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Inventor(s)	Naik; Pradeep et al.

GAS TURBINE ENGINE HAVING A COMBUSTION SECTION WITH STEAM PROVIDED TO SECOND COMBSUTOR PLENUM

Abstract

A gas turbine engine includes a steam generating system, and a combustion section having a first combustor and a second combustor in fluid communication with a secondary combustion zone of the first combustor. The second combustor is operable to receive compressor bleed air and fuel, along with steam from the steam generating system. During a non-idle operating state and a power-augmentation operating state, when the steam system is operable, steam is provided to the second combustor and then to the secondary combustion zone of the first combustor. When the steam generating system is inoperable, the fuel and bleed air are provided to the second combustor and combusted, and combustion products are provided to the first combustor. When the steam generating system is partially operable, the steam, the bleed air, and the fuel are provided to the second combustor, and combustion products are provided to the first combustor.

Inventors: **Naik; Pradeep (Bengaluru, IN), Cooper; Clayton S. (Loveland, OH), Vise; Steven C. (Loveland, OH), Benjamin; Michael A. (Cincinnati, OH), Pal; Sibtosh (Mason, OH), Marakovits; Steven (Mason, OH), Mohan; Sripathi (Bengaluru, IN), Zelina; Joseph (Waynesville, OH)**

Applicant: **General Electric Company** (Schenectady, NY)

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Background/Summary

TECHNICAL FIELD
[0001] The present disclosure relates to a gas turbine engine having a combustion section.
BACKGROUND
[0002] Gas turbine engines generally include a combustor having a swirler that provides a flow of swirled air mixed with fuel into a combustion chamber, where the fuel and air mixture is ignited and burned. The burning of the fuel and air mixture in the combustion chamber results in carbon monoxide (CO) and nitrous oxide (NO.sub.x) emissions from the combustor. One technique to attempt to reduce the CO and the NO.sub.x emissions is to inject steam or water directly into the swirler via, for example, a fuel nozzle, to mix with the fuel and air mixture.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0003] Features and advantages of the present disclosure will be apparent from the following description of various exemplary embodiments, as illustrated in the accompanying drawings, wherein like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements.
[0004] FIG. **1** is a schematic partial cross-sectional side view of an exemplary high by-pass turbofan jet engine and a steam generating system, according to an aspect of the present disclosure.
[0005] FIG. **2** is a schematic diagram of the high by-pass turbofan jet engine and the steam generating system of FIG. **1**, according to an aspect of the present disclosure.
[0006] FIG. **3** is a partial cross-sectional side view of an exemplary combustion section of the gas turbine engine of FIG. **1**, according to an aspect of the present disclosure.
[0007] FIG. **4** is an enlarged detail view of a second combustor, taken at detail view **204** of FIG. **3**, according to an aspect of the present disclosure.
[0008] FIG. **5** is a partial cross-sectional view of a semi-annular second combustor having multiple second combustion chambers as an alternate to the annular second combustor of FIG. **3**, taken at plane **5-5** of FIG. **3**, according to an aspect of the present disclosure.
[0009] FIG. **6** is a partial cross-sectional side view of an alternate second combustor to that shown in FIG. **4**, according to another aspect of the present disclosure.
[0010] FIG. **7** is a partial cross-sectional view of an alternate second combustor liner, taken at plane **7-7** of FIG. **6**, according to an aspect of the present disclosure.
[0011] FIG. **8** is a schematic diagram depicting an operation of the gas turbine engine of FIG. **1** during a non-power augmentation operating state, according to an aspect of the present disclosure.
[0012] FIG. **9** is a schematic diagram depicting an operation of the gas turbine engine of FIG. **1** during a non-idle operating state, and, during a power-augmentation operating state when the steam generating system is operational to generate the steam at a first steam generating level, according to an aspect of the present disclosure.
[0013] FIG. **10** is a schematic diagram depicting an operation of the gas turbine engine of FIG. **1**

during a non-idle operating state, and during a power-augmentation operating state, but with a total loss of steam generation by the steam generating system, according to an aspect of the present disclosure.

[0014] FIG. **11** is a schematic diagram depicting an operation of the gas turbine engine of FIG. **1** during a non-idle operating state, and during a power-augmentation operating state, but with a partial loss of steam generation by the steam generating system, according to an aspect of the present disclosure.

[0015] FIG. **12** is a flowchart of process steps for a method of operating the gas turbine engine of FIG. **1**, according to an aspect of the present disclosure.

DETAILED DESCRIPTION

[0016] Features, advantages, and embodiments of the present disclosure are set forth or apparent from a consideration of the following detailed description, drawings, and claims. Moreover, the following detailed description is exemplary and intended to provide further explanation without limiting the scope of the disclosure as claimed.

[0017] Various embodiments are discussed in detail below. While specific embodiments are discussed, this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations may be used without departing from the scope of the present disclosure.

[0018] As used herein, the terms “first” or “second” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

[0019] The terms “upstream” and “downstream” refer to the relative direction with respect to fluid flow in a fluid pathway. For example, “upstream” refers to the direction from which the fluid flows, and “downstream” refers to the direction to which the fluid flows.

[0020] The terms “forward” and “aft” refer to relative positions within a turbine engine or a vehicle, and refer to the normal operational attitude of the turbine engine or the vehicle. For example, with regard to a turbine engine, forward refers to a position closer to an engine inlet and aft refers to a position closer to an engine nozzle or an exhaust.

[0021] The terms “coupled,” “fixed,” “attached,” “connected,” and the like, refer to both direct coupling, fixing, attaching, or connecting, as well as indirect coupling, fixing, attaching, or connecting through one or more intermediate components or features, unless otherwise specified herein.

[0022] The singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise.

[0023] As used herein, the terms “axial” and “axially” refer to directions and orientations that extend substantially parallel to a centerline of the aircraft gas turbine engine. Moreover, the terms “radial” and “radially” refer to directions and orientations that extend substantially perpendicular to the centerline of the aircraft gas turbine engine. In addition, as used herein, the terms “circumferential” and “circumferentially” refer to directions and orientations that extend arcuately about the centerline of the turbine engine.

[0024] As used herein, “top” refers to a highest or uppermost point, portion, or surface of a component in the orientations shown in the figures.

[0025] As used herein, “bottom” refers to a lowest or lowermost point, portion, or surface of a component in the orientations shown in the figures.

[0026] As used herein, the terms “low,” “mid” (or “mid-level”), and “high,” or their respective comparative degrees (e.g., “lower” and “higher”, where applicable), when used with compressor, combustor, turbine, shaft, fan, or turbine engine components, each refers to relative pressures, relative speeds, relative temperatures, or relative power outputs within an engine unless otherwise specified. For example, a “low-power” setting defines the engine or the combustor configured to operate at a power output lower than a “high-power” setting of the engine or the combustor, and a “mid-level power” setting defines the engine or the combustor configured to operate at a power output higher than a “low-power” setting and lower than a “high-power” setting. The terms “low,” “mid” (or “mid-level”) or “high” in such aforementioned terms may additionally, or alternatively, be understood as relative to minimum allowable speeds, pressures, or temperatures, or minimum or maximum allowable speeds, pressures, or temperatures relative to normal, desired, steady state, etc., operation of the engine. A mission cycle for a turbine engine includes, for example, a low-power operation, a mid-level power operation, and a high-power operation. Low-power operation includes, for example, engine start, idle, taxiing, and approach. Mid-level power operation includes, for example, cruise. High-power operation includes, for example, takeoff and climb.

[0027] As used herein, the term “idle operating state” refers to an operating state of the gas turbine engine during engine start and operation of the turbine engine at a power level of less than ten percent of the full power level capability of the turbine engine. For example, the idle operating state may be operating the turbine engine after initial start of the engine while an aircraft is stationed at an airport gate or is waiting to commence taxiing. The idle operating state may also be operating the turbine engine after arriving at the airport gate prior to shut down, or while the aircraft is sitting stationary waiting to commence taxiing to the airport gate at the end of a flight.

[0028] As used herein, the term “non-idle operating state” refers to an operating state of the turbine engine that is greater than ten percent or less than about thirty percent of the full power level capability of the turbine engine. For example, the non-idle operating state includes any of the foregoing low-power operations other than engine start and idle (e.g., includes approach when greater than ten percent or less than about thirty percent of the full power level capability), any of the mid-level power operations, or of the high-power operations. While the foregoing refers to taxiing, approach, cruise, takeoff and climb, such operations are generally applicable to the turbine engine being installed on an aircraft, and operated during a flight of the aircraft on which the turbine engine is mounted. However, the non-idle operating state is also applicable for turbine engines that are implemented on applications other than on an aircraft, such as a land-based implementation or a marine-based implementation. In either a land-based implementation or a marine-based implementation, the turbine engine may be operated to be used for generating power, such as driving an electrical generator or driving a mechanical drive system. In the land-based implementation or in the marine-based implementation, the non-idle operating state may be a state in which the power level of the turbine engine is sufficient to provide necessary power for generating electricity, or for driving the mechanical drive system.

[0029] As used herein, the term “non-power-augmentation operating state” refers to an operating state of the gas turbine engine in which normal combustion within a first combustor of the gas turbine engine occurs, but in which a second combustor is idle such that neither fuel nor steam are provided to the second combustor. The non-power-augmentation operating state may occur during either the idle operating state as defined above, or during the non-idle operating state define above when power augmentation is not being performed.

[0030] As used herein, the term “power-augmentation operating state” refers to an operating state of the gas turbine engine during the non-idle operating state as defined above, but in which power or thrust augmentation is being performed. In the power-augmentation operating state, in the case when the steam generating system is generating steam normally, the steam generated by a steam generating system is provided to both a steam turbine and to the second combustor to provide power or thrust augmentation. Alternatively, in a case when power augmentation is being performed, but the steam generating system is not generating sufficient steam, the power-augmentation operating state is implemented by performing combustion within the second combustor and providing combustion products from the second combustor to the first combustor to obtain the power or thrust augmentation.

[0031] Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about,” “approximately,” “generally,” and “substantially” is not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or the machines for constructing the components and/or the systems or manufacturing the components and/or the systems. For example, the approximating language may refer to being within a one, two, four, ten, fifteen, or twenty percent margin in either individual values, range(s) of values and/or endpoints defining range(s) of values.

[0032] Here and throughout the specification and claims, range limitations are combined, and interchanged. Such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

[0033] In an aircraft gas turbine engine, a combustor may generally include a swirler that provides a flow of swirled air mixed with fuel into a combustion chamber, where the fuel and air mixture is ignited and burned to generate combustion gases that do work on turbines within a turbine section to rotate turbine rotors. The turbine rotors are generally connected to, and drive, compressor rotors that compress inlet air that is provided to the combustor. In some operating conditions of the gas turbine engine (e.g., during takeoff or climb-out of an aircraft), additional power may be needed. When the gas turbine engine increases power, additional carbon monoxide (CO) and nitrous oxide (NO.sub.x) emissions are generated by the combustor. One technique to attempt to reduce the CO and the NO.sub.x emissions in a high-power operating state is to include a steam turbine in the gas turbine engine, and to inject steam into the steam turbine to add additional power to the gas turbine engine, thereby reducing the CO and NO.sub.x emissions. The steam may also be injected into the combustor to increase the density of the combustion gases, thereby providing for additional work to be extracted by the turbine section from the denser exhaust gases. The use of the steam turbine, however, is generally only practical when the steam generating system is functioning properly to generate sufficient steam to be provided to the steam turbine or to the combustor.

[0034] The present disclosure provides a technique to continue to provide additional power to the gas turbine engine during a non-idle operating state, even if the steam generating system has a reduced steam generating capacity or is not able to generate steam at all. According to the present disclosure, a second combustor is provided in parallel with a first (or a main) combustor, and a second combustion chamber within the second combustor is connected to a first combustion chamber within the first combustor. When the steam generating system is functioning properly, steam can be provided to the second combustor, and the steam can then flow from the second combustion chamber into the first combustion chamber of the first combustor, thereby augmenting the thrust of the gas turbine engine at the non-idle operating state. On the other hand, when the steam generating system is not generating steam, fuel and compressor bleed air can be provided to the second combustor to generate combustion products within the second combustion chamber, and the combustion products from the second combustion chamber can flow into the first combustion chamber to mix with combustion gases generated by the first combustor so as to augment the thrust of the gas turbine engine. Additionally, in a case when the steam generating system is generating steam, but at a diminished level that is insufficient to provide all of the needed additional power via the steam turbine, the lower amount of steam can be provided to the second combustor, and the second combustor can also utilize the compressor bleed air and fuel to ignite a steam-air-fuel mixture within the second combustion chamber. The combustion products of the second combustor can then be provided to the first combustion chamber to, again, augment the thrust of the gas turbine engine.

[0035] Referring now to the drawings, FIG. **1** is a schematic cross-sectional diagram of an aircraft gas turbine engine **10** that may be installed on an aircraft (not shown) and that includes a steam generating system **100** (described below), taken along a longitudinal centerline axis **12** (provided for reference) of the aircraft gas turbine engine **10**, according to an embodiment of the present disclosure. The present disclosure may be implemented in any of various types of aircraft turbine engines, including high bypass turbofan engines, open rotor turbo engines, turbojet engines, and turboprop engines. The gas turbine engine **10** may be controlled by a controller **13** that may monitor various systems within the gas turbine engine **10**, and provides commands for controlling operations of the gas turbine engine **10**. As shown in FIG. **1**, the aircraft gas turbine engine **10** has a longitudinal direction L (extending parallel to the longitudinal centerline axis **12**) and a radial direction R that is normal to the longitudinal direction L. In general, the aircraft gas turbine engine **10** includes a fan section **14** and a turbo-engine **16** disposed downstream from the fan section **14**.

[0036] The turbo-engine **16** includes an outer casing **18** that encases the turbo-engine **16** and that is substantially tubular and defines an annular inlet **20**. As schematically shown in FIG. **1**, the turbo-engine **16** includes, in serial flow relationship, a compressor section **21** including a booster or a low-pressure compressor (LPC) **22**, followed downstream by a high-pressure compressor (HIPC) **24**, a combustion section **26**, a turbine section **27** including a high-pressure turbine (HPT) **28** followed downstream by a low-pressure turbine (LPT) **30**, and an exhaust section **31** that includes one or more exhaust nozzles **32**. A high-pressure (HP) shaft **34** drivingly connects the HPT **28** to the HPC **24** to rotate the HPT **28** and the HPC **24** in unison. A low-pressure (LP) shaft **36** drivingly connects the LPT **30** to the LPC **22** to rotate the LPT **30** and the LPC **22** in unison. The compressor section **21**, the combustion section **26**, the turbine section **27**, and the exhaust section **31** including the one or more exhaust nozzles **32** together define a turbo-engine air flow path **33** therethrough.

[0037] For the embodiment depicted in FIG. **1**, the fan section **14** includes a fan **38** (e.g., a variable pitch fan) having a plurality of fan blades **40** coupled to a disk **42** in a circumferentially spaced-apart manner. As depicted in FIG. **1**, the fan blades **40** extend outwardly from the disk **42** generally along the radial direction R. Each fan blade **40** is rotatable relative to the disk **42** about a pitch axis P by virtue of the fan blades **40** being operatively coupled to an actuator **44** configured to collectively vary the pitch of the fan blades **40** in unison. The fan blades **40**, the disk **42**, and the actuator **44** are together rotatable about the longitudinal centerline axis **12** via a fan shaft **45** that is powered by the LP shaft **36** across a power gearbox, also referred to as a gearbox assembly **46**. The gearbox assembly **46** is shown schematically in FIG. **1**, but includes a plurality of gears (not shown) for adjusting the rotational speed of the fan shaft **45** and, adjusting the rotational speed of the fan **38** relative to the LP shaft **36**.

[0038] Referring still to FIG. **1**, the disk **42** is covered by a rotatable fan hub **48** that is aerodynamically contoured to promote an airflow through the plurality of fan blades **40**. In addition, the fan section **14** includes an annular fan casing or a nacelle **50** that circumferentially surrounds the fan **38** and/or at least a portion of the turbo-engine **16**. The nacelle **50** is supported relative to the turbo-engine **16** by a plurality of circumferentially spaced struts or outlet guide vanes **52**. Moreover, a downstream section **54** of the nacelle **50** extends over an outer portion of the turbo-engine **16** to define a bypass airflow passage **56** therebetween. The one or more exhaust nozzles **32** may extend through the nacelle **50** and be formed therein. In the embodiment of FIG. **1**, the one or more exhaust nozzles **32** include one or more discrete nozzles that are spaced circumferentially about the nacelle **50**. Other arrangements of the one or more exhaust nozzles **32** may be used including, for example, a single exhaust nozzle that is annular, or partially annular, about the nacelle **50**.

[0039] During a standard operating mode of the aircraft gas turbine engine **10**, a volume of air **58** enters the aircraft gas turbine engine **10** through an inlet **60** of the nacelle **50** and/or the fan section **14**. As the volume of air **58** passes across the fan blades **40**, a first portion of the air **58**, shown as bypass air **62**, is directed or routed into the bypass airflow passage **56**, and a second portion of the air **58**, shown as turbo-engine inlet air **64**, is directed or is routed into the upstream section of the turbo-engine air flow path **33**, or, more specifically, into the annular inlet **20** of the LPC **22**. A ratio between the bypass air **62** and the turbo-engine inlet air **64** is known as a bypass ratio. The pressure of the turbo-engine inlet air **64** is then increased by the LPC **22**, generating compressed air **65**, and the compressed air **65** is routed through the HPC **24**, where it is further compressed before being directed into the combustion section **26**, where the compressed air **65** is mixed with fuel **67** and burned to generate combustion gases **66** (also referred to as combustion products). One or more stages may be used in each of the LPC **22** and the HPC **24**, with each subsequent stage further compressing the compressed air **65**.

[0040] The combustion gases **66** are routed from the combustion section **26** into the HPT **28** and expanded through the HPT **28**, where a portion of thermal energy and/or kinetic energy from the combustion gases **66** is extracted via sequential stages of HPT stator vanes **68** that are coupled to the outer casing **18**, and HPT rotor blades **70** that are coupled to rotors connected to the HP shaft **34**, thus, causing the HP shaft **34** to rotate, thereby supporting operation of the HPC **24**. The combustion gases **66** are then routed into the LPT **30** and are further expanded through the LPT **30**. Here, a second portion of thermal energy and/or the kinetic energy is extracted from the combustion gases **66** via sequential stages of LPT stator vanes **72** that are coupled to the outer casing **18**, and LPT rotor blades **74** that are coupled to LPT rotors connected to the LP shaft **36**, thus, causing the LP shaft **36** to rotate, thereby supporting operation of the LPC **22** and rotation of the fan **38** via the gearbox assembly **46**. One or more stages may be used in each of the HPT **28** and the LPT **30**.

[0041] The combustion gases **66** are subsequently routed through the one or more exhaust nozzles **32** of the turbo-engine **16** to provide propulsive thrust. Simultaneously with the flow of the turbo-engine inlet air **64** through the turbo-engine air flow path **33**, the bypass air **62** is routed through the bypass airflow passage **56** before being exhausted from a fan bypass nozzle **76** of the aircraft gas turbine engine **10**, also providing propulsive thrust. The HPT **28**, the LPT **30**, and the one or more exhaust nozzles **32** at least partially define a hot gas path **78** for routing the combustion gases **66** through the turbo-engine **16**.

[0042] As noted above, the compressed air **65** is mixed with the fuel **67** in the combustion section **26** to form a fuel and air mixture, and the fuel and air mixture is then combusted, generating the combustion gases **66** (combustion products). The fuel **67** can include any type of hydrocarbon fuel used for turbine engines, such as, for example, sustainable aviation fuels (SAF) including biofuels, Jet A, Jet A-1, or other hydrocarbon fuels. Other fuel types, which may or may not be hydrocarbon fuels, but that may generally be used in an aircraft gas turbine engine may also be utilized to implement the present disclosure.

[0043] The compressor section **21** also includes a compressor bleed air system **94**, which may generally be arranged at a downstream end of the HPC **24** and is arranged to bleed-off some of the compressed air **65** from the HPC **24** as a flow of compressor bleed air **69**. The flow of compressor bleed air **69** is provided to a compressor bleed air valve **95** via a compressor bleed air duct **96**. The compressor bleed air valve **95** can be controlled to divert at least a portion of the flow of compressor bleed air **69**, via a compressor bleed air duct **97**, to the combustion section **26**. The compressor bleed air valve **95** can also be controlled to provide at least a portion of the flow of the compressor bleed air **69** to other systems within the gas turbine engine **10** via a compressor bleed air duct **99**.

[0044] The aircraft gas turbine engine **10** includes a fuel system **80** for providing the fuel **67** to the combustion section **26**. The fuel system **80** includes a fuel tank **82** for storing the fuel **67** therein, and a fuel delivery system **84**. The fuel tank **82** can be located on an aircraft (not shown) to which the aircraft gas turbine engine **10** is attached. While a single fuel tank **82** is shown in FIG. **1**, the fuel system **80** can include any number of fuel tanks **82**, as desired. The fuel delivery system **84** delivers the fuel **67** from the fuel tank **82** to the combustion section/**26** via one or more fuel supply lines **85**. The fuel delivery system **84** also includes a fuel pump **86** to induce the flow of the fuel **67** through the fuel supply lines **85** to the combustion section **26**. In this way, the fuel pump **86** pumps the fuel **67** from the fuel tank **82**, through the fuel supply lines **85**, and into the combustion section

26.

[0045] The aircraft gas turbine engine **10** of the present disclosure includes the steam generating system **100**, which is in fluid communication with the one or more exhaust nozzles **32** and the fan bypass nozzle **76**. As will be described in more detail below, the steam generating system **100** generates steam from the combustion gases **66** as the combustion gases **66** flow through the steam generating system **100**, and may deliver at least a portion of the generated steam to the combustion section **26**.

[0046] The aircraft gas turbine engine **10** depicted in FIG. **1** is by way of example only. In other exemplary embodiments, the aircraft gas turbine engine **10** may have any other suitable configuration. For example, in other exemplary embodiments, the fan **38** may be configured in any other suitable manner (e.g., as a fixed pitch fan) and further may be supported using any other suitable fan frame configuration. Moreover, in other exemplary embodiments, any other suitable number or configuration of compressors, turbines, shafts, or a combination thereof may be provided. In still other exemplary embodiments, aspects of the present disclosure may be incorporated into any other suitable aircraft gas turbine engine, such as, for example, turbofan engines, open rotor turbo-engines, propfan engines, and/or turboprop engines.

[0047] FIG. **2** is a schematic diagram of the aircraft gas turbine engine **10** and the steam generating system **100** of FIG. **1**, according to an aspect of the present disclosure. For clarity, the aircraft gas turbine engine **10** is shown schematically in FIG. **2** and some components depicted and described above with regard to FIG. **1** are not shown in FIG. **2**. As shown in FIG. **2**, the steam generating system **100** includes a boiler **102**, a condenser **104**, a water/exhaust separator **106**, a water pump **108**, and a steam turbine **110**.

[0048] The boiler **102** is a heat exchanger that vaporizes liquid water from a water source to generate steam or water vapor, as detailed further below. The boiler **102** is thus a steam source. In particular, the boiler **102** is an exhaust gas-water heat exchanger. The boiler **102** is in fluid communication with the hot gas path **78** (FIG. **1**) and is positioned downstream of the LPT **30**. The boiler **102** is also in fluid communication with the water pump **108**, as detailed further below. The boiler **102** can include any type of boiler or heat exchanger for extracting heat from the combustion gases **66** and vaporizing liquid water into steam or water vapor as the liquid water and the combustion gases **66** flow through the boiler **102**.

[0049] The condenser **104** is a heat exchanger that further cools the combustion gases **66** as the combustion gases **66** flow through the condenser **104**, as detailed further below. In particular, the condenser **104** is an air-exhaust gas heat exchanger. The condenser **104** is in fluid communication with the boiler **102** and is positioned within the bypass airflow passage **56**. The condenser **104** can include any type of condenser for condensing water from the exhaust (e.g., the combustion gases **66**).

[0050] The water/exhaust separator **106** is in fluid communication with the condenser **104** for receiving cooled exhaust (combustion gases **66**) having condensed water entrained therein. The water/exhaust separator **106** is also in fluid communication with the one or more exhaust nozzles **32** and with the water pump **108**. The water/exhaust separator **106** includes any type of water separator for separating water from the exhaust. For example, the water/exhaust separator **106** can include a cyclonic separator that uses vortex separation to separate the water from the exhaust. In such embodiments, the water/exhaust separator **106** generates a cyclonic flow within the water/exhaust separator **106** to separate the water from the cooled exhaust. In FIG. **2**, the water/exhaust separator **106** is schematically depicted as being in the nacelle **50**, but the water/exhaust separator **106** could be located at other locations within the aircraft gas turbine engine **10**, such as, for example, radially inward of the nacelle **50**, closer to the turbo-engine **16**. The water/exhaust separator **106** may be driven to rotate by one of the engine shafts, such as the HP shaft **34** or the LP shaft **36**, via an accessory gearbox (not shown). As noted above, the boiler **102** receives liquid water from a water source to generate steam or water vapor. The water source may be a water storage tank **107** that is provided between the water/exhaust separator **106** and the water pump **108**. In the embodiment depicted in FIG. **2**, the water storage tank **107** may, therefore, be the water source for the boiler **102**.

[0051] The water pump **108** is in fluid communication with the water storage tank **107** and with the boiler **102**. The water pump **108** may be any suitable pump, such as a centrifugal pump or a positive displacement pump. The water pump **108** directs separated water **112** that is stored in the water storage tank **107** through the boiler **102**, where it is converted back to steam **114**. The steam **114** is sent through the steam turbine **110** via a steam supply line **88** to provide work to drive the steam turbine **110**.

[0052] In operation, the combustion gases **66**, also referred to as exhaust, flow from the LPT **30** into the boiler **102** and into the condenser **104**. The combustion gases **66** transfer heat into water **111** within the boiler **102** to generate the steam **114** within the boiler **102**, as detailed further below. The combustion gases **66** then flow into the condenser **104**, where the condenser **104** condenses the water contained within the combustion gases **66**. The bypass air **62** flows through the bypass airflow passage **56** and over or through the condenser **104**, and extracts heat from the combustion gases **66**, cooling the combustion gases **66** and condensing the water from the combustion gases **66**, to generate an exhaust-water mixture **116**. The bypass air **62** is then exhausted out of the aircraft gas turbine engine **10** through the fan bypass nozzle **76** to generate thrust, as detailed above. The condenser **104** thus may be positioned in the bypass airflow passage **56**.

[0053] The exhaust-water mixture **116** flows into the water/exhaust separator **106**. The water/exhaust separator **106** separates the water and the exhaust gases from the exhaust-water mixture **116** to generate separate exhaust gases **118** and the water **112**. The exhaust gases **118** are exhausted out of the aircraft gas turbine engine **10** through the one or more exhaust nozzles **32** to generate thrust, as detailed above. The boiler **102**, the condenser **104**, and the water/exhaust separator **106** thus also define a portion of the hot gas path **78** (FIG. **1**) for routing the combustion gases **66**, the exhaust-water mixture **116**, and the exhaust gases **118** through the steam generating system **100** of the aircraft gas turbine engine **10**.

[0054] The water pump **108** helps to urge the water **112** from the water/exhaust separator **106** into the water storage tank **107**, and pumps the water **112** through one or more water lines (as indicated by the arrow for the water **112** in FIG. **2**) so that the water **112** flows into the boiler **102** to mix with the water **111**. The water **111** flows through the boiler **102** and the combustion gases **66** flowing through the boiler **102** transfer heat into the water **111** to vaporize the water **111** and to generate the steam **114**.

[0055] The steam turbine **110** is coupled to the LP shaft **36**, but may also be coupled to the HP shaft **34**. The steam turbine **110** includes one or more stages of steam turbine blades (not shown) and steam turbine stators (not shown). The steam **114** flows from the boiler **102** via a steam supply line **88** into the steam turbine **110**, causing the steam turbine blades of the steam turbine **110** to rotate, thereby generating additional work in the LP shaft **36**. Additionally, at least a portion of the steam **114** may flow through one or more combustor steam supply lines **98** into the combustion section **26**, and a steam control valve **92** may be provided within the combustor steam supply line **98** to control a flow of the steam **114** into the combustion section **26**. As for the steam **114** provided to the steam turbine **110**, the remaining steam (as steam **120**) may then flow from the steam turbine **110**, through one or more steam supply lines **90**, back into the boiler **102**.

[0056] As was described above, the compressor section **21** (FIG. **1**) includes the compressor bleed air system **94**, which may generally be arranged at a downstream end of the HPC **24** and is arranged to bleed-off some of the compressed air **65** from the HPC **24** as a flow of compressor bleed air **69**. The flow of compressor bleed air **69** is provided to the compressor bleed air valve **95** via the compressor bleed air duct **96**. The compressor bleed air valve **95** can be controlled to divert at least a portion of the flow of compressor bleed air **69**, via the compressor bleed air duct **97**, to the combustion section **26**. The compressor bleed air valve **95** can also be controlled to provide at least a portion of the flow of the compressor bleed air **69** to other systems within the gas turbine engine **10** via the compressor bleed air duct **99**.

[0057] FIG. **3** is a partial cross-sectional side view of an exemplary combustion section **26** of the turbo-engine **16** as shown in FIG. **1**, according to an aspect of the present disclosure. The exemplary combustion section **26** shown in FIG. **3** is depicted as an annular type combustion section that extends circumferentially about the longitudinal centerline axis **12**. With respect to the combustion section **26**, the longitudinal centerline axis **12** may also correspond to a combustor centerline axis **12′**. The combustion section **26** includes a combustor outer casing **124** and a combustor inner casing **126** that each extends annularly about the combustor centerline axis **12′**. A first combustor **125** is arranged within the combustor outer casing **124** and the combustor inner casing **126**. The first combustor **125** includes a first combustor inner liner **130**, a first combustor outer liner **132**, and a dome structure **134**, each of which extends circumferentially about the combustor centerline axis **12′**. A first combustion chamber **131** is defined between the first combustor inner liner **130**, the first combustor outer liner **132**, and the dome structure **134**. As will be described in more detail below, the first combustion chamber **131** may be theoretically divided into a primary combustion zone **133** and a secondary combustion zone **137** downstream of the primary combustion zone **133**, where, in FIG. **3**, a dashed line **135** represents the theoretical division between the primary combustion zone **133** and the secondary combustion zone **137**.

[0058] The first combustor outer liner **132** may include various airflow openings therethrough, including a plurality of primary zone cooling openings **136**, a plurality of dilution openings **138** (one shown in FIG. **3**), and a plurality of secondary zone cooling openings **140**. Similarly, the first combustor inner liner **130** may include various airflow openings therethrough, including a plurality of primary zone cooling openings **142**, a plurality of dilution openings **144** (one shown in FIG. **3**), and a plurality of secondary zone cooling openings **146**. In addition, the dome structure **134** may include a plurality of cooling airflow openings **148** therethrough. Further, a downstream end **143** of the combustor outer casing **124** may include a plurality of airflow openings **141** to provide a flow of turbine cooling air **183** into the HPT **28**, and a downstream end **149** of the combustor inner casing **126** may include a plurality of airflow openings **147** to provide a flow of turbine cooling air **189** to the HPT **28**.

[0059] The first combustor **125** further includes a plurality of swirler assemblies **156** (one shown in FIG. **3**) that are connected to the dome structure **134**, and a plurality of first fuel nozzles **158** (one shown in FIG. **3**) that are connected to respective ones of the plurality of swirler assemblies **156**. As will be described below, each of the plurality of first fuel nozzles **158** injects the fuel **67** into a respective one of the swirler assemblies **156**.

[0060] The first combustor inner liner **130** and the first combustor outer liner **132** are connected to the dome structure **134**, thereby defining the first combustion chamber **131** therebetween. The first combustor inner liner **130** and the first combustor outer liner **132** extend from the dome structure **134** to a combustor outlet **150** at an entry to the HPT **28** (FIG. **1**), thus, at least partially defining a hot gas path between the dome structure **134** and the HPT **28**. In addition, a cowl **152** is connected to the first combustor inner liner **130**, to the first combustor outer liner **132**, and to the dome structure **134**, thereby defining a plenum **154** therewithin. The cowl **152** extends circumferentially about the combustor centerline axis **12′** and may be formed of a single cowl structure, or may be formed by multiple cowl structures that are connected together. The cowl **152** includes a plurality of cowl airflow openings **157** (one shown in FIG. **3**), where each opening corresponds to a respective one of the plurality of swirler assemblies **156**. Each cowl airflow opening **157** provides a flow of air therethrough into the plenum **154**. The cowl **152** is connected to the combustor outer casing **124** via a cowl mounting arm **153**.

[0061] As shown in FIG. **3**, the combustor outer casing **124** and the combustor inner casing **126** surround the first combustor outer liner **132** and the first combustor inner liner **130**. An outer airflow passage **160** is defined between the combustor outer casing **124** and the first combustor outer liner **132**, and an inner airflow passage **162** is defined between the combustor inner casing **126** and the first combustor inner liner **130**. A diffuser **164** is connected to the combustion section **26** between an upstream end **166** of the combustor outer casing **124** and an upstream end **168** of the combustor inner casing **126**. A pressure plenum **170** is defined between the upstream end **166** of the combustor outer casing **124** and the upstream end **168** of the combustor inner casing **126**. The diffuser **164** provides a flow of the compressed air **65** from the HPC **24** into the pressure plenum **170**.

[0062] Referring still to FIG. **3**, during operation of the aircraft gas turbine engine **10**, the compressed air **65** flows through the diffuser **164** and into the pressure plenum **170** of the combustion section **26** to pressurize the pressure plenum **170**. A first portion of the compressed air **65** in the pressure plenum **170**, as indicated schematically by an arrow denoting compressed air **172**, flows from the pressure plenum **170** into the plenum **154** of the cowl **152**. The compressed air **172** then flows through the swirler assemblies **156**, where it is mixed with the fuel **67** provided by the first fuel nozzles **158**. A fuel-air mixture **191** is generated within each of the swirler assemblies **156** and the fuel-air mixture **191** is then injected into the first combustion chamber **131** by the swirler assemblies **156**, where the air/fuel mixture is ignited by an ignitor (not shown) and burned to generate the combustion gases **66** within the first combustion chamber **131**. A portion of the compressed air **172** within the plenum **154**, shown schematically by arrows denoting cooling air **190**, may flow through the cooling airflow openings **148** in the dome structure **134** to provide cooling of a downstream side of the dome structure **134**. While not shown in FIG. **3**, the dome structure **134** may include a deflector or a heat shield on the downstream side to protect the dome structure **134** from heat generated in the first combustion chamber **131**, and the cooling airflow openings **148** would extend through the deflector or the heat shield.

[0063] A second portion of the compressed air **65** in the pressure plenum **170**, as indicated schematically by arrows denoting compressed air **174** and compressed air **176**, may be routed into the outer airflow passage **160**, and into the inner airflow passage **162**, respectively. A portion of the compressed air **174** flowing through the outer airflow passage **160**, shown schematically as cooling air **178**, may be routed through the plurality of primary zone cooling openings **136** into the primary combustion zone **133** of the first combustion chamber **131**. Another portion of the compressed air **174** flowing through the outer airflow passage **160**, shown schematically as cooling air **182**, may be routed through the secondary zone cooling openings **140** into the secondary combustion zone **137** of the first combustion chamber **131**. Similarly, a portion of the compressed air **176** flowing through the inner airflow passage **162**, shown schematically as cooling air **184**, may be routed through the plurality of primary zone cooling openings **142** into the primary combustion zone **133** of the first combustion chamber **131**. Another portion of the compressed air **176** flowing through the inner airflow passage **162**, shown schematically as dilution airflow **186**, may be routed through the dilution openings **144** of the first combustor inner liner **130** into the first combustion chamber **131** to provide quenching of the combustion gases **66**. Yet another portion of the compressed air **176** flowing through the inner airflow passage **162**, shown schematically as cooling air **188**, may be routed through the secondary zone cooling openings **146** into the secondary combustion zone **137** of the first combustion chamber **131**.

[0064] In FIG. **3**, the combustion section **26** further includes a second combustor **192** that is arranged within the outer airflow passage **160**. While FIG. **3** depicts the second combustor **192** as being arranged within the outer airflow passage **160**, the second combustor **192** may be arranged within the inner airflow passage **162** instead. The second combustor **192** includes a second combustor casing **194** and a second combustor liner **196** arranged within the second combustor casing **194**. The second combustor liner **196** defines therewithin a second combustion chamber **198**. The compressor bleed air duct **97** is connected to the second combustor **192** to provide the flow of compressor bleed air **69** to the second combustor **192**. In addition, the combustor steam supply line **98** is connected to the second combustor **192** to provide the flow of the steam **114** to the second combustor **192**. Further, the second combustor **192** includes a second fuel nozzle **200** that is arranged to provide a second flow of fuel **67***b* to the second combustion chamber **198**, and an ignitor **202** is arranged to provide a spark to the second combustion chamber **198** for igniting a fuel-air mixture (described below) within the second combustion chamber **198**.

[0065] FIG. **4** is an enlarged detail view of the second combustor **192**, taken at detail view **204** of FIG. **3**, according to an aspect of the present disclosure. As was briefly described above, the second combustor **192** is arranged within the outer airflow passage **160** between the combustor outer casing **124** and the first combustor outer liner **132**. The second combustor **192** includes the second combustor casing **194**, which may be mounted to the first combustor outer liner **132** via one or more mounting brackets **206**. The second combustor casing **194** may, however, be mounted to the combustor outer casing **124**. Included within the second combustor casing **194** is the second combustor liner **196**, which defines therewithin, the second combustion chamber **198**. In the FIG. **4** aspect, a single second combustor liner **196** is provided within the second combustor casing **194**. However, as will be described below, more than one second combustor liner **196** may be provided within the second combustor casing **194**. The second combustor liner **196** of FIG. **4** is shown to be configured as a trapped vortex combustor liner **197**, but other types of combustor liners may also be implemented instead of a trapped vortex combustor liner. The second combustor liner **196** includes an outlet **199** that extends through the second combustor casing **194** and also extends through the first combustor outer liner **132** via the dilution opening **138**. The outlet **199** provides fluid communication from the second combustion chamber **198** to the secondary combustion zone **137** of the first combustion chamber **131**. The second combustor liner **196** may be mounted within the second combustor casing **194** via one or more mounting brackets **208** that include one or more openings **209** therethrough. A second combustor plenum **210** is defined between the second combustor casing **194** and the second combustor liner **196** and surrounds the second combustor liner **196**. The openings **209** through the mounting brackets **208** allow for a free flow of air or steam throughout the second combustor plenum **210** around the exterior side of the second combustor liner **196**. Alternatively, rather than the second combustor liner **196** being connected to the first combustor outer liner **132** via the mounting brackets **208**, the second combustor liner **196** may be formed integral with the first combustor outer liner **132**. For example, the second combustor liner **196** may be welded to, or brazed to, the first combustor outer liner **132**.

[0066] As shown in FIG. **4**, the compressor bleed air duct **97** extends through the combustor outer casing **124** and is connected to the second combustor casing **194** so as to provide fluid communication from the compressor bleed air duct **97** into the second combustor plenum **210**. In addition, the combustor steam supply line **98** extends through the combustor outer casing **124** and is connected to the second combustor casing **194** so as to provide fluid communication from the combustor steam supply line **98** into the second combustor plenum **210**. As will be described below, in some operating states of the gas turbine engine **10**, the compressor bleed air **69** is provided to the second combustor plenum **210** via the compressor bleed air duct **97**, or the steam **114** is provided to the second combustor plenum **210** via the combustor steam supply line **98**. The second fuel nozzle **200** extends through the combustor outer casing **124**, and extends through the second combustor liner **196** to provide the second flow of fuel **67***b* to the second combustion chamber **198**. The ignitor **202** also extends through the combustor outer casing **124** and through the second combustor liner **196**, and, when combustion is to be effected within the second combustion chamber **198**, the ignitor **202** provides a spark to ignite a fuel-air mixture **218** within the second combustion chamber **198**.

[0067] The second combustor liner **196** includes a plurality of openings **212** that extend through the second combustor liner **196**. Each of the openings **212** provides fluid communication from the second combustor plenum **210** and the second combustion chamber **198**. As will be described below, when the compressor bleed air **69** is provided to the second combustor plenum **210** via the compressor bleed air duct **97**, the compressor bleed air **69** flows through the openings **212** from the second combustor plenum **210** into the second combustion chamber **198**. As described above, the second combustor liner **196** may be configured as the trapped vortex combustor liner **197**. The openings **212** are, therefore, arranged through the trapped vortex combustor liner **197** so as to generate a trapped vortex flow **214** within the trapped vortex combustor liner **197**. In FIG. **4**, the arrangement of the openings **212** is such as to generate a counter-clockwise trapped vortex flow **214**. In the case when the compressor bleed air **69** is provided to the second combustion chamber **198** via the openings **212**, and combustion is to be effected within the second combustion chamber **198**, a second combustor fuel valve **216** is opened to allow the second flow of fuel **67***b* (a first flow of the fuel **67***a* being provided to the swirler assembly **156** via the first fuel nozzle **158** as described above for FIG. **3**) to flow into the second combustion chamber **198**. The second flow of fuel **67***b* and the compressor bleed air **69** are mixed together in the trapped vortex flow **214** to generate the fuel-air mixture **218**, and the fuel-air mixture **218** is ignited by the ignitor **202**, thereby generating first combustion products **220** within the second combustion chamber **198**. The first combustion products **220** then flow through the outlet **199** into the secondary combustion zone **137** of the first combustion chamber **131** of the first combustor **125**. Thus, in the case when combustion is to be implemented within the second combustor **192** (e.g., during the non-idle operating state of the gas turbine engine **10**), the first combustion products **220** can mix with the combustion gases **66** (FIG. **3**) within the first combustion chamber **131** so as to augment the thrust of the gas turbine engine **10**.

[0068] Continuing with the discussion of FIG. **4**, in the case when the steam **114** is provided to the second combustor plenum **210** via the combustor steam supply line **98**, the steam **114** flows through the openings **212** from the second combustor plenum **210** into the second combustion chamber **198**. The steam **114** can then flow from the outlet **199** of the second combustion chamber **198** into the secondary combustion zone **137** of the first combustion chamber **131** in the first combustor **125**. In this manner, the steam **114** flowing into the first combustion chamber **131** can mix with the combustion gases **66** (FIG. **3**) to provide some quenching of the combustion gases **66**, and, to increase the density of combustion gases **66** so as to provide additional kinetic energy for driving the turbine section **27** (FIG. **1**) during the non-idle operating state of the gas turbine engine **10** (FIG. **1**).

[0069] In yet another case when both the steam **114** is provided to the second combustor plenum **210** and the compressor bleed air **69** is provided to the second combustor plenum **210**, the compressor bleed air **69** and the steam **114** mix together within the second combustor plenum **210** to form a steam-air mixture **222** within the second combustor plenum **210**. The steam-air mixture **222** then flows through the openings **212** of the second combustor liner **196** into the second combustion chamber **198**. The second fuel nozzle **200** is also enabled to provide the second flow of fuel **67***b* into the second combustion chamber **198**, and the second flow of fuel **67***b* mixes with the steam-air mixture **222** within the second combustion chamber **198** to form a steam-air-fuel mixture **224**. The steam-air-fuel mixture **224** is ignited by the ignitor **202** and burned to generate second combustion products **226**. The second combustion products **226** then flow through the outlet **199** into the secondary combustion zone **137** of the first combustion chamber **131**. Thus, the second combustion products **226**, similar to the first combustion products **220**, can mix with the combustion gases **66** (FIG. **3**) within the first combustion chamber **131** to augment the thrust of the gas turbine engine **10**.

[0070] FIG. **5** is a partial cross-sectional view of a semi-annular second combustor **192′** having multiple second combustion chambers as an alternate to the annular second combustor **192** of FIG. **3**, taken at plane **5-5** of FIG. **3**, according to an aspect of the present disclosure. As was stated above, the second combustor casing **194** (FIG. **4**) may include more than one second combustor liner **196** (FIG. **4**). FIG. **5** depicts a second combustor casing **194′** that includes multiple second combustor liners, including a second combustor liner **196***a* and a second combustor liner **196***b*. Both the second combustor liner **196***a* and the second combustor liner **196***b* may be similar to the second combustor liner **196** of FIG. **4**, and, both the second combustor liner **196***a* and the second combustor liner **196***b* may be trapped vortex combustor liners similar to the trapped vortex combustor liner **197** of FIG. **4**. A second fuel nozzle **200***a* extends through the combustor outer casing **124**, extends through the second combustor casing **194′**, and extends through the second combustor liner **196***a* so at provide a flow of the fuel, the second flow of fuel **67***b* to a second combustion chamber **198***a* of the second combustor liner **196***a*. Similar to the FIG. **4** aspect, the compressor bleed air duct **97** extends through the combustor outer casing **124** and through the second combustor casing **194′** so as to provide a flow of the compressor bleed air **69** to a second combustor plenum **210′**. In addition, the combustor steam supply line **98** extends through the combustor outer casing **124** and through the second combustor casing **194′** to provide a flow of the steam **114** to the second combustor plenum **210′**.

[0071] Each of the second combustor liner **196***a* and the second combustor liner **196***b* includes the openings **212** of FIG. **4**, but, also includes additional openings. For example, a first sidewall **228** of the second combustor liner **196***a* includes at least one sidewall opening **213***a* therethrough, and a second sidewall **230** of the second combustor liner **196***a* includes at least one sidewall opening **215***a* therethrough. Similarly, for the second combustor liner **196***b*, a first sidewall **232** of the second combustor liner **196***b* includes at least one sidewall opening **213***b* therethrough, and a second sidewall **234** of the second combustor liner **196***b* includes at least one sidewall opening **215***b* therethrough. Similar to the openings **212** of FIG. **4**, any one of the compressor bleed air **69**, the steam **114**, or the steam-air mixture **222** can flow through the sidewall opening **213***a*, through the sidewall opening **215***a*, through the sidewall opening **213***b*, and through the sidewall opening **215***b* into the second combustion chamber **198***a* and into the second combustion chamber **198***b*, respectively. The sidewall opening **213***a* and the sidewall opening **215***a* of the second combustor liner **196***a* are arranged to generate a swirled flow **236***a* within the second combustion chamber **198***a*, and the sidewall opening **213***b* and the sidewall opening **215***b* of the second combustor liner **196***b* are arranged to generate a swirled flow **236***b* within the second combustion chamber **198***b*. The swirled flow **236***a* and the swirled flow **236***b* can help to provide better mixing of the fuel **67** with either the compressor bleed air **69** or with the steam-air mixture **222**.

[0072] As also shown in FIG. **5**, the second combustor liner **196***a* has an outlet **199***a* (similar to the outlet **199** of FIG. **4**), and the second combustor liner **196***b* has an outlet **199***b* (again, similar to the outlet **199** of FIG. **4**). Each of the outlet **199***a* and the outlet **199***b* is in fluid communication with the secondary combustion zone **137** of the first combustion chamber **131** of the first combustor **125**. Thus, as was discussed above for FIG. **4**, for the FIG. **5** aspect, the outlet **199***a* of the second combustor liner **196***a* provides a flow of any one of first combustion products **220***a*, steam **114***a*, or second combustion products **226***a* into the secondary combustion zone **137**. Similarly, the outlet **199***b* of the second combustor liner **196***b* provides a flow of any one of first combustion products **220***b*, steam **114***b*, or second combustion products **226***b* into the secondary combustion zone **137**.

[0073] As further shown in FIG. **5**, the second combustor **192′** extends partially annularly about the combustor centerline axis **12′**. Thus, the second combustor **192′** may be considered to be a localized combustor **193** that does not extend annularly about the combustor longitudinal centerline axis **12′**. In other words, the second combustor **192′** is a partial-annular combustor **195** that extends partially annularly about the combustor centerline axis **12′**. While a single second combustor **192′** is shown in FIG. **5**, the combustion section **26** may include more than one second combustor **192′**, where the second combustors **192′** are spaced apart circumferentially about the combustor centerline axis **12′**. In addition, multiple second combustors **192** (FIG. **4**) may be included in the combustion section **26** (FIG. **1**), where, again, each second combustor **192** is circumferentially spaced apart about the combustor centerline axis **12′**.

[0074] FIG. **6** is a partial cross-sectional side view of an alternate second combustor **237** to that shown in FIG. **4**, according to another aspect of the present disclosure. In FIG. **6**, an alternate second combustor **237** includes a second combustor casing **238** and a second combustor liner **240**, with a second combustor plenum **242** being defined between the second combustor casing **238** and the second combustor liner **240**. The second combustor casing **238** is similar to the second combustor casing **194** of the FIG. **4** aspect. Similar to the FIG. **4** aspect, in the FIG. **6** aspect, the second combustor **237** includes the compressor bleed air duct **97** extending through the combustor outer casing **124** and extending through the second combustor casing **238** to provide the flow of the compressor bleed air **69** into the second combustor plenum **242**. In addition, the second combustor **237** includes the combustor steam supply line **98** that extends through the combustor outer casing **124** and through the second combustor casing **238** to provide the flow of steam **114** to the second combustor plenum **242**. In some aspects as described below, both the compressor bleed air **69** and the steam **114** may be simultaneously provided to the second combustor plenum **242**, thereby resulting in a steam-air mixture **244** being generated within the second combustor plenum **242**.

[0075] In contrast to the FIG. **4** aspect, the second combustor liner **240** of the FIG. **6** aspect is not a trapped vortex combustor liner, but, rather, is an axial-flow second combustor liner **246** that includes a dome **248**, an upstream liner portion **250**, and a downstream liner portion **252** that define therewithin a second combustion chamber **253**. The upstream liner portion **250** and the downstream liner portion **252** also define an outlet **254** therebetween. The upstream liner portion **250** and the downstream liner portion **252** are arranged at an angle **256** with respect to the combustor centerline axis **12′** so that the outlet **254** is arranged at the angle **256** to direct the flow exiting the outlet **254** in a generally downstream direction **258**. The outlet **254** may also be arranged at a circumferential angle (not shown) with respect to the circumferential direction C about the centerline axis **12′**. By arranging the outlet **254** at a circumferential angle, a tangential flow from the outlet **254** can be imparted into the secondary combustion zone **137** of the combustion chamber **131** so as to provide quicker and better mixing with the combustion gases **66**.

[0076] The dome **248** includes a plurality of dome openings **260** extending through the dome **248**. Each of the plurality of dome openings **260** may be arranged at an angle **261** so as to provide for a swirled flow **263** within the second combustion chamber **253**. The plurality of dome openings **260** provide for any one of the compressor bleed air **69**, the steam **114**, or the steam-air mixture **244** to flow from the second combustor plenum **242** into the second combustion chamber **253**. Similar to the FIG. **4** aspect, the second combustor **237** includes the at least one second fuel nozzle **200** and the ignitor **202** that both extend through the combustor outer casing **124**, extend through the second combustor casing **238**, and extend through the dome **248** of the second combustor liner **240**. The at least one second fuel nozzle **200** can therefore provide the second flow of fuel **67*b*** into the second combustor liner **240** to mix with the compressor bleed air **69** to form a fuel-air mixture **262**, or to mix with the steam-air mixture **244** to form a steam-air-fuel mixture **264**, within the second combustion chamber **253**. The ignitor **202** can then provide a spark to ignite the fuel-air mixture **262** to generate first combustion products **266**, or to ignite the steam-air-fuel mixture **264** to generate second combustion products **268**. Depending on the operating state of the second combustor **237**, as will be described below, any one of the steam **114**, the first combustion products **266**, or the second combustion products **268** flow from the outlet **254** into the secondary combustion zone **137** of the first combustion chamber **131** to mix with the combustion gases **66** (FIG. **3**).

[0077] FIG. **7** is a partial cross-sectional view of the alternate second combustor liner **240**, taken at plane **7-7** of FIG. **6**, according to an aspect of the present disclosure. In FIG. **7**, the plurality of dome openings **260** are shown to be arranged at a tangential angle **270**, with respect to a radial direction **272** extending from the combustor centerline axis **12′**. In addition, the second fuel nozzles **200** are arranged at the tangential angle **270**. As a result, the plurality of dome openings **260** can provide the flow of any of the compressor bleed air **69**, the steam **114**, or the steam-air mixture **244** into the second combustion chamber **253** in a tangential direction (i.e., tangential to the circumferential direction C about the combustor centerline axis **12′**) to allow for better mixing within the second combustion chamber **253**.

[0078] The foregoing description of FIG. **1** to FIG. **7** describes various structures of the combustion section **26** of the gas turbine engine **10**. The gas turbine engine **10** may be operated in any of a low power operating state (e.g., during descent or landing of an aircraft), a normal power operating state (e.g., during taxiing, or during cruise of the aircraft), or a high power operating state (e.g., during takeoff and climb-out of the aircraft). The foregoing description also discussed providing any one of the compressor bleed air **69**, the steam **114**, or both the compressor bleed air **69** and the steam **114** to the second combustor **192** or to the second combustor **237**. The following description will discuss various operating states of the combustion section **26**, with a focus on the operation of the second combustor **192** or the second combustor **237**, in conjunction with the operation of the steam generating system **100**. More particularly, the following description generally describes a first case when the steam generating system **100** functions normally to provide steam to the second combustor **192** during a non-idle operating state, a second case when the steam generating system **100** has a total (or a near total) loss of steam generating capability during the non-idle operating state, and a third case in which the steam generating system **100** has a partial loss of steam generating capability during the non-idle operating state.

[0079] FIG. **8** is a schematic diagram depicting an operation of the gas turbine engine **10** during a non-power-augmentation operating state in which the steam **114** is not provided to the second combustor **192** or to the steam turbine **110**, according to an aspect of the present disclosure. The non-power-augmentation operating state of the gas turbine engine **10** in FIG. **8** may be the idle operating state, or may be the non-idle operating state in which thrust augmentation is not being performed and therefore, the steam **114** is not being provided to either the second combustor **192** or to the steam turbine **110**. Generally, in the non-power-augmentation operating state, although the steam generating system **100** may be operating normally to generate the steam **114** (FIG. **2**), the second combustor **192** and the steam turbine **110** are generally idle and not operating. As shown in FIG. **8**, and as was described above with regard to FIG. **1** to FIG. **3**, during operation of the gas turbine engine **10**, compressed air **65** is provided to the combustion section **26** from the HPC **24**. The compressor bleed air system **94** may be operational and may bleed-off some of the compressed air **65** via the compressor bleed air valve **95** to provide the compressor bleed air **69** to various other systems (other than to the second combustor **192**). However, during the non-power-augmentation operating state, the compressor bleed air **69** is not provided to the second combustor **192**. A first flow of the fuel **67***a* is provided by the fuel delivery system **84** to the swirler assemblies **156** via the first fuel nozzle **158**. The second combustor fuel valve **216** may also be closed off so as not to provide a second flow of fuel **67***b* to the second combustor **192**. The fuel-air mixture **191** (FIG. **3**) is injected into the first combustion chamber **131** of the first combustor **125** and is ignited and burned to generate the combustion gases **66** that flow to the HPT **28** and the LPT **30**. The combustion gases **66** flow through the steam generation system **100**, and then through the exhaust nozzles **32** (FIG. **1** and FIG. **2**). During the non-power-augmentation operating state, the steam generating system **100** may be generating the steam **114**, but the steam control valve **92** is closed so as not to provide the steam **114** to either the steam turbine **110** or to the second combustor **192**. Each of the foregoing operations is controlled by the controller **13** (FIG. **1**).

[0080] FIG. **9** is a schematic diagram depicting an operation of the gas turbine engine **10** during a non-idle operating state, and during a power-augmentation operating state when the steam generating system **100** is operational to generate the steam **114** at a first steam generating level, according to an aspect of the present disclosure. The first steam generating level generally refers to the steam generating system **100** operating normally so as to generate a sufficient amount of the steam **114** to be capable of normally operating the steam turbine **110** at, or near, full capability to provide power or thrust augmentation, and to operate the second combustor **192** normally to provide power or thrust augmentation. In other words, the steam generating system **100** is operating without any appreciable loss of steam generating capability, even though some small loss of steam generating capability may be present within the steam generating system **100**. In FIG. **9**, the first combustor **125** operates normally as described above, albeit at the non-idle operating state rather than at the idle operating state. As for the second combustor **192**, while operating at the non-idle operating state, and, when power or thrust augmentation may be desired for the combustion section **26**, the controller **13** controls the steam generating system **100** to generate the steam **114**, and controls the steam control valve **92** so as to provide the flow of the steam **114** to the second combustor **192** (shown schematically by an arrow connecting the steam control valve **92** and the second combustor **192**), and, to the steam turbine **110**. As was described above for the FIG. **4** aspect, for example, the steam **114** is provided to the second combustor plenum **210** via the combustor steam supply line **98**. The steam **114** flows through the openings **212** in the second combustor liner **196** into the second combustion chamber **198**, and, then from the second combustion chamber **198** into the secondary combustion zone **137** of the first combustion chamber **131** via the outlet **199**. At the same time, the controller **13** controls the compressor bleed air valve **95** to be closed so as to disable the compressor bleed air system **94** from providing the flow of compressor bleed air **69** to the second combustor plenum **210**. The controller **13** also controls the second combustor fuel valve **216** to be in a closed state so as to disable the second flow of fuel **67***b* from flowing to the second combustion chamber **198**. Thus, in the FIG. **9** aspect, power or thrust augmentation can be achieved by supplying the flow of the steam **114** to both the steam turbine **110** and to the second combustor **192**.

[0081] FIG. **10** is a schematic diagram depicting an operation of the gas turbine engine **10** during a non-idle operating state, and during a power-augmentation operating state, but with a total loss of steam generation capability by the steam generating system **100**, according to an aspect of the present disclosure. Here, a total loss of steam generation capability is intended to mean that the steam generating system **100** is inoperable to generate the steam **114** (e.g., not sufficient water **111** in the boiler **102**) and has been shut down by the controller **13**, or, that the steam generating system **100** may only be capable of generating a small amount of steam, but, the generated amount is significantly deficient so as to not be capable of operating the steam turbine **110** or to provide power augmentation via the steam **114** being provided to the second combustor **192**.

[0082] In FIG. **10**, as with the FIG. **8** and FIG. **9** aspects, the first combustor **125** (FIG. **3**) operates normally as described above, albeit at the non-idle operating state rather than at the idle operating state. As for the second combustor **192**, while the gas turbine engine **10** is operating at the non-idle operating state, and, when power augmentation may be desired for the combustion section **26**, but, the steam generating system **100** has a total loss of steam generation capability, the controller **13** controls the compressor bleed air valve **95** to be opened so as to provide the flow of the compressor bleed air **69** to the second combustor **192**, and the controller **13** also controls the second combustor fuel valve **216** to be open so as to provide the second flow of fuel **67***b* to the second combustor **192**. In the meantime, since the steam generating system **100** is not generating the steam **114** (shown by the absence of the arrow labeled with the steam **114** leading from the steam generating system **100** to the steam control valve **92**), the controller **13** controls the steam control valve **92** to be in a closed state.

[0083] As was described above for FIG. **4**, in the case when the second flow of fuel **67***b* and the flow of the compressor bleed air **69** are provided to the second combustor **192**, the flow of the compressor bleed air **69** flows into the second combustor plenum **210**, and, then through the openings **212** into the second combustion chamber **198**. The second flow of fuel **67***b* is injected into the second combustion chamber **198** and mixes with the compressor bleed air **69** to generate the fuel-air mixture **218**. The fuel-air mixture **218** is ignited by the spark from the ignitor **202** to generate the first combustion products **220**. The first combustion products **220** then flow through the outlet **199** into the secondary combustion zone **137** of the first combustion chamber **131**. Thus, by adding the first combustion products **220** to mix with the combustion gases **66**, the power (or thrust) augmentation can be obtained, even though the steam generating system **100** has a total loss of steam generation capability.

[0084] FIG. **11** is a schematic diagram depicting an operation of the gas turbine engine **10** during a non-idle operating state, and during a power-augmentation operating state, but with the steam generating system **100** operating to generate steam at a second steam generating level less than the first steam generating level. The second steam generating level refers to a case when the steam generating system **100** has suffered a partial, but significant, loss of steam generating capability such that the steam generating system **100** is operable to generate the steam **114**, but, at a diminished capacity (e.g., at fifty percent or less capacity). That is, the steam generating system **100** is capable of operating the steam turbine **110** at about half of a normal full power capability. In FIG. **11**, as with the FIG. **8**, FIG. **9**, and FIG. **10** aspects, the first combustor **125** operates normally as described above, albeit at the non-idle operating state rather than at the idle operating state. As for the second combustor **192**, while operating at the non-idle operating state, and, when power or thrust augmentation may be desired for the combustion section **26**, but, the steam generating system **100** has a partial loss of steam generation capability, the controller **13** controls the steam control valve **92** to be opened so as to provide the flow of the steam **114** (albeit, a diminished flow of the steam **114**) to the second combustor **192** and to the steam turbine **110**. The controller **13** further controls the compressor bleed air valve **95** to be opened so as to provide the flow of the compressor bleed air **69** to the second combustor **192**, and the controller **13** also controls the second combustor fuel valve **216** to be open so as to provide the second flow of fuel **67***b* to the second combustor **192**.

[0085] As was described above with regard to FIG. **4**, the flow of the compressor bleed air **69** flows into the second combustor plenum **210** via the compressor bleed air duct **97**, and the (diminished flow of) steam **114** flows into the second combustor plenum **210** via the combustor steam supply line **98**. The compressor bleed air **69** and the steam **114** mix together within the second combustor plenum **210** to generate the steam-air mixture **222**. The steam-air mixture **222** flows through the openings **212** into the second combustion chamber **198**. At the same time, the second flow of fuel **67***b* is injected into the second combustion chamber **198** by the second fuel nozzle **200**, and the fuel **67***b* mixes with the steam-air mixture **222** within the second combustion chamber **198** to generate the steam-air-fuel mixture **224**. The steam-air-fuel mixture **224** is ignited by the ignitor **202** and burned within the second combustion chamber **198** to generate the second combustion products **226**. The second combustion products **226** flow through the outlet **199** into the secondary combustion zone **137** of the first combustion chamber **131** to mix with the combustion gases **66** (FIG. **3**). Thus, by adding the second combustion products **226** to mix with the combustion gases **66**, the power (or thrust) augmentation can be obtained, even though the steam generating system **100** has a partial loss of steam generation capability.

[0086] FIG. **12** is a flowchart of process steps for a method of operating the gas turbine engine **10**, according to an aspect of the present disclosure. The method of FIG. **12** can be implemented in the gas turbine engine **10** with regard to the aspects described above for FIG. **1** to FIG. **11**. In step S**1201**, the gas turbine engine **10** is operated in the non-idle operating state and in the non-power-augmentation operating state. The operation of the gas turbine engine **10** in the non-idle operating state and in the non-power-augmentation operating state may correspond to the description above. In step S**1202**, a determination is made, by the controller **13** (FIG. **1**) while operating in the non-idle operating state and in the non-power-augmentation operating state, whether or not the gas turbine engine **10** is commanded to operate in the power-augmentation operating state so as to provide power (or thrust) augmentation. The controller **13** may be notified by an avionics system within the aircraft of a power increase above, for example, ten percent of the full power capability of the gas turbine engine **10**, or above thirty percent of the full power capability of the gas turbine engine **10**. The controller **13** may also utilize, as part of the determination, avionics signals indicating a flight status of the aircraft, such as whether the aircraft is in a take-off state, or a climb-out state, or if the aircraft is in a cruise state, or in a landing approach state. If the determination in step S**1202** is NO, then, the gas turbine engine **10** continues to operate in the non-idle operating state and in the non-power-augmentation operating state of step S**1201**.

[0087] On the other hand, if the determination in step S**1202** is YES, then another determination is made in step S**1203** whether or not the steam generating system **100** (FIG. **1**, FIG. **2**) is operating normally. That is, the controller **13** monitors the status of the steam generating system **100** during the operation of the gas turbine engine **10**, and the controller **13** determines whether the steam generating system **100** is operating normally to generate a sufficient amount of the steam **114** to operate the steam turbine **110**. If the determination in step S**1203** is YES, then, in step S**1204**, the controller **13** controls the gas turbine engine **10** to operate as described above with regard to FIG. **9** so as to provide the flow of the steam **114** to the second combustor **192** and to the steam turbine **110**.
[0088] On the other hand, if the determination in step S**1203** is NO (i.e., the steam generating system **100** is not operating normally and is either not producing steam or is producing a diminished capacity of the steam), then, in step S**1205**, a determination is made by the controller **13** whether the steam generating system **100** is partially operating to generate the steam **114** (i.e., whether there is a partial loss of steam generation capability). If the determination in step S**1205** is NO, then, the controller **13** determines that a total loss of steam generation capability has occurred and, in step S**1206**, controls the gas turbine engine **10** to operate in the manner described above for FIG. **10** by providing the compressor bleed air **69** and the second flow of fuel **67***b* to the second combustor **192**, while disabling the flow of the steam **114** from flowing from the steam generating system **100** to the second combustor **192** and to the steam turbine **110**.
[0089] When the determination in step S**1205** is YES (i.e., there is a partial loss of steam generating capability by the steam generating system **100**), then, in step S**1207**, the controller **13** controls the gas turbine engine **10** to operate in the manner described above with regard to FIG. **11**, so as to provide the flow of the compressor bleed air **69**, the second flow of fuel **67***b*, and the steam **114** to the second combustor **192**.
[0090] Further aspects of the present disclosure are provided by the subject matter of the following clauses.
[0091] A gas turbine engine including a compressor section having a compressor bleed air system connected thereto, a steam turbine, a combustion section including a combustor outer casing and a combustor inner casing defining a first combustor pressure plenum therewithin, a first combustor arranged within the combustor outer casing and the combustor inner casing, and having (a) a first combustor outer liner and a first combustor inner liner that define a first combustion chamber having a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, and (b) at least one swirler assembly, an outer flow passage being defined between the combustor outer casing and the first combustor outer liner, and an inner flow passage being defined between the combustor inner casing and the first combustor inner liner, the first combustor being arranged to receive a flow of compressed air from the compressor section and to provide a flow of the compressed air into the first combustion chamber, and a second combustor arranged within one of the outer flow passage or the inner flow passage, the second combustor having a second combustor casing and a second combustor liner defining a second combustion chamber therewithin, a second combustor plenum being defined between the second combustor casing and the second combustor liner, the second combustion liner having an outlet, the second combustor casing being in fluid communication with the compressor bleed air system to receive a flow of compressor bleed air from the compressor bleed air system into the second combustor plenum, and the outlet providing fluid communication between the second combustion chamber and the first combustion chamber of the first combustor, a first fuel nozzle assembly arranged to provide a first flow of fuel to the at least one swirler assembly of the first combustor, a second fuel nozzle arranged to provide a second flow of fuel to the second combustion chamber, and a steam generating system arranged to provide a flow of steam to the second combustor plenum and to the steam turbine.
[0092] The gas turbine engine according to the preceding clause, wherein the outlet is arranged to

direct a flow of steam or a flow of combustion products therefrom in a downstream direction within the secondary combustion zone of the first combustion chamber.
[0093] The gas turbine engine according to any preceding clause, wherein the compressor bleed air system includes a bleed air valve that controls the flow of the compressor bleed air to the second combustor plenum, and the steam generating system includes a steam control valve that controls the flow of steam to the second combustor plenum.
[0094] The gas turbine engine according to any preceding clause, wherein the second combustor includes (i) a plurality of second combustor liners, each of the plurality of second combustor liners defining a respective second combustion chamber that each have a respective outlet in fluid communication with the secondary combustion zone of the first combustion chamber, and (ii) a plurality of second fuel nozzles, respective ones of the plurality of second fuel nozzles being arranged to provide the second flow of fuel to a respective one of the plurality of second combustion chambers.
[0095] The gas turbine engine according to any preceding clause, wherein the steam generating system is arranged downstream of an exhaust section of the gas turbine engine, and utilizes exhaust gases from the exhaust section to generate steam within a boiler.
[0096] The gas turbine engine according to any preceding clause, wherein the steam generating system further includes a condenser and a separator that utilize the exhaust gases to recover water from the exhaust gases and to replenish water within the boiler.
[0097] The gas turbine engine according to any preceding clause, wherein the outlet of the second combustor liner is in fluid communication with the secondary combustion zone of the first combustion chamber.
[0098] The gas turbine engine according to any preceding clause, wherein the outlet is arranged to extend through at least one dilution opening in one of the first combustor outer liner or the first combustor inner liner.
[0099] The gas turbine engine according to any preceding clause, wherein the combustor outer casing and the combustor inner casing extend annularly about a combustor centerline axis, the first combustor is an annular combustor extending annularly about the combustor centerline axis, and the second combustor is a localized combustor that does not extend annularly about the combustor centerline axis.
[0100] The gas turbine engine according to any preceding clause, wherein the second combustor is a partial-annular combustor that extends partially annularly about the combustor centerline axis.
[0101] The gas turbine engine according to any preceding clause, wherein the second combustor casing surrounds the second combustor liner.
[0102] The gas turbine engine according to any preceding clause, wherein the second combustor liner is a trapped vortex combustor liner.
[0103] The gas turbine engine according to any preceding clause, wherein the second combustor liner includes a plurality of openings therethrough providing fluid communication between the second combustor plenum and the second combustion chamber.
[0104] The gas turbine engine according to any preceding clause, wherein, in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate the steam at a first steam generating level, (i) the flow of steam is provided by the steam generating system to the second combustor plenum, to the second combustion chamber via the plurality of openings, and to the secondary combustion zone of the first combustion chamber, (ii) the compressor bleed air system is disabled from providing compressor bleed air to the second combustor plenum, and (iii) the second fuel nozzle is disabled from providing the second flow of fuel to the second combustion chamber.
[0105] The gas turbine engine according to any preceding clause, wherein, in the non-idle operating state and in the power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate steam at a second steam

generating level less than the first steam generating level, (iv) the steam is provided by the steam generating system to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (v) the compressor bleed air system is enabled and provides the flow of the compressor bleed air to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (vi) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber, the fuel, the compressor bleed air, and the steam mixing within the second combustion chamber to form a steam-air-fuel mixture, and (vii) the steam-air-fuel mixture is ignited and burned within the second combustion chamber to generate combustion products that are provided to the secondary combustion zone of the first combustion chamber via the outlet.

[0106] The gas turbine engine according to any preceding clause, wherein, in the non-idle operating state and in the power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is not generating the steam, (viii) the steam generating system is disabled from providing steam to the second combustor plenum, (ix) the compressor bleed air system is enabled to provide the flow of compressor bleed air to the second combustor plenum, and the compressor bleed air flows into the second combustion chamber via the plurality of openings, (x) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber to generate a fuel-air mixture within the second combustion chamber, (xi) the fuel-air mixture is ignited within the second combustion chamber to generate second combustion products, and (xii) the second combustion products are provided from the second combustion chamber to the secondary combustion zone of the first combustion chamber via the outlet.

[0107] The gas turbine engine according to any preceding clause, wherein the plurality of openings are arranged to generate a swirled flow of the compressor bleed air within the second combustion chamber.

[0108] The gas turbine engine according to any preceding clause, wherein the second combustor liner defines a trapped vortex combustor liner, and the swirled flow is a trapped vortex flow of the compressor bleed air within the trapped vortex combustor liner.

[0109] The gas turbine engine according to any preceding clause, wherein the second combustor liner defines an axial-flow second combustion chamber, and the axial-flow second combustor liner includes a dome having a plurality of dome openings extending through the dome.

[0110] The gas turbine engine according to any preceding clause, wherein the plurality of dome openings are arranged at a tangential angle, and the second fuel nozzle is arranged at the tangential angle.

[0111] A gas turbine engine including a compressor section having a compressor bleed air system connected thereto, a steam turbine, a combustion section including a combustor outer casing and a combustor inner casing defining a first combustor pressure plenum therewithin, a first combustor arranged within the combustor outer casing and the combustor inner casing, and having (a) a first combustor outer liner and a first combustor inner liner that define a first combustion chamber having a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, and (b) at least one swirler assembly, an outer flow passage being defined between the combustor outer casing and the first combustor outer liner, and an inner flow passage being defined between the combustor inner casing and the first combustor inner liner, the first combustor being arranged to receive a flow of compressed air from the compressor section and to provide a flow of the compressed air into the first combustion chamber, and a second combustor arranged within one of the outer flow passage or the inner flow passage, the second combustor having a second combustor casing and a second combustor liner defining a second combustion chamber therewithin, a second combustor plenum being defined between the second combustor casing and the second combustor liner, the second combustion liner having an outlet, the second combustor casing being in fluid communication with the compressor bleed air system to receive a flow of compressor bleed air from the compressor bleed air system into the second combustor plenum, and the outlet providing fluid communication between the second combustion chamber and the first combustion chamber of the first combustor, a first fuel nozzle assembly arranged to provide a first flow of fuel to the at least one swirler assembly of the first combustor, a second fuel nozzle arranged to provide a second flow of fuel to the second combustion chamber, and a steam generating system arranged to provide a flow of steam to the second combustor plenum and to the steam turbine, wherein the second combustor includes (i) a plurality of second combustor liners, each of the plurality of second combustor liners defining a respective second combustion chamber that each have a respective outlet in fluid communication with the secondary combustion zone of the first combustion chamber, and (ii) a plurality of second fuel nozzles, respective ones of the plurality of second fuel nozzles being arranged to provide the second flow of fuel to a respective one of the plurality of second combustion chamber.

[0112] The gas turbine engine according to any preceding clause, wherein the compressor bleed air system includes a bleed air valve that controls the flow of the compressor bleed air to the second combustor plenum, and the steam generating system includes a steam control valve that controls the flow of steam to the second combustor plenum.

[0113] The gas turbine engine according to any preceding clause, wherein the steam generating system is arranged downstream of an exhaust section of the gas turbine engine, and utilizes exhaust gases from the exhaust section to generate steam within a boiler.

[0114] The gas turbine engine according to any preceding clause, wherein the steam generating system further includes a condenser and a separator that utilize the exhaust gases to recover water from the exhaust gases and to replenish water within the boiler.

[0115] The gas turbine engine according to any preceding clause, wherein the outlet of the second combustor liner is in fluid communication with the secondary combustion zone of the first combustion chamber.

[0116] The gas turbine engine according to any preceding clause, wherein the outlet is arranged to extend through at least one dilution opening in one of the first combustor outer liner or the first combustor inner liner.

[0117] The gas turbine engine according to any preceding clause, wherein the combustor outer casing and the combustor inner casing extend annularly about a combustor centerline axis, the first combustor is an annular combustor extending annularly about the combustor centerline axis, and the second combustor is a localized combustor that does not extend annularly about the combustor centerline axis.

[0118] The gas turbine engine according to any preceding clause, wherein the second combustor is a partial-annular combustor that extends partially annularly about the combustor centerline axis.

[0119] The gas turbine engine according to any preceding clause, wherein the second combustor casing surrounds the second combustor liner.

[0120] The gas turbine engine according to any preceding clause, wherein the second combustor liner is a trapped vortex combustor liner.

[0121] The gas turbine engine according to any preceding clause, wherein the second combustor liner includes a plurality of openings therethrough providing fluid communication between the second combustor plenum and the second combustion chamber.

[0122] The gas turbine engine according to any preceding clause, wherein, in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate the steam at a first steam generating level, (i) the flow of steam is provided by the steam generating system to the second combustor plenum, to the second combustion chamber via the plurality of openings, and to the secondary combustion zone of the first combustion chamber, (ii) the compressor bleed air system is disabled from providing compressor bleed air to the second combustor plenum, and (iii) the second fuel nozzle is disabled from providing the second flow of fuel to the second combustion chamber.

[0123] The gas turbine engine according to any preceding clause, wherein, in the non-idle operating state and in the power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate steam at a second steam generating level less than the first steam generating level, (iv) the steam is provided by the steam generating system to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (v) the compressor bleed air system is enabled and provides the flow of the compressor bleed air to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (vi) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber, the fuel, the compressor bleed air, and the steam mixing within the second combustion chamber to form a steam-air-fuel mixture, and (vii) the steam-air-fuel mixture is ignited and burned within the second combustion chamber to generate combustion products that are provided to the secondary combustion zone of the first combustion chamber via the outlet.

[0124] The gas turbine engine according to any preceding clause, wherein, in the non-idle operating state and in the power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is not generating the steam, (viii) the steam generating system is disabled from providing steam to the second combustor plenum, (ix) the compressor bleed air system is enabled to provide the flow of compressor bleed air to the second combustor plenum, and the compressor bleed air flows into the second combustion chamber via the plurality of openings, (x) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber to generate a fuel-air mixture within the second combustion chamber, (xi) the fuel-air mixture is ignited within the second combustion chamber to generate second combustion products, and (xii) the second combustion products are provided from the second combustion chamber to the secondary combustion zone of the first combustion chamber via the outlet.

[0125] The gas turbine engine according to any preceding clause, wherein the plurality of openings are arranged to generate a swirled flow of the compressor bleed air within the second combustion chamber.

[0126] The gas turbine engine according to any preceding clause, wherein the second combustor liner defines a trapped vortex combustor liner, and the swirled flow is a trapped vortex flow of the compressor bleed air within the trapped vortex combustor liner.

[0127] The gas turbine engine according to any preceding clause, wherein the second combustor liner defines an axial-flow second combustion chamber, and the axial-flow second combustor liner includes a dome having a plurality of dome openings extending through the dome.

[0128] The gas turbine engine according to any preceding clause, wherein the plurality of dome openings are arranged at a tangential angle, and the second fuel nozzle is arranged at the tangential angle.

[0129] A method of operating a gas turbine engine including a compressor section having a compressor bleed air system connected thereto, a steam turbine, a combustion section including a combustor outer casing and a combustor inner casing defining a first combustor pressure plenum therewithin, a first combustor arranged within the combustor outer casing and the combustor inner casing, and having (a) a first combustor outer liner and a first combustor inner liner that define a first combustion chamber having a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, and (b) at least one swirler assembly, an outer flow passage being defined between the combustor outer casing and the first combustor outer liner, and an inner flow passage being defined between the combustor inner casing and the first combustor inner liner, the first combustor being arranged to receive a flow of compressed air from the compressor section and to provide a flow of the compressed air into the first combustion chamber, and a second combustor arranged within one of the outer flow passage or the inner flow passage, the second combustor having a second combustor casing and a second combustor liner defining a second combustion chamber therewithin, a second combustor plenum being defined between the second combustor casing and the second combustor liner, the second combustion liner having an outlet, the second combustor casing being in fluid communication with the compressor bleed air system to receive a flow of compressor bleed air from the compressor bleed air system into the second combustor plenum, and the outlet providing fluid communication between the second combustion chamber and the first combustion chamber of the first combustor, a first fuel nozzle assembly arranged to provide a first flow of fuel to the at least one swirler assembly of the first combustor, a second fuel nozzle arranged to provide a second flow of fuel to the second combustion chamber, and a steam generating system arranged to provide a flow of steam to the second combustor plenum and to the steam turbine. The method includes operating the gas turbine engine in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate the steam at a first steam generating level, (i) the flow of steam is provided by the steam generating system to the second combustor plenum, to the second combustion chamber via the plurality of openings, and to the secondary combustion zone of the first combustion chamber, (ii) the compressor bleed air system is disabled from providing compressor bleed air to the second combustor plenum, and (iii) the second fuel nozzle is disabled from providing the second flow of fuel to the second combustion chamber.

[0130] The method according to the preceding clause, wherein, in a case when the steam generating system is operational to generate steam at a second steam generating level less than the first steam generating level, (iv) the steam is provided by the steam generating system to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (v) the compressor bleed air system is enabled and provides the flow of the compressor bleed air to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (vi) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber, the fuel, the compressor bleed air, and the steam mixing within the second combustion chamber to form a steam-air-fuel mixture, and (vii) the steam-air-fuel mixture is ignited and burned within the second combustion chamber to generate combustion products that are provided to the secondary combustion zone of the first combustion chamber via the outlet.

[0131] The method according to any preceding clause, wherein, in a case when the steam generating system is not generating the steam, (viii) the steam generating system is disabled from providing steam to the second combustor plenum, (ix) the compressor bleed air system is enabled to provide the flow of compressor bleed air to the second combustor plenum, and the compressor bleed air flows into the second combustion chamber via the plurality of openings, (x) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber to generate a fuel-air mixture within the second combustion chamber, (xi) the fuel-air mixture is ignited within the second combustion chamber to generate second combustion products, and (xii) the second combustion products are provided from the second combustion chamber to the secondary combustion zone of the first combustion chamber via the outlet.

[0132] The method according to any preceding clause, wherein the outlet is arranged to direct a flow of steam or a flow of combustion products therefrom in a downstream direction within the secondary combustion zone of the first combustion chamber.

[0133] The method according to any preceding clause, wherein the compressor bleed air system includes a bleed air valve that controls the flow of the compressor bleed air to the second combustor plenum, and the steam generating system includes a steam control valve that controls the flow of steam to the second combustor plenum.

[0134] The method according to any preceding clause, wherein the second combustor includes (i) a plurality of second combustor liners, each of the plurality of second combustor liners defining a respective second combustion chamber that each have a respective outlet in fluid communication with the secondary combustion zone of the first combustion chamber, and (ii) a plurality of second

fuel nozzles, respective ones of the plurality of second fuel nozzles being arranged to provide the second flow of fuel to a respective one of the plurality of second combustion chambers.
[0135] The method according to any preceding clause, wherein the steam generating system is arranged downstream of an exhaust section of the gas turbine engine, and utilizes exhaust gases from the exhaust section to generate steam within a boiler.
[0136] The method according to any preceding clause, wherein the steam generating system further includes a condenser and a separator that utilize the exhaust gases to recover water from the exhaust gases and to replenish water within the boiler.
[0137] The method according to any preceding clause, wherein the outlet of the second combustor liner is in fluid communication with the secondary combustion zone of the first combustion chamber.
[0138] The method according to any preceding clause, wherein the outlet is arranged to extend through at least one dilution opening in one of the first combustor outer liner or the first combustor inner liner.
[0139] The method according to any preceding clause, wherein the combustor outer casing and the combustor inner casing extend annularly about a combustor centerline axis, the first combustor is an annular combustor extending annularly about the combustor centerline axis, and the second combustor is a localized combustor that does not extend annularly about the combustor centerline axis.
[0140] The method according to any preceding clause, wherein the second combustor is a partial-annular combustor that extends partially annularly about the combustor centerline axis.
[0141] The method according to any preceding clause, wherein the second combustor casing surrounds the second combustor liner.
[0142] The method according to any preceding clause, wherein the second combustor liner is a trapped vortex combustor liner.
[0143] The method according to any preceding clause, wherein the second combustor liner includes a plurality of openings therethrough providing fluid communication between the second combustor plenum and the second combustion chamber.
[0144] The method according to any preceding clause, wherein the plurality of openings are arranged to generate a swirled flow of the compressor bleed air within the second combustion chamber.
[0145] The method according to any preceding clause, wherein the second combustor liner defines a trapped vortex combustor liner, and the swirled flow is a trapped vortex flow of the compressor bleed air within the trapped vortex combustor liner.
[0146] The method according to any preceding clause, wherein the second combustor liner defines an axial-flow second combustion chamber, and the axial-flow second combustor liner includes a dome having a plurality of dome openings extending through the dome.
[0147] The method according to any preceding clause, wherein the plurality of dome openings are arranged at a tangential angle, and the second fuel nozzle is arranged at the tangential angle.
[0148] A method of operating a combustor of a gas turbine engine in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, the gas turbine engine including a combustion section having a first combustor and a second combustor in fluid communication with a combustion chamber of the first combustor, and a steam generating system, the method including, in a case when the steam generating system is operational to generate steam at a first steam generating level, (i) providing a flow of steam by the steam generating system to a second combustor plenum of the second combustor and to a second combustion chamber of the second combustor via a plurality of openings in a second combustor liner, and to a secondary combustion zone of the combustion chamber of the first combustor, (ii) disabling a compressor bleed air system from providing compressor bleed air to the second combustor plenum, and (iii) disabling a second fuel nozzle of the second combustor from providing a second flow of fuel to the second combustion

chamber.
[0149] The method according to the preceding clause, wherein the method further includes, in a case when the steam generating system is operational to generate steam at a second steam generating level less than the first steam generating level, (iv) providing the steam by the steam generating system to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (v) enabling the compressor bleed air system to provide the flow of the compressor bleed air to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (vi) enabling the second fuel nozzle to provide the second flow of fuel to the second combustion chamber, the fuel, the compressor bleed air, and the steam mixing within the second combustion chamber to form a steam-air-fuel mixture, and (vii) igniting and burning the steam-air-fuel mixture within the second combustion chamber to generate combustion products that are provided to the secondary combustion zone of the first combustion chamber via the outlet.
[0150] The method according to any preceding clause, wherein, the method further includes, in a case when the steam generating system is not generating the steam, (viii) disabling the steam generating system from providing steam to the second combustor plenum, (ix) enabling the compressor bleed air system to provide the flow of compressor bleed air to the second combustor plenum, and the compressor bleed air flowing into the second combustion chamber via the plurality of openings, (x) enabling the second fuel nozzle to provide the second flow of fuel to the second combustion chamber to generate a fuel-air mixture within the second combustion chamber, (xi) igniting and burning the fuel-air mixture within the second combustion chamber to generate second combustion products, and (xii) providing the second combustion products from the second combustion chamber to the secondary combustion zone of the first combustion chamber via the outlet.
[0151] Although the foregoing description is directed to some exemplary embodiments of the present disclosure, other variations and modifications will be apparent to those skilled in the art, and may be made without departing from the present disclosure. Moreover, features described in connection with one embodiment of the present disclosure may be used in conjunction with other embodiments, even if not explicitly stated above.

Claims

1. A gas turbine engine comprising: a compressor section having a compressor bleed air system connected thereto; a steam turbine; a combustion section, comprising: a combustor outer casing and a combustor inner casing defining a first combustor pressure plenum therewithin; a first combustor arranged within the combustor outer casing and the combustor inner casing, and having (a) a first combustor outer liner and a first combustor inner liner that define a first combustion chamber having a primary combustion zone and a secondary combustion zone downstream of the primary combustion zone, and (b) at least one swirler assembly, an outer flow passage being defined between the combustor outer casing and the first combustor outer liner, and an inner flow passage being defined between the combustor inner casing and the first combustor inner liner, the first combustor being arranged to receive a flow of compressed air from the compressor section and to provide a flow of the compressed air into the first combustion chamber; and a second combustor arranged within one of the outer flow passage or the inner flow passage, the second combustor having a second combustor casing and a second combustor liner defining a second combustion chamber therewithin, a second combustor plenum being defined between the second combustor casing and the second combustor liner, the second combustion liner having an outlet, the second combustor casing being in fluid communication with the compressor bleed air system to receive a flow of compressor bleed air from the compressor bleed air system into the second combustor plenum, and the outlet providing fluid communication between the second combustion chamber and the first combustion chamber of the first combustor; a first fuel nozzle arranged to provide a first flow of fuel to the at least one swirler assembly of the first combustor; a second fuel nozzle arranged to provide a second flow of fuel to the second combustion chamber; and a steam generating system arranged to provide a flow of steam to the second combustor plenum and to the steam turbine.

2. The gas turbine engine according to claim 1, wherein the outlet is arranged to direct a flow of steam or a flow of combustion products therefrom in a downstream direction within the secondary combustion zone of the first combustion chamber.

3. The gas turbine engine according to claim 1, wherein the compressor bleed air system includes a bleed air valve that controls the flow of the compressor bleed air to the second combustor plenum, and the steam generating system includes a steam control valve that controls the flow of steam to the second combustor plenum.

4. The gas turbine engine according to claim 1, wherein the second combustor includes (i) a plurality of second combustor liners, each of the plurality of second combustor liners defining a respective one of a plurality of second combustion chambers that each have a respective outlet in fluid communication with the secondary combustion zone of the first combustion chamber, and (ii) a plurality of second fuel nozzles, respective ones of the plurality of second fuel nozzles being arranged to provide the second flow of fuel to a respective one of the plurality of second combustion chambers.

5. The gas turbine engine according to claim 1, wherein the steam generating system is arranged downstream of an exhaust section of the gas turbine engine, and utilizes exhaust gases from the exhaust section to generate steam within a boiler.

6. The gas turbine engine according to claim 5, wherein the steam generating system further includes a condenser and a separator that utilize the exhaust gases to recover water from the exhaust gases and to replenish water within the boiler.

7. The gas turbine engine according to claim 1, wherein the outlet of the second combustor liner is in fluid communication with the secondary combustion zone of the first combustion chamber.

8. The gas turbine engine according to claim 7, wherein the outlet is arranged to extend through at least one dilution opening in one of the first combustor outer liner or the first combustor inner liner.

9. The gas turbine engine according to claim 1, wherein the combustor outer casing and the combustor inner casing extend annularly about a combustor centerline axis, the first combustor is an annular combustor extending annularly about the combustor centerline axis, and the second combustor is a localized combustor that does not extend annularly about the combustor centerline axis.

10. The gas turbine engine according to claim 9, wherein the second combustor is a partial-annular combustor that extends partially annularly about the combustor centerline axis.

11. The gas turbine engine according to claim 1, wherein the second combustor casing surrounds the second combustor liner.

12. The gas turbine engine according to claim 11, wherein the second combustor liner is a trapped vortex combustor liner.

13. The gas turbine engine according to claim 11, wherein the second combustor liner includes a plurality of openings therethrough providing fluid communication between the second combustor plenum and the second combustion chamber.

14. The gas turbine engine according to claim 13, wherein, in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate the steam at a first steam generating level, (i) the flow of steam is provided by the steam generating system to the second combustor plenum, to the second combustion chamber via the plurality of openings, and to the secondary combustion zone of the first combustion chamber, (ii) the compressor bleed air system is disabled from providing compressor bleed air to the second combustor plenum, and (iii) the second fuel nozzle is disabled from providing the second flow of fuel to the second combustion chamber.

15. The gas turbine engine according to claim 13, wherein, in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is operational to generate steam at a second steam generating level less than a first steam generating level, (i) the steam is provided by the steam generating system to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (ii) the compressor bleed air system is enabled and provides the flow of the compressor bleed air to the second combustor plenum, and to the second combustion chamber via the plurality of openings, (iii) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber where the second flow of fuel, the compressor bleed air, and the steam mix within the second combustion chamber to form a steam-air-fuel mixture, and (iv) the steam-air-fuel mixture is ignited and burned within the second combustion chamber to generate combustion products that are provided to the secondary combustion zone of the first combustion chamber via the outlet.
16. The gas turbine engine according to claim 13, wherein, in a non-idle operating state and in a power-augmentation operating state of the gas turbine engine, and, in a case when the steam generating system is not generating the steam, (i) the steam generating system is disabled from providing steam to the second combustor plenum, (ii) the compressor bleed air system is enabled to provide the flow of compressor bleed air to the second combustor plenum, and the compressor bleed air flows into the second combustion chamber via the plurality of openings, (iii) the second fuel nozzle is enabled and provides the second flow of fuel to the second combustion chamber to generate a fuel-air mixture within the second combustion chamber, (iv) the fuel-air mixture is ignited within the second combustion chamber to generate second combustion products, and (v) the second combustion products are provided from the second combustion chamber to the secondary combustion zone of the first combustion chamber via the outlet.
17. The gas turbine engine according to claim 13, wherein the plurality of openings are arranged to generate a swirled flow of the compressor bleed air within the second combustion chamber.
18. The gas turbine engine according to claim 17, wherein the second combustor liner defines a trapped vortex combustor liner, and the swirled flow is a trapped vortex flow of the compressor bleed air within the trapped vortex combustor liner.
19. The gas turbine engine according to claim 17, wherein the second combustor liner defines an axial-flow second combustor liner, and the axial-flow second combustor liner includes a dome having a plurality of dome openings extending through the dome.
20. The gas turbine engine according to claim 19, wherein the plurality of dome openings are arranged at a tangential angle, and the second fuel nozzle is arranged at the tangential angle.