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POWER SYSTEM FOR A FLIGHT VEHICLE

Abstract

A power system for a flight vehicle includes a first power plant and a second power plant. The second power plant is configured to combust a fuel-fluid mixture. The first power plant includes a closed fluid loop configured to contain a working fluid. The first power plant includes a compressor configured to compress the working fluid. The first power plant includes a thermal engine coupled to the compressor and configured to operate the compressor. In certain configurations, the first power plant includes a container encasing the closed fluid loop, the compressor, and the thermal engine. In various configurations, the power system is coupled to a primary propulsor of the flight vehicle and configured to provide power to the primary propulsor. The power system is separate from the primary propulsor such that the primary propulsor is continuously operable independently of the power system to provide power to operate the flight vehicle.

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Background/Summary

BACKGROUND

[0001] Many flight vehicles are powered by one or more turbine engines and may have an auxiliary power unit configured of a small gas turbine and a recuperator. However, the small gas turbine traditionally encounters low compression ratios due to the physics and manufacturability of the small gas turbine. Furthermore, a traditional recuperator is heavy due to the materials used to withstand exhaust gas temperatures of the small gas turbine that are directed through the traditional recuperator. For example, one traditional recuperator is a solid-state recuperator, which is typically made mostly of nickel alloys.

SUMMARY

[0002] Traditional recuperators may be heavy due to the types of materials being used to form the recuperator, such as nickel alloys. Therefore, it is desirable to develop a power system that improves a small gas turbine without using a traditional recuperator as discussed above. That is, the power system described herein provides improved power to weight ratio.

[0003] The present disclosure provides a power system for a flight vehicle. The power system includes a first power plant and a second power plant. The second power plant is configured to combust a fuel-fluid mixture. The first power plant includes a closed fluid loop configured to contain a working fluid. The first power plant also includes a compressor configured to compress the working fluid. The first power plant further includes a thermal engine coupled to the compressor and configured to operate the compressor.

[0004] The present disclosure also provides a flight vehicle that includes a primary propulsor and a power system coupled to the primary propulsor and configured to provide power to the primary propulsor. The power system is separate from the primary propulsor such that the primary propulsor is continuously operable independently of the power system to provide power to operate the flight vehicle. The power system includes a first power plant. The first power plant includes a closed fluid loop configured to contain a working fluid. The first power plant also includes a compressor configured to compress the working fluid. The first power plant further includes a thermal engine coupled to the compressor and configured to operate the compressor.

[0005] The present disclosure further provides a first power plant for a power system of a flight vehicle. The flight vehicle includes a primary propulsor. The first power plant includes a closed fluid loop configured to contain a working fluid. The first power plant also includes a compressor configured to compress the working fluid. The first power plant further includes a thermal engine coupled to the compressor and configured to operate the compressor. The first power plant includes a container encasing the closed fluid loop, the compressor, and the thermal engine. The first power plant is continuously operable independently of the primary propulsor to provide power to operate the flight vehicle.

[0006] The detailed description and the drawings or figures are supportive and descriptive of the disclosure, but the claim scope of the disclosure is defined solely by the claims. While some of the best modes and other configurations for carrying out the claims have been described in detail, various alternative designs and configurations exist for practicing the disclosure defined in the appended claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a schematic illustration of a flight vehicle and a power system for the flight vehicle.

[0008] FIG. **2** is a schematic illustration of the power system including a first power plant having a closed fluid loop and a second power plant having an exhaust-fluid path.

[0009] FIG. **3** is a schematic illustration of a first configuration of the first power plant and the second power plant of the power system.

[0010] FIG. **4** is a schematic illustration of a second configuration of the first power plant and the second power plant of the power system.

[0011] FIG. **5** is a schematic illustration, in partial cross-sectional view, of a third configuration of the first power plant and the second power plant of the power system.

[0012] FIG. **6** is a schematic illustration of a fourth configuration of the first power plant and the second power plant of the power system.

[0013] FIG. **7** is a schematic illustration, in partial cross-sectional view, of a fifth configuration of the first power plant and the second power plant of the power system.

[0014] FIG. **8** is a graph of an example supercritical working fluid.

[0015] FIG. **9** is a schematic illustration of a container that houses the first power plant and the second power plant of any of the first-fifth configurations.

[0016] FIG. **10** is a schematic illustration of a plurality of the containers of FIG. **9** stacked relative to each other.

[0017] The present disclosure may be extended to modifications and alternative forms, with representative configurations shown by way of example in the drawings and described in detail below. Inventive aspects of the disclosure are not limited to the disclosed configurations. Rather, the present disclosure is intended to cover modifications, equivalents, combinations, and alternatives falling within the scope of the disclosure as defined by the appended claims.

DETAILED DESCRIPTION

[0018] Those having ordinary skill in the art will recognize that all directional references (e.g., above, below, upward, up, downward, down, top, bottom, left, right, vertical, horizontal, etc.) are used descriptively for the FIGS. to aid the reader's understanding, and do not represent limitations (for example, to the position, orientation, or use, etc.) on the scope of the disclosure, as defined by the appended claims. Moreover, terms such as “first,” “second,” “third,” and so on, may be used to describe separate components. Such terminology may include the words specifically mentioned above, derivatives thereof, and words of similar import. Furthermore, the term “substantially” can refer to a slight imprecision or slight variance of a condition, quantity, value, or dimension, etc., some of which are within manufacturing variance or tolerance ranges.

[0019] As used herein, an element or step recited in the singular and preceded by the word “a” or “an” should be understood as not necessarily excluding the plural of the elements or steps. Further, any reference to “one configuration” is not intended to be interpreted as excluding the existence of additional configurations that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, configurations “comprising” or “having” an element or a plurality of elements having a particular property may include additional elements not having that property. The phrase “at least one of” as used herein should be construed to include the non-exclusive logical “or”, i.e., A and/or B and so on depending on the number of components.

[0020] Referring to the figures, wherein like numerals indicate like or corresponding parts throughout the several views, a flight vehicle **10** and a power system **12**A-**12**E for the flight vehicle **10** is generally shown in FIG. **1**. Generally, the power system **12**A-**12**E as described herein may be used to provide sufficient power to operate the flight vehicle **10** without the use of a traditional recuperator as discussed above, which provides various benefits, improvements, advantages, etc., some of which are discussed below.

[0021] The flight vehicle **10** may be any suitable configuration, and non-limiting examples of the flight vehicle **10** may include an aircraft, a helicopter, a jet, a vertical take-off and landing (VTOL) aircraft, a space shuttle, a drone, a payload, or any other suitable flight vehicle **10**. As such, the flight vehicle **10** may be a manned vehicle that is flown by one or more pilots therein, or may be an unmanned flight vehicle **10** that is flown without a pilot therein (e.g., a drone, etc.).

[0022] The structure of the flight vehicle **10** as shown in FIG. **1** is one non-limiting example, and it is to be appreciated that the flight vehicle **10** may be configured differently than shown and still utilize the features described herein. In the example of FIG. **1**, the flight vehicle **10** may include a fuselage **14** and a plurality of wings **16** extending from opposite sides of fuselage **14**. The flight vehicle **10** may include a tail **18** having one or more tail-wings that extend from the fuselage **14** and/or the tail **18**.

[0023] The flight vehicle **10** may include a primary propulsor **20**, and in the example of FIG. **1**, one primary propulsor **20** is attached one of the wings **16** and another primary propulsor **20** is attached to another one of the wings **16**. The primary propulsor **20** may provide thrust for wing-borne flight, and may include one or more propellers, fans, rotors, etc. Optionally, the primary propulsor **20** may include one or more engines including jet engines, electric machines, electric motors, or any other suitable engine to drive one or more of the propellers, fans, rotors, etc. Various power may be distributed to other locations of the flight vehicle **10** from the primary propulsor(s) **20**, and for illustrative purposes, FIG. **1** illustrates an electrical power feed **20**A, a hydraulic power feed **20**B, and an optional pneumatic power feed **20**C.

[0024] Referring to FIG. **1**, the power system **12**A-**12**E is coupled to the primary propulsor **20**, and thus, may be configured to provide power to the primary propulsor **20** or other locations of the flight vehicle **10**. In certain configurations, the power system **12**A-**12**E may be housed in the tail **18** of the flight vehicle **10**, and is electrically connected to various controllers and/or systems of the flight vehicle **10**, such as electrical systems, battery systems, the primary propulsors **20**, primary or secondary systems, flight controllers, system controllers, etc., to provide electrical power thereto. Generally, the power system **12**A-**12**E is separate from the primary propulsor **20** such that the primary propulsor **20** is continuously operable independently of the power system **12**A-**12**E to provide power to operate the flight vehicle **10**. In other words, the primary propulsor **20** will continue to thrust the flight vehicle **10** through the atmosphere, while the power system **12**A-**12**E provides power, such as electrical power, to other systems of the flight vehicle **10**.

[0025] Referring to FIG. **2**, the power system **12**A-**12**E is generally illustrated without providing the specific features of each of the configurations of FIGS. **3-7**. That is, FIG. **2** is a high-level illustration of the power system **12**A-**12**E that is suitable for any of the configurations of FIGS. **3-7**. The details of the power system **12**A-**12**E are provided below when each configuration is discussed.

[0026] Continuing with FIG. **2**, the power system **12**A-**12**E includes a first power plant **22**, and may include a second power plant **24** that cooperates with the first power plant **22** to provide an efficient-small engine. Generally, the second power plant **24** may include a turbine engine that creates hot exhaust gases as a by-product of operation of the turbine engine, and the first power plant **22** may use heat created by the exhaust gases of the second power plant **24** to operate as a heat pump. Therefore, the power system **12**A-**12**E may include a power generator being optimized by the first power plant **22** as the heat pump, and the power system **12**A-**12**E may be continuously operable, and thus, thermal management of batteries and/or electronics may be improved by being able to continuously maintain optimum operational temperatures while the power system **12**A-**12**E remains continuously operable. Furthermore, by the first power plant **22** operating as the heat pump, the traditional recuperator as discussed above under the background section may be eliminated. That is, the first power plant **22** is not a solid-state recuperator, which as discussed under the background heading is typically formed mostly of nickel alloys. A weight savings may be obtained by using the first power plant **22** as compared to using the traditional recuperator.

[0027] In certain configurations, the first power plant **22** is continuously operable independently of the primary propulsor **20** to provide power to operate the flight vehicle **10**. In other words, the primary propulsor **20** will continue to thrust the flight vehicle **10** through the atmosphere, while the first power plant **22** provides power to other systems of the flight vehicle **10** and may provide thermal management of one or more battery packs and/or electronics.

[0028] Generally, the first power plant **22** includes a closed fluid loop **26** configured to contain a working fluid **28**. In certain configurations, the closed fluid loop **26** is a Brayton cycle, in which heat from the hot exhaust gases (produced via the second power plant **24**) are thermally transferred to the closed fluid loop **26** and used in the Brayton cycle to operate as the heat pump. Therefore, the first power plant **22** with the associated fluid loop **26** may be referred to as a closed loop Brayton cycle, while the second power plant **24** and associated path (discussed below) may be referred to as an open loop Brayton cycle.

[0029] In certain configurations, the working fluid **28** is in a supercritical state. That is, depending on the type of the working fluid **28** being used, the working fluid **28** may be in the supercritical state. For example, the working fluid **28** may be used in the closed fluid loop **26** due to a magnitude of heat generated via the flight vehicle **10** at the high speed, and the magnitude of heat absorbed by the working fluid **28** maintains the working fluid **28** in the supercritical state. The working fluid **28** attains the supercritical state when a temperature and a pressure of the working fluid **28** is above a critical point (see FIG. **8**). Therefore, heat from the second power plant **24** of the flight vehicle **10** is thermally transferred to the working fluid **28** in the fluid loop, which maintains the working fluid **28** at the temperature and the pressure above the critical point. Components to assist in achieving/maintaining the working fluid **28** at the desired temperature and the desired pressure are discussed further below.

[0030] FIG. **8** graphically illustrates the critical point of the working fluid **28**, where temperatures and pressures above the critical point will result in the supercritical state. The working fluid **28** may be any suitable substance, some of which achieve the supercritical state and some of which do not achieve the supercritical state. Non-limiting examples of the working fluid **28** may include supercritical carbon dioxide (SCO.sub.2), supercritical helium (sHe), molten salt(s), sodium-potassium alloy (NaK), cesium, lithium, etc. Therefore, examples of the working fluid **28** that achieve the supercritical state may include carbon dioxide, helium, methane, inert gas including argon, neon, etc., or any other suitable working fluid that achieves the supercritical state, and examples of the working fluid **28** that do not achieve the supercritical state may include molten salt(s), sodium-potassium alloy (NaK), cesium, lithium, oil including turbine oil, dielectric oil, etc., water, or any other suitable working fluid that does not achieve the supercritical state.

[0031] Referring to FIG. **2**, the power system **12**A-**12**E may also include the second power plant **24** configured to combust a fuel-fluid mixture. More specifically, the second power plant **24** may include a combustor **30** (see FIGS. **3-7**) to combust the fuel-fluid mixture. The fuel-fluid mixture may include any suitable fuels and fluids, and non-limiting examples of the fuel may include petroleum; jet fuel; hydrocarbon fuel including methane, propane, ethane, hexane, etc.; or any other suitable fuel, and non-limiting examples of the fluid may include air, free-oxygen O.sub.2, or any other suitable fluid.

[0032] As discussed above, in certain configurations, the second power plant **24** may include the turbine engine that combusts the fuel-fluid mixture. Generally, the second power plant **24** utilizes exhaust gases from combusting the fuel-fluid mixture to create power. That is, operation of the second power plant **24** creates a work output **32**. Optionally, the work output **32** via the second power plant **24** may be torque that is outputted via a shaft **34**A or more than one shaft **34**A. The power created by the second power plant **24** may be used to operate various components of the flight vehicle **10**, such as a generator, a pump including a hydraulic pump, an oil pump, a fuel pump, etc., a compressor including a pneumatic compressor, a load compressor etc., or any other suitable components of the flight vehicle that may be electrically connected to the power created by the second power plant **24**. By using the first power plant **22** in conjunction with the second power plant **24**, the second power plant **24** may be a smaller in size gas turbine than the small gas turbine discussed in the background section, with the smaller in size gas turbine providing the same or more work output **32** than the small gas turbine discussed in the background section. Furthermore, by using the first power plant **22** in conjunction with the second power plant **24**, the power system **12**A-**12**E may be as thermodynamically efficient as a large gas turbine. For example, the large gas turbine may be equal to or greater than 500 kilowatts (kW), and the small gas turbine may be equal to or less than 200 kW. Therefore, in certain configurations, the power system **12**A-**12**E may operate as a compact turbo generator with significant work output **32** in which the turbine is considered small, but yet operates with sufficient thermodynamic efficiency. It is to be appreciated that the shafts **34**A-**34**D identified in various FIGS. **3-7** are for illustrative purposes, and more or less shafts than illustrated may be used to mechanically connect the various components.

[0033] Continuing with FIG. **2**, generally, the exhaust gases flow through the second power plant **24** along an exhaust-fluid path **36**. The exhaust gases of the exhaust-fluid path **36** is heated due to combusting of the fuel-fluid mixture, and the heat from the exhaust gases is thermally transferred to the working fluid **28** of the closed fluid loop **26** in which the first power plant **22** utilizes to create power. That is, operation of the first power plant **22** creates a work output **32**. Optionally, the work output **32** via the first power plant **22** may be torque that is outputted via a shaft **34**B or more than one shaft **34**B.

[0034] Generally, the power system **12**A-**12**E forms two separate paths, one is an exhaust path and another is a working fluid path, but the working fluid path uses the heat produced from the exhaust path, so these paths cooperate with each other. That is, the heat (from the exhaust-fluid path **36**) is thermally transferred to the working fluid **28** of the closed fluid loop **26** in which the first power plant **22** utilizes to create power. As such, the working fluid **28** is heated to a first temperature T.sub.1 when heat from the exhaust-fluid path **36** is transferred to the closed fluid loop **26**, and the working fluid **28** is cooled to a second temperature T.sub.2 by the time the working fluid **28** reaches the end of the closed fluid loop **26** where the working fluid **28** is again heated thermally via the exhaust-fluid path **36**, and the process is repeated. This concept is generally illustrated via FIG. **2**.

[0035] Referring to FIGS. **3-7**, the first power plant **22** also includes a compressor **38** configured to compress the working fluid **28**. Generally, the compressor **38** of the first power plant **22** compresses the working fluid **28** to an increased pressure. Therefore, depending on the type of working fluid **28**, the compressor **38** compresses the working fluid **28** to the pressure and the temperature above the critical point, e.g., above a point that the working fluid **28** would condense into liquid form when operating the power system **12**A-**12**E. Generally, the compressor **38** of the first power plant **22** is disposed along the fluid loop.

[0036] Continuing with FIGS. **3-7**, the first power plant **22** further includes a thermal engine **40** coupled to the compressor **38** and configured to operate the compressor **38**. For example, the thermal engine **40** and the compressor **38** may be coupled to each other mechanically or electrically. In one example, the thermal engine **40** includes a shaft **34**B or more than one shaft **34**B coupled to the compressor **38**. As such, the work output **32** from the thermal engine **40** is transferred to the compressor **38** through the shaft **34**B, or the work output **32** is transferred to the compressor **38** via an electrical connection. Regardless of the way the work output **32** is coupled to the compressor **38**, the work output **32** causes the compressor **38** to operate.

[0037] Therefore, for example, the thermal engine **40** may produce torque as the work output **32** which is transferred through the shaft **34**B to the compressor **38**. Using the closed fluid loop **26** allows the compressor **38**, the thermal engine **40**, and other components along the closed fluid loop **26** to be smaller and lighter as compared to traditional recuperators and/or small gas turbines as discussed above under the background section.

[0038] Next, more specific details of each of the configurations of the first power plant **22** and the second power plant **24** are discussed with reference to FIGS. **3**-**7**.

[0039] Referring to FIG. **3**, in certain configurations, the power system **12**A is illustrated, and the compressor **38** may be further defined as a first compressor **38**. In this configuration, the first power plant **22** may also include a gearbox **42** connected to the first compressor **38** and the thermal engine **40** along a first mechanical path **44**. Also, in this configuration, the first power plant **22** may include a generator **46** connected to the gearbox **42** along a second mechanical path **48** such that work output **32** from the gearbox **42** is used via the generator **46**. As shown in FIG. **3**, the first mechanical path **44** and the second mechanical path **48** are offset from each other. Also, in this configuration, the exhaust-fluid path **36** and the first mechanical path **44** may be offset from each other. In addition, in this configuration, the exhaust-fluid path **36** and the second mechanical path **48** may align with each other.

[0040] Continuing with FIG. **3**, in this configuration, the thermal engine **40** may be further defined as a first thermal engine **40**. In certain configurations, a shaft **34**B or more than one shaft **34**B may connect the first compressor **38** and the first thermal engine **40** together along the first mechanical path **44**. Furthermore, in certain configurations, a shaft **34**C or more than one shaft **34**C may connect the gearbox **42** and the generator **46** together along the second mechanical path **48**. The first thermal engine **40** may be any suitable configuration to transfer torque and/or extract the work output **32** from the pressurized working fluid **28**, and non-limiting examples may include a turbine, a scroll expander, a thermoelectric converter, a thermoionic converter, or any other suitable thermal engine.

[0041] Again, continuing with FIG. **3**, in this configuration, the second power plant **24** may include a second compressor **50** connected to the gearbox **42** along the exhaust-fluid path **36**. For example, a shaft **34**C or more than one shaft **34**C may connect the second compressor **50** to the gearbox **42**. The second compressor **50** is configured to increase the pressure of fluid, such as air, to define compressed or expanded fluid. The fluid is compressed via the second compressor **50** before combustion occurs at the combustor **30**.

[0042] The first power plant **22** may also include a precooler-heat-exchanger **52** disposed downstream from the second compressor **50** along the exhaust-fluid path **36**. Also, the precooler-heat-exchanger **52** is disposed along the closed fluid loop **26**, and the heat from expanding the working fluid **28** is transferred to the fluid of the exhaust-fluid path **36** through the precooler-heat-exchanger **52**. The precooler-heat-exchanger **52** may be configured to remove excess heat from the working fluid **28**. Therefore, for example, the precooler-heat-exchanger **52** may ensure that the temperature of the working fluid **28** does not exceed an operating temperature range of the first compressor **38**.

[0043] The excess heat from the precooler-heat-exchanger **52** may be expelled or rejected to the surrounding atmosphere or transferred to a secondary fluid, in a heat sink loop, for another system of the flight vehicle **10**. As such, the heat sink loop may transfer the excess heat from the precooler-heat-exchanger **52** to a storage structure containing the secondary fluid or to a thermal energy storage device including a battery, etc. The secondary fluid of the heat sink loop may be any suitable fluid, and non-limiting examples may include fuel such as hydrocarbon fuel (e.g., Jet-A, JP-8, JP-10, kerosene, RP2, etc.), cryogenic fuel (e.g., liquid hydrogen, liquid natural gas, etc.), etc., water, or other types of fluid disposed in the flight vehicle **10**.

[0044] In addition, the second power plant **24** may include a second thermal engine **54** disposed downstream from the precooler-heat-exchanger **52** along the exhaust-fluid path **36**, and also disposed downstream from the combustor **30** along the exhaust-fluid path **36**. Therefore, combustion at the combustor **30** causes operation of the second thermal engine **54** to produce torque. The second thermal engine **54** may be any suitable configuration to transfer torque and/or extract the work output **32** from the exhaust-fluid path **36**. Non-limiting examples of the second thermal engine **54** may include a turbine, a scroll expander, a thermoelectric converter, a thermoionic converter, or any other suitable thermal engine **40**.

[0045] Also, in this configuration, the first power plant **22** may include a heat intake **56** disposed downstream from the second thermal engine **54** along the exhaust-fluid path **36**. The heat intake **56** may be any suitable configuration, and non-limiting examples of the heat intake **56** may include a heat exchanger. Therefore, heat from the exhaust gases exiting the second thermal engine **54** is thermally transferred to the working fluid **28** of the closed fluid loop **26** through the heat intake **56** (heat exchanger).

[0046] Optionally, a recuperator **58** may be disposed along the closed fluid loop **26** between the first thermal engine **40** and the precooler-heat-exchanger **52**. The recuperator **58** is configured to transfer heat from a low-pressure leg **60** of the closed fluid loop **26** to a high-pressure leg **62** of the closed fluid loop **26**. Generally, the recuperator **58** may improve thermal efficiency of the first power plant **22**. Therefore, the recuperator **58** may operate as a heat exchanger. Transferring heat to the working fluid **28** via the recuperator **58** prior to further heating the working fluid **28** via the heat intake **56** increases the temperature of the working fluid **28** that enters the first thermal engine **40**, which increase an amount of the work output **32** that may be extracted from the working fluid **28**.

[0047] The working fluid **28** path is a closed loop, and thus referred to as the closed fluid loop **26**. As shown in FIG. **3**, the precooler-heat-exchanger **52**, the first compressor **38**, the heat intake **56**, and the first thermal engine **40** are arranged along the closed fluid loop **26**. Therefore, the flow (as identified as A, B, C, D, E, and F) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the recuperator **58** if utilizing the recuperator **58**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the recuperator **58** if utilizing the recuperator **58**, then back to the precooler-heat-exchanger **52** where the closed loop starts again. If the recuperator **58** is eliminated, the flow (as identified as A, B, D, and E) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the precooler-heat-exchanger **52** where the closed loop starts again.

[0048] Now turning to the exhaust-fluid path **36**, the components, in sequence, starting at the inlet **64** are: the generator **46**, then part of the gearbox **42**, then the second compressor **50**, then the precooler-heat-exchanger **52**, then the combustor **30**, then the second thermal engine **54**, then the heat intake **56**, and finally through an outlet **66** to expel the exhaust gases outside of the second power plant **24**, which may be to the outside of the flight vehicle **10**.

[0049] Turning to FIG. **4**, the power system **12**B is illustrated, and in this configuration, the gearbox **42** of FIG. **3** is eliminated, and now, a single mechanical path **44** is disposed along or aligns with the exhaust-fluid path **36** instead of two separate mechanical paths **44**, **48**. In this configuration, the components arranged on the exhaust-fluid path **36** are the same components as the components of FIG. **3**, but the components arranged on the first mechanical path **44** of FIG. **3** are now arranged along the first mechanical path **44** of FIG. **4**. That is, in the arrangement of FIG. **4**, the components arranged on the mechanical path **44** are arranged along the components of the exhaust-fluid path **36**.

[0050] The compressor **38** may be further defined as the first compressor **38**, and the thermal engine **40** may be further defined as the first thermal engine **40**. Generally, in this configuration, the first compressor **38** may be connected to the first thermal engine **40** along the first mechanical path **44**. Therefore, a shaft **34**B or more than one shaft **34**B may connect the first compressor **38** and the first thermal engine **40** together along the first mechanical path **44**. Furthermore, the first power plant **22** may include the generator **46** connected to the first thermal engine **40** along the first mechanical path **44** such that work output **32** from the first thermal engine **40** is used via the generator **46**. Since the first compressor **38**, the first thermal engine **40**, and the generator **46** are each connected together along the same mechanical path, the shaft **34**B may also connect the generator **46** to the first compressor **38** and/or the first thermal engine **40**. As such, in this configuration, the first thermal engine **40** and the generator **46** are coaxial to each other, and the first thermal engine **40** and the first compressor **38** are coaxial to each other. In other words, the shaft(s) **34**B that connect the first thermal engine **40**, the generator **46**, and the first compressor **38** together are coaxial to each other along the first mechanical path **44**.

[0051] Continuing with FIG. **4**, the second power plant **24** may include the second compressor **50** and the second thermal engine **54** coupled to each other along the exhaust-fluid path **36**. Therefore, a shaft **34**A or more than one shaft **34**A may connect the second compressor **50** and the second thermal engine **54** together along the exhaust-fluid path **36**. Due to the first compressor **38** and the first thermal engine **40** being disposed coaxial with the second compressor **50** and the second thermal engine **54**, the exhaust-fluid path **36** includes a first outer path **68** in which the compressed fluid flows around the first compressor **38** and includes a second outer path **70** in which the exhaust gases flow around the first thermal engine **40**. The shaft **34**A, **34**B illustrated in FIG. **4** is schematic, and therefore, generally the shaft **34**A, **34**B represents any number of shafts **34**A, **34**B that would be mechanically connected to the appropriate components there along.

[0052] The first power plant **22** may also include the precooler-heat-exchanger **52** disposed downstream from the first compressor **38** and the second compressor **50** along the exhaust-fluid path **36**. In this configuration, the first thermal engine **40** and the second thermal engine **54** are disposed downstream from the precooler-heat-exchanger **52** along the exhaust-fluid path **36**. Also, the precooler-heat-exchanger **52** is disposed along the closed fluid loop **26**, and the heat from expanding the fluid (for combustion) is transferred to the working fluid **28** through the precooler-heat-exchanger **52**. The precooler-heat-exchanger **52** may be configured to remove excess heat from the working fluid **28**. Therefore, for example, the precooler-heat-exchanger **52** may ensure that the temperature of the working fluid **28** does not exceed an operating temperature range of the first compressor **38**.

[0053] Also, in this configuration, the first power plant **22** may include the heat intake **56** disposed downstream from the first thermal engine **40** and the second thermal engine **54** along the exhaust-fluid path **36**. The heat intake **56** may be any suitable configuration, and non-limiting examples of the heat intake **56** may include a heat exchanger. Therefore, heat from the exhaust gases exiting the second thermal engine **54** is thermally transferred to the working fluid **28** of the closed fluid loop **26** through the heat intake **56** (heat exchanger).

[0054] Continuing with FIG. **4**, optionally, the recuperator **58** may be disposed along the closed fluid loop **26** between the first thermal engine **40** and the precooler-heat-exchanger **52**. The recuperator **58** is configured to transfer heat from the low-pressure leg **60** of the closed fluid loop **26** to the high-pressure leg **62** of the closed fluid loop **26**. Generally, the recuperator **58** may improve thermal efficiency of the first power plant **22**. Therefore, the recuperator **58** may operate as a heat exchanger. Transferring heat to the working fluid **28** via the recuperator **58** prior to further heating the working fluid **28** via the heat intake **56** increases the temperature of the working fluid **28** that enters the first thermal engine **40**, which increase an amount of the work output **32** that may be extracted from the working fluid **28**.

[0055] The working fluid **28** path is a closed loop, and thus referred to as the closed fluid loop **26**. Therefore, as shown in FIG. **4**, the precooler-heat-exchanger **52**, the first compressor **38**, the heat intake **56**, and the first thermal engine **40** are arranged along the closed fluid loop **26**. The flow (as identified as A, B, C, D, E, and F) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the recuperator **58** if utilizing the recuperator **58**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the recuperator **58** if utilizing the recuperator **58**, then back to the precooler-heat-exchanger **52** where the closed loop starts again. If the recuperator **58** is eliminated, the flow (as identified as A, B, D, and E) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the precooler-heat-exchanger **52**

where the closed loop starts again.
[0056] Now turning to the exhaust-fluid path **36**, the components, in sequence, starting at the inlet **64** are: the generator **46**, then the second compressor **50**, then the precooler-heat-exchanger **52**, then the combustor **30**, then the second thermal engine **54**, then the heat intake **56**, and finally through the outlet **66** to expel the exhaust gases outside of the second power plant **24**, which may be to the outside of the flight vehicle **10**.
[0057] Referring to FIG. **6**, the power system **12**D is illustrated, and in this configuration, the gearbox **42** is again eliminated, and this configuration is a rearrangement of some of the components of FIG. **4**. Generally, the first compressor **38**, the first thermal engine **40**, the heat intake **56**, and the second thermal engine **54** are rearranged in FIG. **6** as compared to the arrangement of FIG. **4**. The configuration of FIG. **4** and the configuration of FIG. **6** may have the same components, just in a different arrangement, and therefore, see the above discussion for additional details of the components. The below discussion for FIG. **6** focuses on the different arrangement.
[0058] In the configuration of FIG. **6**, the second power plant **24** may include the second compressor **50** and the second thermal engine **54** coupled to each other along the exhaust-fluid path **36**. Therefore, a shaft **34**A or more than one shaft **34**A may connect the second compressor **50** and the second thermal engine **54** together along the exhaust-fluid path **36**. Continuing with the configuration of FIG. **6**, the precooler-heat-exchanger **52** of the first power plant **22** is disposed downstream from the first thermal engine **40** along the exhaust-fluid path **36**. The second compressor **50** is disposed upstream from the precooler-heat-exchanger **52** and the first thermal engine **40** along the exhaust-fluid path **36**. Also, in this configuration, the heat intake **56** of the first power plant **22** is disposed upstream from the first compressor **38** and the second thermal engine **54** along the exhaust-fluid path **36**.
[0059] The working fluid **28** path is a closed loop, and thus referred to as the closed fluid loop **26**. Therefore, as shown in FIG. **6**, the precooler-heat-exchanger **52**, the first compressor **38**, the heat intake **56**, and the first thermal engine **40** are arranged along the closed fluid loop **26**. The flow (as identified as A, B, C, D, E, and F) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the optional recuperator **58**, is: to the first compressor **38**, then to the heat intake **56**, then the recuperator **58** if utilizing the recuperator **58**, then to the first thermal engine **40**, then to the precooler-heat-exchanger **52**, then back to the recuperator **58** if utilizing the recuperator **58**, then back to the first compressor **38** where the closed loop starts again. If the recuperator **58** is eliminated, the flow (as identified as A, B, C, and E) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the precooler-heat-exchanger **52** where the closed loop starts again. With this configuration, optionally, the work output **32** via the second power plant **24** may be torque that is outputted via the shaft **34**A, and the work output **32** via the second power plant **24** may be used to power other systems, mechanical components, etc., of the flight vehicle **10**. Additional shafts **34**B, **34**C may be used for the configuration of FIG. **6**, and one or more other shafts, not illustrated, may be used in the configuration of FIG. **6**.
[0060] Now turning to the exhaust-fluid path **36** of FIG. **6**, the components, in sequence, starting at the inlet **64** are: the generator **46**, then the second compressor **50**, then the precooler-heat-exchanger **52**, then the combustor **30**, then the heat intake **56**, then the second thermal engine **54**, and finally through the outlet **66** to expel the exhaust gases outside of the second power plant **24**, which may be to the outside of the flight vehicle **10**.
[0061] Turning to FIGS. **5** and **7**, two additional configurations of the power system **12**C, **12**E are illustrated. In these configurations, the optional recuperator **58** of FIGS. **4** and **6** is eliminated, and also the gearbox **42** of FIG. **3** is eliminated. Additionally, the generator **46** may be eliminated, but it is to be appreciated that the work output **32** produced via the second power plant **24** may be used to

power another generator, a load compressor, other mechanical components, etc. In these configurations, the compressor **38** may be further defined as the first compressor **38**, and the thermal engine **40** may be further defined as the first thermal engine **40**. In these configurations, the first compressor **38** and the first thermal engine **40** are connected together to define a first turbine. Also, in these configurations, the second power plant **24** may include the second compressor **50** and the second thermal engine **54** connected together to define a second turbine. Therefore, in these configurations, the first turbine and the second turbine are mounted to a shaft **34**D or more than one shaft **34**D such that the first turbine and the second turbine are coaxial to each other. In addition, in these configurations, the first compressor **38** and the second compressor **50** are coaxial along the shaft **34**D. Generally, the first mechanical path **44** and the exhaust-fluid path **36** are disposed offset from to each other.

[0062] Referring to FIGS. **5** and **7**, these configurations may also include the precooler-heat-exchanger **52** and the heat intake **56**. The precooler-heat-exchanger **52** may be referred to as a condenser, and the heat intake **56** may be referred to as an evaporator. The combustor **30** of the FIGS. **5** and **7** may be referred to as a burner.

[0063] The working fluid **28** path is a closed loop, and thus referred to as the closed fluid loop **26**. Therefore, as shown in FIG. **5**, the precooler-heat-exchanger **52**, the first compressor **38**, the heat intake **56**, and the first thermal engine **40** are arranged along the closed fluid loop **26**. As shown in FIG. **5**, the first compressor **38** is disposed upstream of the first thermal engine **40** relative to the direction of flow of the exhaust-fluid path **36**. That is, the first compressor **38** is disposed upstream from the first thermal engine **40**. The flow (as identified as A, B, D and E) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the precooler-heat-exchanger **52** where the closed loop starts again.

[0064] Now turning to the exhaust-fluid path **36** of FIG. **5**, the components, in sequence, starting at the inlet **64** are: the second compressor **50**, then the precooler-heat-exchanger **52**, then the combustor **30**, then the second thermal engine **54**, and finally through the outlet **66** to expel the exhaust gases outside of the second power plant **24**, which may be to the outside of the flight vehicle **10**.

[0065] Referring to FIG. **7**, in this configuration of the power system **12**E, some of the components are rearranged as compared to the arrangement of the power system **12**C of FIG. **5**. In the configuration of FIG. **7**, the first compressor **38** is disposed downstream of the first thermal engine **40**. In other words, the first thermal engine **40** is disposed upstream of the first compressor **38** relative to the direction of flow of the exhaust-fluid path **36**. Furthermore, the second thermal engine **54** is disposed downstream of the heat intake **56**, which reduces the temperature of the exhaust gases that then passes through the second thermal engine **54**, which may assist in extending the life of the second thermal engine **54**.

[0066] The working fluid **28** path is a closed loop, and thus referred to as the closed fluid loop **26**. Therefore, in the configuration of FIG. **7**, the precooler-heat-exchanger **52**, the first compressor **38**, the heat intake **56**, and the first thermal engine **40** are arranged along the closed fluid loop **26**. The flow (as identified as A, B, C, and E) of the working fluid **28** through the closed fluid loop **26**, in sequence starting at the precooler-heat-exchanger **52**, is: to the first compressor **38**, then to the heat intake **56**, then to the first thermal engine **40**, then back to the precooler-heat-exchanger **52** where the closed loop starts again.

[0067] Now turning to the exhaust-fluid path **36** of FIG. **7**, the components, in sequence, starting at the inlet **64** are: the second compressor **50**, then the precooler-heat-exchanger **52**, then the combustor **30**, then the second thermal engine **54**, and finally through the outlet **66** to expel the exhaust gases outside of the second power plant **24**, which may be to the outside of the flight vehicle **10**.

[0068] Optionally, as shown in FIGS. **9** and **10**, the power system **12**A-**12**E may include a container **72** that houses the first power plant **22**. In certain configurations, the container **72** hermetically seals the first power plant **22**. That is, the container **72** encasing the closed fluid loop **26**, the compressor **38**, and the thermal engine **40**. Therefore, the container **72** houses the closed fluid loop **26**, the compressor **38**, and the thermal engine **40** such that the container **72** hermetically seals the power system **12**A-**12**E therein, which may improve acoustic attenuation and lower a thermal signature outside of the container **72**.

[0069] Optionally, the container **72** may include a container heat exchanger **74** configured to circulate a secondary container fluid, via a secondary loop **76**, outside of the container **72** to warm an external component **78** disposed outside of the first power plant **22**. Therefore, part of the secondary loop **76** is disposed within the container **72** and another part of the secondary loop **76** is disposed outside of the container **72** which leads to the external component **78** to be warmed. It is to be appreciated that the secondary container fluid may be any suitable fluid, and non-limiting examples may include propylene-glycol water, water-glycol mixture, oil including dielectric oil, engine oil, polymer based oil, petroleum based oil, etc., refrigerants, or any other suitable fluids.

[0070] In certain configurations of FIGS. **9** and **10**, the container **72** may encase the first power plant **22** and the second power plant **24**. For example, the turbine engine of the second power plant **24** and the heat pump of the first power plant **22** may be encased in the container **72**. More specifically, any of the configurations of FIGS. **3-7** may be encased in the container **72**. The container heat exchanger **74**, which transfers heat to the secondary container fluid via the working fluid **28**, is also encased in the container **72**. The container heat exchanger **74** may transfer heat to the secondary container fluid via the closed fluid loop **26** of the first power plant **22**. Therefore, the secondary container fluid may be heated via heat transfer from the working fluid **28** of the first power plant **22**. Since the power system **12**A-**12**E is continuously on for all operational modes of the flight vehicle **10**, the secondary container fluid may be circulated, via the secondary loop **76**, to one or more batteries to warm the batteries to assist in maintaining the desired temperature of the batteries, and therefore, assists in lowering the power requirements for starting-up main engines, i.e., primary propulsors **20**, or other components that require a draw of power.

[0071] As shown in FIG. **9**, electrical connectors or wires **80** may extend from the container **72**, via the generator **46**, to provide power to another system, etc., of the flight vehicle **10**, for example, a power bus **86**, the primary propulsor **20**, one or more energy storage devices including batteries, etc., and/or electrical components.

[0072] Furthermore, the power system **12**A-**12**E may be designed to accommodate different power demands. That is, one or more of the containers **72** may be used depending on the desired power output. Therefore, if the desired power output requires a plurality of the containers **72**, these containers **72** may be electrically connected to each other in a series connection, to provide the desired power output. In this case, the containers **72** are also configured to be stackable which provides a space savings. Therefore, the containers **72** may each include a frame **82** disposed outside of the respective containers **72**. The frame **82** may be a structure mounted to the outside of the containers **72** or the frame **82** may be formed as the outer surface of the container **72**.

[0073] Referring to FIG. **10**, for example, in certain configurations, the container **72** may be further defined as a first container **72** having a first frame **82** configuration, and further including a second container **72** having a second frame **82** configuration having the same configuration as the first frame **82** configuration, such that the second container **72** may be stacked with the first container **72**. That is, the first container **72** and the second container **72** may have the same configuration such that the first container **72** and the second container **72** are stackable adjacent with each other.

[0074] Therefore, the first power plant **22** and the second power plant **24** may be further defined as a first unit **84**A, and further including a second unit **84**B configured the same as the first unit **84**A, which may be stacked on the first unit **84**A, and so on depending on the desired number of units **84**A, **84**B, which may be determined by the desired power output. The second unit **84**B may be configured the same as the first unit **84**A, and the second unit **84**B may be electrically connected to the first unit **84**A to increase a total power output. Therefore, the desired number of units **84**A, **84**B may be electrically connected in a series connection to obtain the desired total power output. Any of the configurations of FIGS. **3-7** may form one or more of the first units **84**A and one or more of the second units **84**B, which may be the same as each other or one or more may be different from each other. For example, the configuration of the first power plant **22** and the second power plant **24** of the first unit **84**A may be one of the configurations of FIGS. **3-7** and the configuration of the first power plant **22** and the second power plant **24** of the second unit **84**B may be a different configuration from the selected configuration of the first unit **84**A, and so on depending on the desired number of the units **84**A, **84**B.

[0075] While the best modes and other configurations for carrying out the disclosure have been described in detail, those familiar with the art to which this disclosure relates will recognize various alternative designs and configurations for practicing the disclosure within the scope of the appended claims. Furthermore, the configurations shown in the drawings or the characteristics of various configurations mentioned in the present description are not necessarily to be understood as configurations independent of each other. Rather, it is possible that each of the characteristics described in one of the examples of a configuration can be combined with one or a plurality of other desired characteristics from other configurations, resulting in other configurations not described in words or by reference to the drawings. Accordingly, such other configurations fall within the framework of the scope of the appended claims.

[0076] As used herein, a system, apparatus, structure, article, element, component, or hardware "configured to" perform a specified function is indeed capable of performing the specified function without any alteration, rather than merely having potential to perform the specified function after further modification. In other words, the system, apparatus, structure, article, element, component, or hardware "configured to" perform a specified function is specifically selected, created, implemented, utilized, programmed, and/or designed for the purpose of performing the specified function. As used herein, "configured to" denotes existing characteristics of a system, apparatus, structure, article, element, component, or hardware that enable the system, apparatus, structure, article, element, component, or hardware to perform the specified function without further modification. For purposes of this disclosure, a system, apparatus, structure, article, element, component, or hardware described as being "configured to" perform a particular function may additionally or alternatively be described as being "adapted to" and/or as being "operative to" perform that function.

[0077] The illustrations of the configurations described herein are intended to provide a general understanding of the structure of the various configurations. The illustrations are not intended to serve as a complete description of all of the elements and features of apparatus and systems that utilize the structures or methods described herein. Many other configurations may be apparent to those of skill in the art upon reviewing the disclosure. Other configurations may be utilized and derived from the disclosure, such that structural and logical substitutions and changes may be made without departing from the scope of the disclosure. Accordingly, the disclosure and the figures are to be regarded as illustrative rather than restrictive.

[0078] The following Clauses provide some example configurations of the power system **12**A-**12**E, the flight vehicle **10**, and the first power plant **22** as disclosed herein.

[0079] Clause 1: A power system for a flight vehicle, the power system comprising: a first power plant; a second power plant configured to combust a fuel-fluid mixture; and wherein the first power plant includes: a closed fluid loop configured to contain a working fluid; a compressor configured to compress the working fluid; and a thermal engine coupled to the compressor and configured to operate the compressor.

[0080] Clause 2: The power system as set forth in clause 1 wherein: the second power plant utilizes exhaust gases from combusting the fuel-fluid mixture to create power; the exhaust gases flow through the second power plant along an exhaust-fluid path; and the exhaust gases of the exhaust-fluid path is heated due to combusting of the fuel-fluid mixture, and heat from the exhaust gases is thermally transferred to the working fluid of the closed fluid loop in which the first power plant utilizes to create power.

[0081] Clause 3: The power system as set forth in one of clauses 1 or 2 wherein the working fluid is in a supercritical state.

[0082] Clause 4: The power system as set forth in any one of the preceding clauses wherein: the compressor is further defined as a first compressor; the first power plant includes a gearbox connected to the first compressor and the thermal engine along a first mechanical path; the first power plant includes a generator connected to the gearbox along a second mechanical path such that work output from the gearbox is used via the generator; and the first mechanical path and the second mechanical path are offset from each other.

[0083] Clause 5: The power system as set forth in any one of the preceding clauses wherein: the thermal engine is further defined as a first thermal engine; and the second power plant includes a second compressor connected to the gearbox along an exhaust-fluid path; the first power plant includes a precooler-heat-exchanger disposed downstream from the second compressor along the exhaust-fluid path; the second power plant includes a second thermal engine disposed downstream from the precooler-heat-exchanger along the exhaust-fluid path; and the first power plant includes a heat intake disposed downstream from the second thermal engine along the exhaust-fluid path.

[0084] Clause 6: The power system as set forth in any one of the preceding clauses wherein the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

[0085] Clause 7: The power system as set forth in one of clauses 1-3 wherein: the compressor is further defined as a first compressor; the thermal engine is further defined as a first thermal engine; the first compressor is connected to the first thermal engine along a first mechanical path; the first power plant includes a generator connected to the first thermal engine along the first mechanical path such that work output from the first thermal engine is used via the generator; and the first thermal engine and the generator are coaxial to each other.

[0086] Clause 8: The power system as set forth in one of clauses 1-3 or 7 wherein: the second power plant includes a second compressor and a second thermal engine coupled to each other along an exhaust-fluid path; the first power plant includes a precooler-heat-exchanger disposed downstream from the first compressor and the second compressor along the exhaust-fluid path; the first thermal engine and the second thermal engine are disposed downstream from the precooler-heat-exchanger along the exhaust-fluid path; and the first power plant includes a heat intake disposed downstream from the first thermal engine and the second thermal engine along the exhaust-fluid path.

[0087] Clause 9: The power system as set forth in one of clauses 1-3, 7, or 8 wherein the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

[0088] Clause 10: The power system as set forth in one of clauses 1-3 or 7 wherein: the second power plant includes a second compressor and a second thermal engine coupled to each other along an exhaust-fluid path; the first power plant includes a precooler-heat-exchanger disposed downstream from the first thermal engine along the exhaust-fluid path; the second compressor disposed upstream from the precooler-heat-exchanger and the first thermal engine along the exhaust-fluid path; and the first power plant includes a heat intake disposed upstream from the first compressor and the second thermal engine along the exhaust-fluid path.

[0089] Clause 11: The power system as set forth in one of clauses 1-3, 7, or 10 wherein the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

[0090] Clause 12: The power system as set forth in one of clauses 1-3 wherein: the compressor is further defined as a first compressor; the thermal engine is further defined as a first thermal engine;

the first compressor and the first thermal engine are connected together to define a first turbine; the second power plant includes a second compressor and a second thermal engine connected together to define a second turbine; and the first turbine and the second turbine are mounted to a shaft such that the first turbine and the second turbine are coaxial to each other.

[0091] Clause 13: The power system as set forth in one of clauses 1-3 or 12 wherein: the first power plant includes a precooler-heat-exchanger and a heat intake; and the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

[0092] Clause 14: The power system as set forth in any one of the preceding clauses further including a container that houses the first power plant, wherein the container hermetically seals the first power plant.

[0093] Clause 15: The power system as set forth in any one of the preceding clauses wherein the container includes a container heat exchanger configured to circulate a secondary container fluid outside of the container to warm an external component disposed outside of the first power plant.

[0094] Clause 16: The power system as set forth in any one of the preceding clauses: wherein the first power plant and the second power plant are further defined as a first unit; further including a second unit configured the same as the first unit, with the second unit electrically connected to the first unit to increase a total power output; wherein the container is further defined as a first container having a first frame configuration; and further including a second container having a second frame configuration being the same configuration as the first frame configuration such that the first container and the second container are stackable adjacent with each other.

[0095] Clause 17: A flight vehicle comprising: a primary propulsor; a power system coupled to the primary propulsor and configured to provide power to the primary propulsor, wherein the power system is separate from the primary propulsor such that the power system is continuously operable independently of the primary propulsor to provide power to operate the flight vehicle; and wherein the power system includes a first power plant comprising: a closed fluid loop configured to contain a working fluid; a compressor configured to compress the working fluid; and a thermal engine coupled to the compressor and configured to operate the compressor.

[0096] Clause 18: The flight vehicle as set forth in clause 17 further including a container that houses the closed fluid loop, the compressor, and the thermal engine such that the container hermetically seals the power system therein.

[0097] Clause 19: A first power plant for a power system of a flight vehicle, wherein the flight vehicle includes a primary propulsor, the first power plant comprising: a closed fluid loop configured to contain a working fluid; a compressor configured to compress the working fluid; a thermal engine coupled to the compressor and configured to operate the compressor; and a container encasing the closed fluid loop, the compressor, and the thermal engine, wherein the first power plant is continuously operable independently of the primary propulsor to provide power to operate the flight vehicle.

[0098] Clause 20: The flight vehicle as set forth in clause 19 wherein the container hermetically seals the first power plant therein.

Claims

1. A power system for a flight vehicle, the power system comprising: a first power plant; a second power plant configured to combust a fuel-fluid mixture; and wherein the first power plant includes: a closed fluid loop configured to contain a working fluid; a compressor configured to compress the working fluid; and a thermal engine coupled to the compressor and configured to operate the compressor.

2. The power system as set forth in claim 1 wherein: the second power plant utilizes exhaust gases from combusting the fuel-fluid mixture to create power; the exhaust gases flow through the second power plant along an exhaust-fluid path; and the exhaust gases of the exhaust-fluid path is heated due to combusting of the fuel-fluid mixture, and heat from the exhaust gases is thermally transferred to the working fluid of the closed fluid loop in which the first power plant utilizes to create power.

3. The power system as set forth in claim 2 wherein the working fluid is in a supercritical state.

4. The power system as set forth in claim 1 wherein: the compressor is further defined as a first compressor; the first power plant includes a gearbox connected to the first compressor and the thermal engine along a first mechanical path; the first power plant includes a generator connected to the gearbox along a second mechanical path such that work output from the gearbox is used via the generator; and the first mechanical path and the second mechanical path are offset from each other.

5. The power system as set forth in claim 4 wherein: the thermal engine is further defined as a first thermal engine; and the second power plant includes a second compressor connected to the gearbox along an exhaust-fluid path; the first power plant includes a precooler-heat-exchanger disposed downstream from the second compressor along the exhaust-fluid path; the second power plant includes a second thermal engine disposed downstream from the precooler-heat-exchanger along the exhaust-fluid path; and the first power plant includes a heat intake disposed downstream from the second thermal engine along the exhaust-fluid path.

6. The power system as set forth in claim 5 wherein the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

7. The power system as set forth in claim 1 wherein: the compressor is further defined as a first compressor; the thermal engine is further defined as a first thermal engine; the first compressor is connected to the first thermal engine along a first mechanical path; the first power plant includes a generator connected to the first thermal engine along the first mechanical path such that work output from the first thermal engine is used via the generator; and the first thermal engine and the generator are coaxial to each other.

8. The power system as set forth in claim 7 wherein: the second power plant includes a second compressor and a second thermal engine coupled to each other along an exhaust-fluid path; the first power plant includes a precooler-heat-exchanger disposed downstream from the first compressor and the second compressor along the exhaust-fluid path; the first thermal engine and the second thermal engine are disposed downstream from the precooler-heat-exchanger along the exhaust-fluid path; and the first power plant includes a heat intake disposed downstream from the first thermal engine and the second thermal engine along the exhaust-fluid path.

9. The power system as set forth in claim 8 wherein the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

10. The power system as set forth in claim 7 wherein: the second power plant includes a second compressor and a second thermal engine coupled to each other along an exhaust-fluid path; the first power plant includes a precooler-heat-exchanger disposed downstream from the first thermal engine along the exhaust-fluid path; the second compressor disposed upstream from the precooler-heat-exchanger and the first thermal engine along the exhaust-fluid path; and the first power plant includes a heat intake disposed upstream from the first compressor and the second thermal engine along the exhaust-fluid path.

11. The power system as set forth in claim 10 wherein the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

12. The power system as set forth in claim 1 wherein: the compressor is further defined as a first compressor; the thermal engine is further defined as a first thermal engine; the first compressor and the first thermal engine are connected together to define a first turbine; the second power plant includes a second compressor and a second thermal engine connected together to define a second turbine; and the first turbine and the second turbine are mounted to a shaft such that the first turbine and the second turbine are coaxial to each other.

13. The power system as set forth in claim 12 wherein: the first power plant includes a precooler-heat-exchanger and a heat intake; and the precooler-heat-exchanger, the first compressor, the heat intake, and the first thermal engine are arranged along the closed fluid loop.

14. The power system as set forth in claim 1 further including a container that houses the first power plant, wherein the container hermetically seals the first power plant.

15. The power system as set forth in claim 14 wherein the container includes a container heat exchanger configured to circulate a secondary container fluid outside of the container to warm an external component disposed outside of the first power plant.

16. The power system as set forth in claim 14: wherein the first power plant and the second power plant are further defined as a first unit; further including a second unit configured the same as the first unit, with the second unit electrically connected to the first unit to increase a total power output; wherein the container is further defined as a first container having a first frame configuration; and further including a second container having a second frame configuration being the same configuration as the first frame configuration such that the first container and the second container are stackable adjacent with each other.

17. A flight vehicle comprising: a primary propulsor; a power system coupled to the primary propulsor and configured to provide power to the primary propulsor, wherein the power system is separate from the primary propulsor such that the power system is continuously operable independently of the primary propulsor to provide power to operate the flight vehicle; and wherein the power system includes a first power plant comprising: a closed fluid loop configured to contain a working fluid; a compressor configured to compress the working fluid; and a thermal engine coupled to the compressor and configured to operate the compressor.

18. The flight vehicle as set forth in claim 17 further including a container that houses the closed fluid loop, the compressor, and the thermal engine such that the container hermetically seals the power system therein.

19. A first power plant for a power system of a flight vehicle, wherein the flight vehicle includes a primary propulsor, the first power plant comprising: a closed fluid loop configured to contain a working fluid; a compressor configured to compress the working fluid; a thermal engine coupled to the compressor and configured to operate the compressor; and a container encasing the closed fluid loop, the compressor, and the thermal engine, wherein the first power plant is continuously operable independently of the primary propulsor to provide power to operate the flight vehicle.

20. The flight vehicle as set forth in claim 19 wherein the container hermetically seals the first power plant therein.
