

The intake assembly **66** includes an intake plenum **78** configured for connection to and fluid communication with the inlet of the compressor **14**. In the embodiment shown and as can be more clearly seen in FIG. **5**, the intake plenum **78** is annular. Other configurations are possible.

Referring to FIGS. **4**, **5** and **6**A, the intake assembly **66** includes first and second intake conduits **80**, **82** providing fluid communication between the air conduit **70** and the intake plenum **78**. The first intake conduit **80** is connected to the air conduit **70** upstream of the heat exchangers **72**, **74**, so that the portion of the air conduit **70** upstream of the heat exchangers **72**, **74** defines a first source of air. The second intake conduit **82** is connected to the air conduit **70** downstream of the heat exchangers **72**, **74**, so that the portion of the air conduit **70** downstream of the heat exchangers **72**, **74** defines a second source of air warmer than the first source. In the embodiment shown and as can be more clearly seen in FIG. **4**, the air conduit **70** is configured to define a diffuser upstream of the heat exchangers **72**, **74**, such as to decelerate the flow to a low velocity flow at the inlet of the heat exchangers **72**, **74**. The first intake conduit **80** is connected in the diffuser; in a particular embodiment, the first intake conduit **80** is connected to the air conduit **70** where air velocity is at a minimum. Such a configuration may allow for minimizing of pressure losses.

Referring to FIGS. **6**A-**6**B, in a particular embodiment, the intake conduits **80**, **82** are in fluid communication with the intake plenum **78** through an engine intake **84** containing an air filter **86**. An air filter bypass valve **88** is provided in the engine intake **84** to allow airflow to the intake plenum **78** around the air filter **86** in case of inadvertent air filter blockage. In a particular embodiment, the air filter bypass valve **86** is a spring loaded pressure differential operated valve.

The intake assembly **66** further includes a selector valve **90** positioned upstream of the air filter **86** and allowing for the selection of the intake conduit **80**, **82** used to circulate the air from the air conduit **70** to the intake plenum **78**. The selector valve **90** is thus configurable between a configuration where the fluid communication between the intake plenum **78** and the air conduit **70** through the first intake conduit **80** is allowed and a configuration where the fluid communication between the intake plenum **78** and the air conduit **70** through the first intake conduit **80** is prevented.

In the particular embodiment shown in FIG. **4**, the selector valve **90** only acts to selectively block or prevent the communication through the first intake conduit **80**, i.e. the intake conduit connected to the air conduit **70** upstream of the heat exchangers **72**, **74**. The communication through the second intake conduit **82** remains open in both configurations.

In the particular embodiment shown in FIGS. **6**A and **6**B, the selector valve **90** is provided at a junction between the two intake conduits **80**, **82**, and acts to selectively block or prevent the communication through both intake conduits **80**, **82**. Accordingly, in the configuration shown in FIG. **6**A, the selector valve **90** allows the fluid communication between the intake plenum **78** and the air conduit **70** through the first intake conduit **80** while preventing the fluid communication between the intake plenum **78** and the air conduit **70** through the second intake conduit **82**; and in the configuration shown in FIG. **6**B, the selector valve **90** prevents the fluid communication between the intake plenum **78** and the air conduit **70** through the first intake conduit **80** while allowing the fluid communication between the intake plenum **78** and the air conduit **70** through the second intake conduit **82**. In the embodiments shown, the selector valve **90** includes a flap pivotable between the two configurations, and blocks the communication through one or the other of the intake conduits **80**, **82** by blocking the communication between that intake conduit **80**, **82** and the intake plenum **78**. Other types of valves **90** and/or valve positions are also possible.

The selector valve **90** thus allows for the selection of cooler air (first intake conduit **80**, taking air upstream of the heat exchangers **72**, **74**) or warmer air (second intake conduit **82**, taking air downstream of the heat exchangers **72**, **74**) to feed the compressor **14** and engine assembly **10**, based on the operating conditions of the engine assembly **10**. For example, in icing conditions, the fluid communication through the second conduit **82** may be selected by blocking the fluid communication through the first conduit **80**, so that that the warmer air from downstream of the heat exchangers **72**, **74** is used to feed the compressor **14**, such as to provide de-icing capability for the engine intake **84**, air filter **86**, intake plenum **78** and compressor inlet with fixed and variable geometries; and in non-icing flight conditions, the fluid communication through the first conduit **80** may be selected so that colder air is used to feed the compressor **14** to provide for better engine performance (as compared to hotter air).

Also, selection of the flow through the second intake conduit **82** to extract the engine air downstream of the heat exchangers **72**, **74** can be used to generate airflow through the heat exchangers **72**, **74**. For example, for a turboprop engine at ground idle, there is no inlet ram pressure to force air through the air conduit **70** and heat exchangers **72**, **74**, and the propeller pressure rise may not be sufficient to draw enough air to provide sufficient cooling in the heat exchangers **72**, **74**; similar conditions may occur at taxi operations on the ground (engine at low power). Extracting the engine air downstream of the heat exchangers **72**, **74** produces a "sucking" effect pulling the air through the heat exchangers **72**, **74**, which in a particular embodiment may allow for sufficient cooling without the need of a fan or blower to provide for the necessary air circulation. A bleed-off Valve **75** can optionally be provided downstream of the compressor **14** and upstream of the engine core **12** (i.e. in the fluid communication between the compressor outlet and the engine core inlet), and opened during idle or taxi operation to increase compressor flow such as to increase the "sucking" effect of extracting the engine air downstream of the heat exchangers **72**, **74**, and accordingly increase the airflow through the heat exchangers **72**, **74**. Moreover, an intercooler may optionally be provided just upstream of the engine core **12** to cool the compressor flow prior to routing it to the engine core.

In a particular embodiment, the engine intake assembly **66** can be configured as an inertial particle separator when the fluid communication through the first conduit **80** is selected, so that when the air from upstream of the heat exchangers **72**, **74** is used to feed the engine, the heavy particles are entrained downstream of the heat exchangers **72**, **74**. In the embodiment shown in FIG. **4**, the junction between the first conduit **80** and the air conduit **70** is configured as the inertial particle separator: the first conduit **80** defines a sharp turn with respect to the air conduit **70** (e.g. by extending close to or approximately perpendicular thereto), extending at a sufficient angle from the air conduit **70** such that the heavier particles (e.g. ice, sand) continue on a straight path while the air follows the sharp turn, and by the first conduit **80** and air conduit **70** are sized to achieve adequate air velocities to ensure separation of the particles.

In the embodiment shown, the air conduit **70** is configured such that all of the air entering the air conduit **70** is circulated through the heat exchangers **72**, **74** and/or to the intake plenum **78**. Alternately, a bypass conduit could be provided such that a portion of the air entering the conduit **70** is diverted from (i.e. bypasses) the heat exchangers **72**, **74** and the intake plenum **78** and is instead directly circulated to the outlet **76**. In a particular embodiment, the junction between the bypass conduit and the air conduit **70** is configured as the inertial particle separator, through selection of an appropriate orientation and relative sizing of the bypass conduit with respect to the air conduit **70**.

In a particular embodiment and as shown in FIG. **7**, the lip of the assembly inlet **68** is de-iced by circulating hot coolant through a coil tube **98** disposed in the lip and made of material having appropriate heat conduction properties. The coil tube **98** has an inlet in fluid communication with the coolant system of the engine core **12** and an outlet in fluid communication with the coolant heat exchanger **74**, such that a fraction of the hot coolant flowing out of the engine core **12** is routed to the coil tube **98** of the inlet lip **68** for de-icing, and then rejoins the remainder of the hot coolant flow from the engine core **12** prior to sending the flow to the heat exchanger **74**.

Although in the embodiment shown the heat exchangers **72**, **74** and engine assembly **10** have a common inlet **68** and the first and second intake conduits **80**, **82** communicate with a same air conduit **70** extending from that inlet, it is understood that alternately the engine assembly **10** and heat exchangers **72**, **74** may have separate inlets. The first intake conduit **80** may thus communicate with a source of fresh air separate from that feeding the heat exchangers **72**, **74**.

Alternately, the common inlet **68** and air conduit **70** used to feed the heat exchangers **72**, **74** and the compressor **14** may be used with a single intake conduit providing the fluid communication between the intake plenum **78** and the air conduit **70**, and connected to the air conduit **70** at any appropriate location (downstream or upstream of the heat exchangers).

Referring back to FIG. **4**, in a particular embodiment, variable cowl flaps **92** are pivotally connected to an outer wall **94** of the air conduit **70** downstream of the heat exchangers **72**, **74**, each adjacent a respective opening **96** defined through the outer wall **94**. The flaps **92** are movable between an extended position (shown) where they extend away from the respective opening **96** and a retracted position where they close the respective opening **96**, such as to modulate the airflow through the air conduit **70** and heat exchangers **72**, **74**. The openings **96** communicate with ambient air outside of or around the assembly **10** when the flaps are extended, for example ambient air outside of a nacelle receiving the assembly, such that air from the air conduit **70** may exit the conduit through the openings **96**. In a particular embodiment, the cowl flaps **92** are positioned in accordance with the power demand on the engine assembly **10**, such as to regulate the temperature of the oil and coolant being cooled in the heat exchangers **72**, **74** while reducing or minimizing cooling drag; for example, the cowl flaps **92** are open at take-off and closed at cruise speed.

The cowl flaps **92** may have any appropriate configuration. For example, in a particular embodiment, the cowl flaps **92** have a straight airfoil shape; in another embodiment, the cowl flaps **92** have a cambered airfoil shape, configured to flow the exit air horizontally to produce a more effective thrust. In a particular embodiment, the cowl flaps **92** are configured as louvers, each connected to a rod, and an actuator slides the rod to pivot the cowl flaps **92** between the extended and retracted positions to open or close the louvers. Other configurations are also possible.

In a particular embodiment, the air conduit outlet **76** downstream of the cowl flaps **92** is shaped to define a nozzle, to form an exit jet opening. In a particular embodiment, the configuration of the nozzle is optimized to minimize the drag induced by the heat exchangers **72**, **74** at the cruise speed operating conditions.

Although any of the above described and shown features and any combination thereof may provide for a suitable configuration to be used as a turboprop engine and/or be received in an aircraft nacelle, in a particular embodiment, the combination of all of the above described and shown features of the compound engine assembly provide for an engine configuration specifically tailored for use as an aircraft turboprop engine.

The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the invention disclosed. For example, although the engine assembly has been described as a compound engine assembly, it is understood that elements of the compound engine assembly can be used with non-compounded engine assemblies, and with compound engine assemblies having different configurations, for example engine assemblies where the compressor is in driving engagement with the turbine section without being directly engaged to the engine core; such elements include, but are not limited to, the intake assembly and its components. Still other modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

The invention claimed is:

1. A compound engine assembly comprising:

a compressor;

an engine core including at least one internal combustion engine each having a rotor sealingly and rotationally received within a respective internal cavity to provide rotating chambers of variable volume in the respective internal cavity, the engine core having an inlet in fluid communication with an outlet of the compressor;

a turbine section having an inlet in fluid communication with an outlet of the engine core, the turbine section configured to compound power with the engine core; and

an air conduit having at least one heat exchanger extending thereacross such that an airflow through the air conduit circulates through the at least one heat exchanger, each of the at least one heat exchanger configured to circulate a fluid to be cooled in heat exchange relationship with the airflow circulating therethrough, the air conduit having opposed inlet and outlets in fluid communication with ambient air around the compound engine assembly;

wherein an outer wall of the air conduit has a plurality of openings defined therethrough downstream of the at least one heat exchanger, each of the plurality of openings being selectively closable by a respective pivotable flap movable between a retracted position where the opening is obstructed and an extended position away from the opening, each of the plurality of openings defining a fluid communication between the air conduit and the ambient air around the compound engine assembly when the respective pivotable flap is in the extended position.

2. The compound engine assembly as defined in claim **1**, wherein the rotor of each of the at least one internal combustion engine has three apex portions separating the rotating chambers and mounted for eccentric revolutions within the respective internal cavity, the respective internal cavity having an epitrochoid shape with two lobes.

3. The compound engine assembly as defined in claim **1**, wherein an inlet of the compressor is in fluid communication with the air conduit through an intake conduit connected to the air conduit upstream of the at least one heat exchanger.

4. The compound engine assembly as defined in claim **3**, wherein the air conduit defines a diffuser upstream of the at least one heat exchanger, the intake conduit being connected to the air conduit in the diffuser.

5. The compound engine assembly as defined in claim **1**, wherein an inlet of the compressor is in fluid communication with the air conduit through a first intake conduit connected to the air conduit upstream of the at least one heat exchanger and through a second intake conduit connected to the air conduit downstream of the at least one heat exchanger, the assembly further comprising a selector valve configurable to selectively open and close at least the fluid communication between the inlet of the compressor and the first intake conduit.

6. The compound engine assembly as defined in claim **1**, wherein the turbine section includes a first stage turbine having an inlet in fluid communication with the outlet of the engine core, and a second stage turbine having an inlet in fluid communication with an outlet of the first stage turbine.

7. The compound engine assembly as defined in claim **6**, wherein the first stage turbine is configured as an impulse turbine with a pressure-based reaction ratio having a value of at most 0.25, the second stage turbine having a higher reaction ratio than that of the first stage turbine.

8. A compound engine assembly comprising:

a compressor;

an engine core including at least one rotary internal combustion engine in driving engagement with an engine shaft, the engine core having an inlet in fluid communication with an outlet of the compressor;

a turbine section having an inlet in fluid communication with an outlet of the engine core, the turbine section including at least one turbine rotor engaged on a rotatable turbine shaft, the turbine shaft and the engine shaft being drivingly engaged to a same rotatable load;

an air conduit having an inlet in fluid communication with ambient air around the compound engine assembly and an opposed outlet, the air conduit having at least one heat exchanger extending thereacross such that an airflow through the air conduit circulates through the at least one heat exchanger, each of the at least one heat exchanger configured to circulate a fluid to be cooled in heat exchange relationship with the airflow circulating therethrough, the air conduit having an outer wall including openings defined therethrough downstream of the at least one heat exchanger; and

a plurality of pivotable flaps each attached to the outer wall adjacent a respective one of the openings and each movable between an extended position away from the opening and a retracted position closing the respective opening.

9. The compound engine assembly as defined in claim **8**, wherein each of the at least one rotary internal combustion engine includes a rotor sealingly and rotationally received within a respective internal cavity to provide rotating chambers of variable volume in the respective internal cavity, the rotor having three apex portions separating the rotating chambers and mounted for eccentric revolutions within the respective internal cavity, the respective internal cavity having an epitrochoid shape with two lobes.

10. The compound engine assembly as defined in claim **8**, wherein the air conduit is in fluid communication with an inlet of the compressor.

11. The compound engine assembly as defined in claim **8**, wherein the air conduit defines a diffuser upstream of the at least one heat exchanger.

12. The compound engine assembly as defined in claim **8**, wherein an inlet of the compressor is in fluid communication with the air conduit through a first intake conduit connected to the air conduit upstream of the at least one heat exchanger and through a second intake conduit connected to the air conduit downstream of the at least one heat exchanger, the assembly further comprising a selector valve configurable to selectively open and close at least the fluid communication between the inlet of the compressor and the first intake conduit.

13. The compound engine assembly as defined in claim **8**, wherein the turbine section includes a first stage turbine having an inlet in fluid communication with the outlet of the engine core, and a second stage turbine having an inlet in fluid communication with an outlet of the first stage turbine.

14. The compound engine assembly as defined in claim **13**, wherein the first stage turbine is configured as an impulse turbine with a pressure-based reaction ratio having a value of at most 0.25, the second stage turbine having a higher reaction ratio than that of the first stage turbine.

15. A method of directing flow through a compound engine assembly, the method comprising:

directing air into an inlet of a compressor of the compound engine assembly;

directing compressed air from the compressor to an inlet of at least one rotary internal combustion engine of the compound engine assembly, the at least one rotary internal combustion engine driving rotation of an engine shaft;

directing exhaust from the at least one rotary internal combustion engine on at least one turbine rotor of a turbine section of the compound engine assembly to drive rotation of a turbine shaft, the turbine shaft compounding power with the engine shaft to drive a rotatable load; and

directing air through an air conduit containing at least one heat exchanger and through the at least one heat exchanger to cool a fluid of the compound engine assembly, including modulating a flow of the air through the at least one heat exchanger by selectively opening and closing a plurality of openings defined in an outer wall of the air conduit downstream of the at least one heat exchanger.

16. The method as defined in claim **15**, wherein directing the air into the inlet of the compressor includes directing the air from the air conduit into the inlet of the compressor.

17. The method as defined in claim **16**, wherein directing the air from the air conduit into the inlet of the compressor includes actuating a selector valve to direct the air through one of first and second intake conduits, the first intake conduit connected to the air conduit upstream of the at least one heat exchanger, and the second intake conduit connected to the air conduit downstream of the at least one heat exchanger and upstream of the plurality of openings.

18. The method as defined in claim **17**, wherein the compound engine assembly is an aircraft engine, the method further comprising determining of the aircraft engine is at ground idle, and operating the selector valve to direct the air through the second intake conduit when the aircraft engine is at ground idle.

19. The method as defined in claim **17**, wherein the compound engine assembly is an aircraft engine, the method further comprising determining if the aircraft engine is operating in icing conditions, and operating the selector valve to direct the air through the second intake conduit when the aircraft engine is operating in icing conditions.

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