United States Patent Application Publication	20250257700
Kind Code	A1
Publication Date	August 14, 2025
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AIRCRAFT HAVING AN AFT ENGINE AND AUXILIARY POWER UNIT

Abstract

An aircraft extending between a forward end and an aft end is provided. The aircraft includes an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct, and a boundary layer ingestion fan positioned proximate the aft end of the aircraft, the boundary layer ingestion fan having a support shaft, wherein the auxiliary power unit exhaust duct extends through a portion of the support shaft of the boundary layer ingestion fan.

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Family ID: **1000008574989**

Appl. No.: **19/184261**

Filed: **April 21, 2025**

Related U.S. Application Data

parent US division 16599430 20191011 PENDING child US 19184261

Publication Classification

Int. Cl.: **F02K3/06** (20060101); **B64C21/01** (20230101); **B64D15/04** (20060101); **B64D41/00** (20060101); **F02C7/32** (20060101)

U.S. Cl.:

CPC **F02K3/06** (20130101); **B64C21/01** (20230101); **B64D15/04** (20130101); **B64D41/00** (20130101); **F02C7/32** (20130101); F05D2220/323 (20130101); F05D2220/50 (20130101)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a divisional application of U.S. application Ser. No. 16/599,430 filed Oct. 11, 2019, which is hereby incorporated by reference in its entirety.

FIELD
[0002] The present subject matter relates generally to an aircraft propulsion system including an engine and auxiliary power unit located at an aft end of an aircraft.
BACKGROUND
[0003] A conventional commercial aircraft generally includes a fuselage, a pair of wings, and a propulsion system that provides thrust. The propulsion system typically includes at least two aircraft engines, such as turbofan jet engines. Each turbofan jet engine is mounted to a respective one of the wings of the aircraft, such as in a suspended position beneath the wing, separated from the wing and fuselage. Such a configuration allows for the turbofan jet engines to interact with separate, freestream airflows that are not impacted by the wings and/or fuselage. This configuration can reduce an amount of turbulence within the air entering an inlet of each respective turbofan jet engine, which has a positive effect on a net propulsive thrust of the aircraft.
[0004] However, a drag on the aircraft including the turbofan jet engines, also has an effect on the net propulsive thrust of the aircraft. A total amount of drag on the aircraft, including skin friction, form, and induced drag, is generally proportional to a difference between a freestream velocity of air approaching the aircraft and an average velocity of a wake downstream from the aircraft that is produced due to the drag on the aircraft.
[0005] Systems have been proposed to counter the effects of drag and/or to improve an efficiency of the turbofan jet engines. For example, certain propulsion systems incorporate boundary layer ingestion systems to route a portion of relatively slow moving air forming a boundary layer across, e.g., the fuselage and/or the wings, into the turbofan jet engines upstream from a fan section of the turbofan jet engines.
[0006] Furthermore, in certain configurations, a gas turbine engine may be used to drive an electric generator. For example, the gas turbine engine may be an auxiliary power unit (APU) of an aircraft, the APU including an electric generator for generating electrical power for various systems of the aircraft.
BRIEF DESCRIPTION
[0007] Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.
[0008] In one exemplary embodiment of the present disclosure, an aircraft extending between a forward end and an aft end is provided. The aircraft includes an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct, and a boundary layer ingestion fan positioned proximate the aft end of the aircraft, the boundary layer ingestion fan having a support shaft, wherein the auxiliary power unit exhaust duct extends through a portion of the support shaft of the boundary layer ingestion fan.
[0009] In certain exemplary embodiments the aircraft includes a mixer in communication with the auxiliary power unit and the boundary layer ingestion fan such that the mixer receives and mixes a

boundary layer airflow from the boundary layer ingestion fan and an auxiliary power unit exhaust flow from the auxiliary power unit exhaust duct.

[0010] In certain exemplary embodiments the aircraft includes a thermal insulation portion between the auxiliary power unit exhaust duct and the support shaft of the boundary layer ingestion fan.

[0011] In certain exemplary embodiments the boundary layer ingestion fan defines a central axis and includes a fan rotatable about the central axis and including a plurality of fan blades attached to a fan shaft; a nacelle encircling the plurality of fan blades; and a structural member extending from the support shaft of the boundary layer ingestion fan to the nacelle.

[0012] In certain exemplary embodiments the auxiliary power unit exhaust duct includes a bypass portion that extends to the nacelle through the structural member, wherein an auxiliary power unit exhaust flow through the bypass portion to the nacelle is configured to de-ice the nacelle.

[0013] In certain exemplary embodiments the aircraft includes a motor having a drive shaft offset from the fan shaft and a gear in communication with the drive shaft and the fan shaft to drive the boundary layer ingestion fan.

[0014] In certain exemplary embodiments the auxiliary power unit exhaust duct extends through a center of the support shaft of the boundary layer ingestion fan along an axial direction of the boundary layer ingestion fan.

[0015] In certain exemplary embodiments the boundary layer ingestion fan is incorporated into a tail section of the aircraft at the aft end of the aircraft.

[0016] In certain exemplary embodiments a portion of the boundary layer ingestion fan makes up the aft end of the aircraft.

[0017] In another exemplary embodiment of the present disclosure, an aircraft extending between a forward end and an aft end is provided. The aircraft includes an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct; and an aft engine. The aft engine is configured to be mounted to the aircraft at the aft end, the aft engine defining a central axis and including a fan rotatable about the central axis of the aft engine and including a plurality of fan blades attached to a fan shaft; a nacelle encircling the plurality of fan blades; and a structural member extending from a portion of the aft engine to the nacelle, wherein the auxiliary power unit exhaust duct extends through the structural member to the nacelle.

[0018] In certain exemplary embodiments the aft engine includes a power source having a drive shaft and a support shaft extending through the fan shaft, wherein the structural member extends from the support shaft to the nacelle and wherein the auxiliary power unit exhaust duct extends around the drive shaft and the support shaft through the structural member to the nacelle.

[0019] In certain exemplary embodiments the auxiliary power unit exhaust duct includes an exit portion that is located at a trailing edge of the nacelle.

[0020] In certain exemplary embodiments the structural member is an inlet guide vane.

[0021] In certain exemplary embodiments the aircraft includes a thermal insulation portion between the auxiliary power unit exhaust duct and the inlet guide vane.

[0022] In certain exemplary embodiments the aft engine is configured as a boundary layer ingestion fan.

[0023] In certain exemplary embodiments an auxiliary power unit exhaust flow through the auxiliary power unit exhaust duct within the nacelle is configured to de-ice the nacelle.

[0024] In certain exemplary embodiments the auxiliary power unit exhaust duct includes a first auxiliary power unit exhaust duct portion that extends around the drive shaft in a first direction through a first portion of the structural member to a first portion of the nacelle and a second auxiliary power unit exhaust duct portion that extends around the drive shaft in a second direction through a second portion of the structural member to a second portion of the nacelle, wherein the first auxiliary power unit exhaust duct portion and the second auxiliary power unit exhaust duct portion are bifurcated.

[0025] In another exemplary embodiment of the present disclosure, an aircraft extending between a forward end and an aft end is provided. The aircraft includes an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct and a boundary layer ingestion fan positioned proximate the aft end of the aircraft between the aft end of the aircraft and the auxiliary power unit, the boundary layer ingestion fan spaced away from the auxiliary power unit, wherein the auxiliary power unit exhaust duct extends radially outward to a tail of the aircraft.
[0026] In certain exemplary embodiments the auxiliary power unit exhaust duct includes an exit portion that is located at a trailing edge of the tail of the aircraft.
[0027] In certain exemplary embodiments the auxiliary power unit exhaust duct extends radially outward to a vertical stabilizer of the aircraft.
[0028] In certain exemplary embodiments the auxiliary power unit exhaust duct extends around the boundary layer ingestion fan thereby an auxiliary power unit exhaust flow through the auxiliary power unit exhaust duct is prevented from interfering with the boundary layer ingestion fan.
[0029] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0030] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:
[0031] FIG. **1** is a top view of an aircraft in accordance with an exemplary embodiment of the present disclosure.
[0032] FIG. **2** is a port side view of the exemplary aircraft of FIG. **1** in accordance with an exemplary embodiment of the present disclosure.
[0033] FIG. **3** is a schematic, cross-sectional view of a gas turbine engine mounted to the exemplary aircraft of FIG. **1** in accordance with an exemplary embodiment of the present disclosure.
[0034] FIG. **4** is a schematic, cross-sectional view of an auxiliary power unit in accordance with an exemplary embodiment of the present disclosure.
[0035] FIG. **5** is a schematic, cross-sectional view of an auxiliary power unit and boundary layer ingestion fan each positioned proximate the aft end of an aircraft in accordance with an exemplary embodiment of the present disclosure.
[0036] FIG. **6** is a close-up, schematic, cross-sectional view of an auxiliary power unit and boundary layer ingestion fan each positioned proximate the aft end of an aircraft in accordance with an exemplary embodiment of the present disclosure.
[0037] FIG. **7** is a schematic, cross-sectional view of an auxiliary power unit and boundary layer ingestion fan each positioned proximate the aft end of an aircraft with a bypass portion of an auxiliary power unit exhaust duct extending to the nacelle through a structural member in accordance with an exemplary embodiment of the present disclosure.
[0038] FIG. **8** is a schematic, cross-sectional view of an auxiliary power unit and boundary layer ingestion fan each positioned proximate the aft end of an aircraft with a motor having a drive shaft offset from a support shaft in accordance with an exemplary embodiment of the present disclosure.
[0039] FIG. **9** is a schematic, cross-sectional view of an auxiliary power unit and boundary layer

ingestion fan each positioned proximate the aft end of an aircraft in accordance with another exemplary embodiment of the present disclosure.

[0040] FIG. **10** is a schematic, cross-sectional view of an auxiliary power unit and boundary layer ingestion fan each positioned proximate the aft end of an aircraft in accordance with another exemplary embodiment of the present disclosure.

[0041] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate exemplary embodiments of the disclosure, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

DETAILED DESCRIPTION

[0042] Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention.

[0043] The following description is provided to enable those skilled in the art to make and use the described embodiments contemplated for carrying out the invention. Various modifications, equivalents, variations, and alternatives, however, will remain readily apparent to those skilled in the art. Any and all such modifications, variations, equivalents, and alternatives are intended to fall within the spirit and scope of the present invention.

[0044] For purposes of the description hereinafter, the terms “upper”, “lower”, “right”, “left”, “vertical”, “horizontal”, “top”, “bottom”, “lateral”, “longitudinal”, and derivatives thereof shall relate to the invention as it is oriented in the drawing figures. However, it is to be understood that the invention may assume various alternative variations, except where expressly specified to the contrary. It is also to be understood that the specific devices illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the invention. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

[0045] As used herein, the terms “first”, “second”, and “third” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms “forward” and “aft” refer to the relative positions of a component based on an actual or anticipated direction of travel. For example, “forward” may refer to a front of an aircraft based on an anticipated direction of travel of the aircraft, and “aft” may refer to a back of the aircraft based on an anticipated direction of travel of the aircraft. 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.

[0046] An aircraft of the present disclosure allows for the integration of an auxiliary power unit (APU) and a boundary layer ingestion (BLI) fan at the aft end of an aircraft. In an exemplary embodiment of the present disclosure, an auxiliary power unit exhaust duct of the APU extends through a portion of a support shaft of the BLI fan to enable the APU to be positioned proximate the aft end of the aircraft while also adding the BLI fan to a position proximate the aft end of the aircraft.

[0047] In another exemplary embodiment of the present disclosure, an auxiliary power unit exhaust duct of the APU extends through a structural member to a nacelle of an aft engine to enable the APU to be positioned proximate the aft end of the aircraft while also adding the BLI fan to a position proximate the aft end of the aircraft.

[0048] In another exemplary embodiment of the present disclosure, an auxiliary power unit exhaust duct of the APU extends radially outward to a tail of the aircraft to enable the APU to be positioned proximate the aft end of the aircraft while also adding the BLI fan to a position proximate the aft end of the aircraft. In this manner, the auxiliary power unit exhaust duct extends around the BLI fan thereby an auxiliary power unit exhaust flow through the auxiliary power unit exhaust duct is prevented from interfering with the boundary layer ingestion fan.

[0049] The embodiments of the present disclosure by allowing for the integration of the APU and the BLI fan at the aft end of an aircraft reduces the exhaust noise of the aircraft. Furthermore, embodiments of the present disclosure include a bypass portion of the auxiliary power unit exhaust duct that extends to the nacelle through the structural member, wherein an auxiliary power unit exhaust flow through the bypass portion to the nacelle is configured to de-ice the nacelle.

[0050] The embodiments of the present disclosure can also include temperature sensors at various locations of an integrated APU and BLI fan system. For example, in an exemplary embodiment, temperature sensors can be included at areas of the system to measure an air temperature just prior to fan blades of the BLI fan thereby allowing an increase or decrease of power to the fan based on such temperature readings. This configuration can prevent stalling of the BLI fan system.

[0051] Referring now to the drawings, wherein identical numerals indicate the same elements throughout the figures, FIG. **1** provides a top view of an exemplary aircraft **10** as may incorporate various embodiments of the present invention. FIG. **2** provides a port side view of the aircraft **10** as illustrated in FIG. **1**. As shown in FIGS. **1** and **2** collectively, the aircraft **10** defines a longitudinal centerline **14** that extends therethrough, a vertical direction V, a lateral direction L, a forward end **16**, and an aft end **18**. Moreover, the aircraft **10** defines a mean line **15** extending between the forward end **16** and aft end **18** of the aircraft **10**. As used herein, the “mean line” refers to a midpoint line extending along a length of the aircraft **10**, not taking into account the appendages of the aircraft **10** (such as the wings **20** and stabilizers discussed below).

[0052] Moreover, the aircraft **10** includes a fuselage **12**, extending longitudinally from the forward end **16** of the aircraft **10** towards the aft end **18** of the aircraft **10**, and a pair of wings **20**. As used herein, the term “fuselage” generally includes all of the body of the aircraft **10**, such as an empennage of the aircraft **10**. The first of such wings **20** extends laterally outwardly with respect to the longitudinal centerline **14** from a port side **22** of the fuselage **12** and the second of such wings **20** extends laterally outwardly with respect to the longitudinal centerline **14** from a starboard side **24** of the fuselage **12**. Each of the wings **20** for the exemplary embodiment depicted includes one or more leading edge flaps **26** and one or more trailing edge flaps **28**. The aircraft **10** further includes a vertical stabilizer **30** having a rudder flap **32** for yaw control, and a pair of horizontal stabilizers **34**, each having an elevator flap **36** for pitch control. The fuselage **12** additionally includes an outer surface or skin **38**. It should be appreciated however, that in other exemplary embodiments of the present disclosure, the aircraft **10** may additionally or alternatively include any other suitable configuration of stabilizer that may or may not extend directly along the vertical direction V or horizontal/lateral direction L.

[0053] The exemplary aircraft **10** of FIGS. **1** and **2** includes a propulsion system **100**, herein referred to as “system **100**”. The exemplary system **100** includes a pair of aircraft engines, at least one of which mounted to each of the pair of wings **20**, and an aft engine. For the embodiment depicted, the aircraft engines are configured as turbofan jet engines **102**, **104** suspended beneath the wings **20** in an under-wing configuration. Additionally, the aft engine is configured as an engine configured to ingest and consume air forming a boundary layer over the fuselage **12** of the aircraft **10**. Specifically, the aft engine is configured as a fan, i.e., a Boundary Layer Ingestion (BLI) fan **106**, configured to ingest and consume air forming a boundary layer over the fuselage **12** of the aircraft **10**. The BLI fan **106** is mounted to the aircraft **10** at a location aft of the wings **20** and/or the jet engines **102**, **104**, such that the mean line **15** extends therethrough. Specifically, for the embodiment depicted, the BLI fan **106** is fixedly connected to the fuselage **12** at the aft end **18**, such that the BLI fan **106** is incorporated into or blended with a tail section at the aft end **18**. However, it should be appreciated that in various other embodiments, some of which will be discussed below, the BLI fan **106** may alternatively be positioned at any suitable location of the aft end **18**.

[0054] In various embodiments, the jet engines **102**, **104** may be configured to provide power to an electric generator **108** and/or an energy storage device **110**. For example, one or both of the jet engines **102**, **104** may be configured to provide mechanical power from a rotating shaft (such as an LP shaft or HP shaft) to the electric generator **108**. Additionally, the electric generator **108** may be configured to convert the mechanical power to electrical power and provide such electrical power to one or both of the energy storage device **110** or the BLI fan **106**. Accordingly, in such an embodiment, the propulsion system **100** may be referred to as a gas-electric propulsion system. It should be appreciated, however, that the aircraft **10** and propulsion system **100** depicted in FIGS. **1** and **2** is provided by way of example only and that in other exemplary embodiments of the present disclosure, any other suitable aircraft **10** may be provided having a propulsion system **100** configured in any other suitable manner.

[0055] Moreover, it will be appreciated that the exemplary aircraft of FIGS. **1** and **2** includes an auxiliary power unit **150**. For the embodiment depicted, the auxiliary power unit **150** is positioned proximate the aft end **18** of the aircraft **10** within the fuselage **12**. The auxiliary power unit **150** may be provided for generating electrical power to operate or drive one or more aircraft systems. Additionally, or alternatively, the auxiliary power unit **150** may be configured to generate electrical power to, e.g., start one or more of the aircraft engines **102**, **104**.

[0056] Referring now to FIG. **3**, in at least certain embodiments, the jet engines **102**, **104** may be configured as high-bypass turbofan jet engines. FIG. **3** is a schematic cross-sectional view of an exemplary high-bypass turbofan jet engine **200**, herein referred to as “turbofan **200**.” In various embodiments, the turbofan **200** may be representative of jet engines **102**, **104**. As shown in FIG. **3**, the turbofan **200** defines an axial direction Al (extending parallel to a longitudinal centerline or axis **201** provided for reference) and a radial direction R**1**. In general, the turbofan **200** includes a fan section **202** and a core turbine engine **204** disposed downstream from the fan section **202**.

[0057] The exemplary core turbine engine **204** depicted generally includes a substantially tubular outer casing **206** that defines an annular inlet **208**. The outer casing **206** encases, in serial flow relationship, a compressor section including a booster or low pressure (LP) compressor **210** and a high pressure (HP) compressor **212**; a combustion section **214**; a turbine section including a high pressure (HP) turbine **216** and a low pressure (LP) turbine **218**; and a jet exhaust nozzle section **220**. A high pressure (HP) shaft or spool **222** drivingly connects the HP turbine **216** to the HP compressor **212**. A low pressure (LP) shaft or spool **224** drivingly connects the LP turbine **218** to the LP compressor **210**.

[0058] For the embodiment depicted, the fan section **202** includes a variable pitch fan **226** having a plurality of fan blades **228** coupled to a disk **230** in a spaced apart manner. As depicted, the fan blades **228** extend outwardly from disk **230** generally along the radial direction R**1**. Each fan blade **228** is rotatable relative to the disk **230** about a pitch axis P by virtue of the fan blades **228** being operatively coupled to a suitable actuation member **232** configured to collectively vary the pitch of the fan blades **228** in unison. The fan blades **228**, disk **230**, and actuation member **232** are together rotatable about the longitudinal axis **201** by LP shaft **224** across a power gear box **234**. The power gear box **234** includes a plurality of gears for stepping down the rotational speed of the LP shaft **224** to a more efficient rotational fan speed.

[0059] Referring still to the exemplary embodiment of FIG. **3**, the disk **230** is covered by rotatable front hub **236** aerodynamically contoured to promote an airflow through the plurality of fan blades **228**. Additionally, the exemplary fan section **202** includes an annular fan casing or outer nacelle **238** that circumferentially surrounds the fan **226** and/or at least a portion of the core turbine engine **204**. It should be appreciated that the nacelle **238** may be configured to be supported relative to the core turbine engine **204** by a plurality of circumferentially-spaced outlet guide vanes **240**. Moreover, a downstream section **242** of the nacelle **238** may extend over an outer portion of the core turbine engine **204** so as to define a bypass airflow passage **244** therebetween.

[0060] It should be appreciated, however, that the exemplary turbofan engine **200** depicted in FIG. **3** is by way of example only, and that in other exemplary embodiments, the turbofan engine **200** may have any other suitable configuration. Further, it should be appreciated, that in other exemplary embodiments, the jet engines **102**, **104** may instead be configured as any other suitable aeronautical engine.

[0061] Referring now to FIG. **4**, a close-up, schematic view of the exemplary auxiliary power unit **150** of FIGS. **1** and **2** is depicted. As will be appreciated, in an exemplary embodiment, the auxiliary power unit **150** is an engine, and more specifically, is a turbine engine defining an axial direction A, an axis **151** extending along the axial direction A, a radial direction R, and a circumferential direction (extending about the axis **151**), and further including a compressor section and a turbine section. More specifically, for the embodiment depicted, the compressor section includes a compressor **152** and the turbine section includes a turbine **154**. The compressor **152** and the turbine **154** together define at least in part a core air flowpath **156** of the auxiliary power unit **150**. Further, the auxiliary power unit **150** includes a drive shaft **158**, the drive shaft **158** coupled to at least one of the compressor **152** or the turbine **154**, and more specifically, the drive shaft **158** extends between and couples the compressor **152** and the turbine **154**. In such a manner the compressor **152** is rotatable with, and driven by, the turbine **154**.

[0062] The auxiliary power unit **150** further defines an inlet **160** configured to receive a flow of air, which may be an ambient airflow from outside of the fuselage **12** of the aircraft **10**. During operation of the auxiliary power unit **150**, air flows from the inlet **160** to the compressor **152**, where an impeller **162** of the compressor **152** (coupled to the drive shaft **158**) compresses the flow of air. Moreover, the exemplary auxiliary power unit **150** includes a combustion section **164**, with the exemplary combustion section **164** depicted including a reverse flow combustor **166**. In such a manner, the compressed air from the compressor section flows around the combustor **166** before mixing with fuel and entering a combustion chamber **168** of the combustor **166**, where the fuel-air mixture is combusted to generate combustion gases. The combustion gases flow through the turbine **154** of the turbine section, and more specifically, drive an impeller **170** of the turbine **154**, rotating the turbine **154**. Further, the drive shaft **158** is coupled to the impeller **170** of the turbine **154**, such that rotation of the turbine **154** rotates/drives the drive shaft **158**.

[0063] Referring still to FIG. **4**, the auxiliary power unit **150** includes an auxiliary power unit exhaust duct **163** (see also FIGS. **5-8**). Exhaust gases from the auxiliary power unit **150**, e.g., an auxiliary power unit exhaust flow, flow out an outlet **161** and through the auxiliary power unit exhaust duct **163** (see also FIGS. **5-8**).

[0064] Additionally, in one exemplary embodiment, the engine, or rather the auxiliary power unit **150**, includes a stationary member and a rotating member. The rotating member is configured to rotate about the centerline axis **151** of the auxiliary power unit **150** during operation of the auxiliary power unit **150** with one or more of the compressor **152** or the turbine **154**. By contrast, the stationary member is configured to remain stationary relative to the rotating member during operation of the auxiliary power unit **150**. For the embodiment depicted, the rotating member is the drive shaft **158** of the auxiliary power unit **150**, and the stationary member is a stationary support member **172**. Notably, the stationary support member **172** is fixedly coupled to an inlet strut **174** positioned within the core air flowpath **156** of the auxiliary power unit **150**, upstream of the compressor **152** of the compressor section of the auxiliary power unit **150**. The stationary support member **172** (which may also be described as a stator assembly mount) may provide for electrical isolation of an electric machine **176**. However, in other embodiments, the stationary member may be any other suitable component that remains stationary relative to the rotating member during operation of the auxiliary power unit **150**.

[0065] Moreover, the exemplary auxiliary power unit **150** further includes an electric machine **176** positioned at a forward end thereof. The exemplary electric machine **176** generally includes a stator assembly **178** and a rotor assembly **180**. Further, as is depicted schematically, the rotor assembly **180** generally includes a rotor **182** and a rotor shaft **184**. Similarly, the stator assembly **178** generally includes a stator **186** and a stator shaft **188**. The electric machine **176** may be configured as any suitable type of electric machine **176**, such as an alternating current electric machine, a direct current electric machine, a permanent magnet electric machine, an induction electric machine, a brushed electric machine, etc. Accordingly, it will be appreciated that the stator **186**, the rotor **182**, or both, may include one or more permanent magnets, electromagnets, coils, etc.

[0066] Further, the electric machine **176** depicted is electrically coupled to an electric communication bus **190** through an electric line **192** of the electric communication bus **190**. More specifically, the stator **186** of the electric machine **176** is electrically coupled to the electric line **192** of the electric communication bus **190**. The electric communication bus may electrically connect the electric machine **176** to a power circuit of an aircraft, of a propulsion system, etc. The electric communication bus **190** further includes, for the embodiment depicted, a controller **194**. The controller **194** may generally include power electronics, sensors, computers, processors, etc. In such a manner, the controller **194** may condition and/or direct the electrical power provided to the electric machine **176**, the electrical power extracted from the electric machine **176**, or both.

[0067] Moreover, the rotor assembly **180** is rotatable relative to the stator assembly **178** during operation of the auxiliary power unit **150**. More specifically, the stator assembly **178** is coupled to the stationary member of the auxiliary power unit **150**, and the rotor assembly **180** is coupled to, or otherwise rotatable with, the rotary component of the auxiliary power unit **150**, which for the embodiment depicted is the drive shaft **158**. Accordingly, when operated as an electric generator, the rotor assembly **180** of the electric machine **176** may be driven by the drive shaft **158** of the auxiliary power unit **150** to generate electrical power, also referred to as extracting power from the auxiliary power unit **150**. By contrast, when operated as an electric motor, the rotor assembly **180** of the electric machine **176** may drive the drive shaft **158** of the auxiliary power unit **150** to, e.g., start the auxiliary power unit **150**.

[0068] Regardless of the operating mode, the stator assembly **178** of the electric machine **176** may generate or receive electrical power having a relatively high-voltage, high levels of current, or both. In the event that, e.g., an insulation within the stator **186** of the stator assembly **178** breaks down or is otherwise insufficient to contain the electrical power, it may be possible for the electricity generated or received by the stator assembly **178** to connect to one or more electrically conductive components of the electric machine **176** through an electrical arc. In such a case, the electrical power may be conducted through, e.g., the rotor assembly **180** and to the drive shaft **158** of the auxiliary power unit **150**. Once conducted to the drive shaft **158** of the auxiliary power unit **150**, such electricity may flow through one or more relatively sensitive components, causing damage to such components (such as one or more bearings, sensors, etc.).

[0069] Accordingly, for the embodiment depicted, the auxiliary power unit **150** further includes an electrical break **196**, with the drive shaft **158** being coupled to the rotor assembly **180** through the electrical break **196**. Specifically, for the embodiment depicted, the rotor assembly **180** is coupled to the drive shaft **158** of the auxiliary power unit **150** solely through the electrical break **196**, such that the electrical break **196** is configured to transfer substantially all of a torque between the drive shaft **158** in the rotor assembly **180** of the electric machine **176**. For example, when operated as an electric motor, substantially all of the torque generated by the electric machine **176** is transferred from the rotor shaft **184** of the rotor assembly **180** of the electric machine **176** to the drive shaft **158** through the electrical break **196**. Similarly, when operated as an electric generator, substantially all of the torque generated by the auxiliary power unit **150** (that is to be transferred to the electric machine **176**) is transferred from the drive shaft **158** through the electrical break **196** to the rotor shaft **184** of the rotor assembly **180** of the electric machine **176**.

[0070] In order to prevent electricity from being conducted from the rotor assembly **180** of the electric machine **176** to the drive shaft **158** of the auxiliary power unit **150**, the electrical break **196** is formed substantially completely of a non-electrically conductive material. For example, in certain exemplary aspects, the non-electrically conductive material may be a plastic material, such as one or more of a polyethylene, polypropylene, polyvinyl chloride, acrylonitrile butadiene styrene, phenolics or phenol formaldehyde, polyetheretherketone, polyimide, etc.

[0071] Referring now to FIG. **5**, a schematic, cross-sectional side view of an aft engine in accordance with various embodiments of the present disclosure is provided. The aft engine depicted is mounted to an aircraft **10** at an aft end **18** of the aircraft **10**. Specifically, for the embodiment depicted, the aft engine is configured as a boundary layer ingestion (BLI) fan **300**. As described herein, an aircraft of the present disclosure allows for the integration of an auxiliary power unit (APU) and a boundary layer ingestion (BLI) fan, i.e., a combined APU and BLI system **500**, at the aft end **18** of an aircraft **10**. Referring to FIGS. **5-8**, in an exemplary embodiment of the present disclosure, an auxiliary power unit exhaust duct or outlet portion **522** of the APU **510** extends through a portion of a support shaft **315** of the BLI fan **300** to enable the APU **510** to be positioned proximate the aft end **18** of the aircraft **10** while also adding the BLI fan **300** to a position proximate the aft end **18** of the aircraft **10**. In this manner, the BLI fan **300** together with an auxiliary power unit **510** forms a combined APU and BLI system **500** that both can be installed proximate the aft end **18** of the aircraft **10**. The BLI fan **300** may be configured in substantially the same manner as the BLI fan **106** described above with reference to FIGS. **1** and **2** and the aircraft **10** may be configured in substantially the same manner as the exemplary aircraft **10** described above with reference to FIGS. **1** and **2**. However, in other embodiments, the aft engine may instead be configured in any other suitable manner.

[0072] As shown in FIG. **5**, the BLI fan **300** defines an axial direction A**2** extending along a longitudinal centerline axis **302** that extends therethrough for reference, as well as a radial direction R**2**.

[0073] In general, the BLI fan **300** includes a fan **304** rotatable about the centerline axis **302**, a nacelle **306** extending around a portion of the fan **304**, and a structural support system **308**. The fan **304** includes a plurality of fan blades **310** and a fan shaft **312**. The plurality of fan blades **310** are attached to the fan shaft **312** and spaced generally along a circumferential direction of the turbofan engine.

[0074] In certain exemplary embodiments, the plurality of fan blades **310** may be attached in a fixed manner to the fan shaft **312**, or alternatively, the plurality of fan blades **310** may be rotatably attached to the fan shaft **312**. For example, the plurality of fan blades **310** may be attached to the fan shaft **312** such that a pitch of each of the plurality of fan blades **310** may be changed, e.g., in unison, by a pitch change mechanism (not shown). Changing the pitch of the plurality of fan blades **310** may increase an efficiency of the BLI fan **300** and/or may allow the BLI fan **300** to achieve a desired thrust profile. With such an exemplary embodiment, the BLI fan **300** may be referred to as a variable pitch BLI fan.

[0075] The fan shaft **312** is mechanically coupled to a power source **314** located at least partially within the fuselage **12** of the aircraft **10**. In certain exemplary embodiments, the BLI fan **300** may be configured with a gas-electric propulsion system, such as the gas-electric propulsion system **100** described above with reference to FIG. **1**. In such an embodiment, the power source **314** may be an electric motor that receives power from one or both of an energy storage device or an electric generator, e.g., such as the auxiliary power unit **150**, the energy storage device **110**, or electric generator **108** of FIGS. **1** and **2**, the electric generator **108** converting mechanical power received from one or more under-wing mounted aircraft engines to electric power. Notably, the electric motor may be an inrunner electric motor, or alternatively may be an outrunner electric motor. In either embodiment, the electric motor may further include a gearbox mechanically coupling the electric motor to the fan shaft **312**. Additionally, in still other exemplary embodiments, the power source **314** may instead be any other suitable power source. For example, the power source **314** may alternatively be configured as a gas engine, such as a gas turbine engine or internal combustion engine. Moreover, in certain exemplary embodiments, the power source **314** may be positioned at any other suitable location within, e.g., the fuselage **12** of the aircraft **10** or the BLI fan **300**. For example, in certain exemplary embodiments, the power source **314** may be configured as a gas turbine engine positioned at least partially within the BLI fan **300**.

[0076] As briefly stated above, the BLI fan **300** additionally includes a structural support system **308** for mounting the BLI fan **300** to the aircraft **10**. The structural support system **308** extends generally from the fuselage **12** of the aircraft **10**, through the fan shaft **312**, and to the nacelle **306** of the BLI fan **300** when the BLI fan **300** is attached the aircraft **10**. More specifically, the structural support system **308** generally includes a support shaft **315** extending between a first end **316** and a second end **317**. Notably, as used herein, the term "support shaft" refers generally to any structural member, such as a support beam or rod. At the first end **316**, the support shaft **315** is attached to the fuselage **12** of the aircraft **10** through a plurality of forward attachment arms **318** of the support shaft **315**. For example, the plurality of forward attachment arms **318** of the support shaft **315** at the first end **316** of the support shaft **315** may be attached to a bulkhead **322** of the fuselage **12** of the aircraft **10**.

[0077] The support shaft **315** extends from the first end **316**, in the aft direction, through at least a portion of the fan shaft **312**. For the embodiment depicted, the support shaft **315** includes a cylindrical body portion **319** extending through a center of the fan shaft **312**—the cylindrical body portion **319** of the support shaft **315** being concentric with the fan shaft **312**. Additionally, the cylindrical body portion **319** of the support shaft **315** supports rotation of the fan shaft **312**. More particularly, for the embodiment depicted, a bearing assembly is provided between the body portion **319** of the support shaft **315** and the fan shaft **312**. The exemplary bearing assembly depicted generally includes roller bearings **324** positioned forward of ball bearings **326**. It should be appreciated, however, that in other embodiments, any other suitable bearing assembly may be provided between the support shaft **315** and the fan shaft **312**. Alternatively, the fan shaft **312** may be supported for rotation in any other suitable manner, using any other suitable bearing assembly.

[0078] Referring still to FIG. **5**, the structural support system **308** further includes one or more structural members **328** extending from the structural support shaft **315** to the nacelle **306**. Specifically, for the embodiment depicted, the structural support shaft **315** includes a plurality of aft support arms **320** and a cylindrical support ring **321**. The plurality of aft support arms **320** extend from the cylindrical body portion **319** of the support shaft **315** to the cylindrical support ring **321**, and the one or more structural members **328** are attached to the cylindrical support ring **321**. Additionally, for the embodiment depicted, the one or more structural members **328** include a plurality of circumferentially spaced structural members **328** attached to the second end **317** of the support shaft **315**, i.e., to the cylindrical support ring **321**. The one or more structural members **328** may provide structural support for the nacelle **306** and, e.g., a tail cone **330** of the BLI fan **300**.

[0079] For the embodiment depicted in FIG. **5**, the plurality of structural members **328** extend substantially along the radial direction R**2** to the nacelle **306**, to provide structural support for the nacelle **306**. Additionally, although not depicted, the structural member **328** may, in certain embodiments, be evenly spaced along the circumferential direction. It should be appreciated, however, that the exemplary structural support system **308** depicted is provided by way of example only, and that in other exemplary embodiments, any other suitable structural support system **308** may be provided. For example, in other exemplary embodiments, the structural members **328** may instead define an angle relative to the radial direction R**2**, and further may be unevenly spaced along the circumferential direction. Additionally, the support shaft **315** may have any other suitable configuration. For example, in other exemplary embodiments, the support shaft **315** may be entirely formed of a cylindrical body portion, such that the cylindrical body portion mounts directly at a forward end to the fuselage **12** of the aircraft **10**. Similarly, in other embodiments, the support shaft **315** may not include one or both of the aft attachment arms **320** or the cylindrical support ring **321**. For example, in certain exemplary embodiments, the one or more structural members **328** may be attached directly to the cylindrical body portion **319** of the support shaft **315**. Moreover, in still other embodiments, the support system **308** may include additional support features, e.g., static support features, positioned radially inward of the fan shaft **312** and, e.g., within the support shaft

315, or elsewhere for providing a desired amount of support for the structural member **328** and nacelle **306**.

[0080] Notably, referring still to embodiment of FIG. **5**, the one or more structural members **328** are attached to the nacelle **306**, and extend from the support shaft **315** to the nacelle **306**, at a location aft of the plurality of fan blades **310**. The one or more structural members **328** may include a plurality of structural members **328** extending substantially along the radial direction R**2**, as is depicted, and substantially evenly spaced along the circumferential direction of the BLI fan **300**. For example, the one or more structural members **328** may include three or more structural members **328**, five or more structural members **328**, eight or more structural members **328**, or twelve or more structural members **328**. However, in other exemplary embodiments, the one or more structural members **328** may include any other suitable number of structural members **328**, and may define any suitable angle with the longitudinal centerline **302**. Additionally, in other exemplary embodiments, the one or more structural members **328** may be spaced in any suitable configuration along the circumferential direction. It should be appreciated, that as used herein, terms of approximation, such as “approximately,” “substantially,” or “about,” refer to being within a ten percent margin of error.

[0081] Moreover, in at least certain exemplary embodiments, the one or more structural members **328** may each be configured as an outlet guide vane. If configured as outlet guide vanes, the one or more structural members **328** may be configured for directing a flow of air through the BLI fan **300**. Additionally, with such configuration, the one or more structural members **328** may be configured as fixed outlet guide vanes, or alternatively as variable outlet guide vanes. For example, each of the one or more structural members **328** may include a flap (not shown) positioned at an aft end rotatable about a substantially radial axis to vary a direction in which the structural member (configured as an outlet guide vane) directs the flow of air.

[0082] Aft of the plurality of fan blades **310** and aft of the one or more structural members **328** of the structural support system **308**, the BLI fan **300** additionally defines a nozzle **338** between the nacelle **306** and the tail cone **330**. The nozzle **338** may be configured to generate an amount of thrust from the air flowing therethrough, and the tail cone **330** may be shaped to minimize an amount of drag on the BLI fan **300**. However, in other embodiments, the tail cone **330** may have any other shape and may, e.g., end forward of an aft end of the nacelle **306** such that the tail cone **330** is enclosed by the nacelle **306** at an aft end. Additionally, in other embodiments, the BLI fan **300** may not be configured to generate any measurable amount of thrust, and instead may be configured to ingest air from a boundary layer of air of the fuselage **12** of the aircraft **10** and add energy/speed up such air to reduce an overall drag on the aircraft **10** (and thus increase a net thrust of the aircraft **10**).

[0083] Referring still to FIG. **5**, the BLI fan **300** defines an inlet **334** at the forward end **336** of the BLI fan **300**, between the nacelle **306** and the fuselage **12** of the aircraft **10**. The nacelle **306** of the BLI fan **300** extends around the mean line **15** of the aircraft **10** and the fuselage **12** of the aircraft **10** at the aft end **18** of the aircraft **10**. Specifically, for the embodiment depicted, the inlet **334** of the BLI fan **300** extends substantially three hundred sixty degrees in the circumferential direction around the mean line **15** of the aircraft **10** and the fuselage **12** of the aircraft **10** when, such as in the embodiment depicted, the BLI fan **300** is mounted to the aircraft **10**.

[0084] Referring now to FIG. **6**, a close-up view is provided of the aft end **18** of the exemplary aircraft **10** described above with reference to FIGS. **1**, **2**, and **5**. As discussed above, the fuselage **12** of the aircraft **10** extends generally from the forward end **16** of the aircraft **10** towards the aft end **18** of the aircraft **10**, with the aft engine or BLI fan **300** and the APU **510** mounted to the fuselage **12** proximate the aft end **18** of the aircraft **10**. The fuselage **12** defines a top side **602** and a bottom side **604** along the vertical direction V. Moreover, the exemplary fuselage **12** depicted defines a frustum **606** located proximate the aft end **18** of the aircraft **10**. Specifically, for the embodiment depicted, the frustum **606** is positioned aft of the pair of wings **20** (FIGS. **1** and **2**) of the aircraft **10**.

As used herein, the term "frustum" refers generally to a portion of a shape lying between two parallel planes. Accordingly, for the embodiment depicted, the frustum **606** is defined between a first, or forward plane **608** and a second, or aft plane **610**, the forward and aft planes **608**, **610** being parallel to one another and perpendicular to the longitudinal centerline **14** of the aircraft **10** (FIGS. **1** and **2**). Referring to FIG. **6**, as discussed above, the aircraft **10** includes a vertical stabilizer **30** having a rudder flap **32** for yaw control.

[0085] FIGS. **5-8** illustrate exemplary embodiments of the present disclosure. Referring to FIGS. **5-8**, a combined APU and BLI system **500** for an aircraft **10** extending between a forward end **16** and an aft end **18** will now be described. As shown in FIGS. **5-8**, the present disclosure allows for the installation of a combined APU and BLI system **500** proximate the aft end **18** of the aircraft **10**.

[0086] Referring to FIGS. **5** and **6**, in an exemplary embodiment, the APU and BLI system **500** includes an auxiliary power unit **510** positioned proximate the aft end **18** of the aircraft **10** and also a boundary layer ingestion fan **300** positioned proximate the aft end **18** of the aircraft **10**. The auxiliary power unit **510** includes an auxiliary power unit inlet duct or inlet **520** and an auxiliary power unit exhaust duct or outlet portion **522**. The boundary layer ingestion fan **300** includes a support shaft **315** as described in detail above. As shown in FIGS. **5** and **6**, in an exemplary embodiment, the auxiliary power unit exhaust duct **522** extends through a portion of the support shaft **315** of the boundary layer ingestion fan **300**. In one embodiment, the auxiliary power unit exhaust duct **522** extends through a center of the support shaft **315** of the boundary layer ingestion fan **300** along an axial direction of the boundary layer ingestion fan **300**, e.g., longitudinal centerline axis **302**. In one embodiment, the auxiliary power unit **510** corresponds to the auxiliary power unit **150** as described above with respect to FIG. **4**. As shown in FIGS. **5** and **6**, an exit portion **528** of the auxiliary power unit exhaust duct **522** allows for exhaust air to be exhausted or exited to atmosphere.

[0087] Referring to FIG. **6**, in one embodiment, the inlet duct **520** of the auxiliary power unit **510** is positioned at a top side **602** of the fuselage and extends towards a central portion of the frustum **606** of the fuselage **12** to the auxiliary power unit **510**. Furthermore, the exhaust duct or outlet duct **522** of the auxiliary power unit **510** extends out from the auxiliary power unit **510** and through a portion of the support shaft **530** of the boundary layer ingestion fan **512**.

[0088] In one embodiment, a portion of the boundary layer ingestion fan **512** makes up the aft end **18** of the aircraft **10** as shown in FIGS. **5** and **6**. For example, as shown in FIGS. **5** and **6**, the boundary layer ingestion fan **512** is incorporated into a tail section or tail cone **330** at the aft end **18** of the aircraft **10**.

[0089] Referring to FIGS. **5-8**, in an exemplary embodiment, the APU and BLI system **500** includes a mixer **530** in communication with the auxiliary power unit **510** and the boundary layer ingestion fan **300** such that the mixer **530** receives and mixes a boundary layer airflow from the boundary layer ingestion fan **300** and an auxiliary power unit exhaust flow from the auxiliary power unit exhaust duct **522**. In this manner, the mixer **530** of the present disclosure provides noise reduction for the APU **510** and/or other components of the aircraft **10** by mixing the boundary layer airflow and the auxiliary power unit exhaust flow.

[0090] In one embodiment, the mixer **530** is formed at the aft-most portion of the tail cone **330** and is in communication with an outlet of the auxiliary power unit exhaust duct **522**. In one embodiment, the mixer **530** comprises a fluted mixer. In another embodiment, the mixer **530** comprises a chevron mixer. In other embodiments, the mixer **530** comprises other mixer mechanisms for mixing two separate flows therein.

[0091] Referring to FIG. **6**, in an exemplary embodiment, the APU and BLI system **500** includes a thermal insulation portion **540** between the auxiliary power unit exhaust duct **522** and the support shaft **315** of the boundary layer ingestion fan **300**. In this manner, the BLI fan **300** is thermally insulated from higher temperatures of the auxiliary power unit exhaust flow exiting the auxiliary power unit exhaust duct **522**.

[0092] Referring to FIG. **7**, in an exemplary embodiment, the APU and BLI system **500** includes a mechanism for de-icing the nacelle **306** of the boundary layer ingestion fan **300**. For example, the auxiliary power unit exhaust duct **522** includes a bypass portion **524** that extends to the nacelle **306** through the structural member **328**. In this manner, the higher temperatures of an auxiliary power unit exhaust flow traveling through the bypass portion **524** to the nacelle **306** is configured to de-ice the nacelle **306**. Essentially the bypass portion **524** allows some of the auxiliary power unit exhaust flow to be routed from the auxiliary power unit exhaust duct **522** to a portion of the nacelle **306** thereby providing de-ice capabilities using this configuration of the bypass portion **524**. As shown in FIG. **7**, the bypass portion **524** can extend to a front edge of the nacelle **306**. Other configurations of the bypass portion **524** through all areas of the nacelle **306** are contemplated, e.g., extending from the front edge to a rear edge of the nacelle **306**.

[0093] Referring to FIG. **8**, in an exemplary embodiment, the APU and BLI system **500** includes a BLI fan **300** having a motor or power source **314** having a drive shaft **341** that is offset from the fan shaft **312**. In this configuration, the BLI fan **300** also includes a gear **344** that is in communication with the drive shaft **341** and the fan shaft **312** to drive the BLI fan **300**. In one embodiment, the gear **344** comprises a ring gear, a single helix, a double helix, a spur gear, or other gear mechanism to allow an offset drive shaft **341** to drive the fan shaft **312** of the BLI fan **300**. It is contemplated that in some embodiments, the power source or motor **314** drives a gear **344** and in some embodiments the power source or motor **314** is a ring motor.

[0094] FIG. **9** illustrates another exemplary embodiment of the present disclosure. Referring to FIG. **9**, a combined APU and BLI system **700** for an aircraft **10** extending between a forward end **16** and an aft end **18** will now be described. As shown in FIG. **9**, the present disclosure allows for the installation of a combined APU and BLI system **700** proximate the aft end **18** of the aircraft **10**.

[0095] Referring to FIG. **9**, in an exemplary embodiment, the APU and BLI system **700** includes an auxiliary power unit **710** positioned proximate the aft end **18** of the aircraft **10** and also an aft engine or boundary layer ingestion fan **712** positioned proximate the aft end **18** of the aircraft **10**. The auxiliary power unit **710** includes an auxiliary power unit inlet duct or inlet **720** and an auxiliary power unit exhaust duct or outlet portion **722**.

[0096] In one embodiment, the aft engine or boundary layer ingestion fan **712** corresponds to the aft engine or boundary layer ingestion fan **300** as described above with respect to FIG. **5**. As described herein, the aft engine is configured as a boundary layer ingestion fan **300**, **712**.

[0097] Referring to FIG. **9**, in an exemplary embodiment of the present disclosure, the auxiliary power unit exhaust duct **722** of the APU **710** extends through a structural member **328** to a nacelle **306** of an aft engine or BLI fan **712** to enable the APU to be positioned proximate the aft end **18** of the aircraft **10** while also adding the BLI fan **712** to a position proximate the aft end **18** of the aircraft **10**. Referring to FIG. **9**, in one embodiment, the auxiliary power unit exhaust duct **722** extends around the drive shaft **341** and the support shaft **315** through the structural member **328** to the nacelle **306**.

[0098] Referring to FIG. **9**, in an exemplary embodiment, the auxiliary power unit exhaust duct **722** of the APU **710** includes a first auxiliary power unit exhaust duct portion **724** and a second auxiliary power unit exhaust duct portion **726**. In one embodiment, the first auxiliary power unit exhaust duct portion **724** extends around the drive shaft **341** in a first direction **740** through a first portion **742** of the structural member **328** to a first portion **744** of the nacelle **306**. Furthermore, the second auxiliary power unit exhaust duct portion **726** extends around the drive shaft **341** in a second direction **746** through a second portion **748** of the structural member **328** to a second portion **750** of the nacelle **306**. As shown in FIG. **9**, the first auxiliary power unit exhaust duct portion **724** and the second auxiliary power unit exhaust duct portion **726** are bifurcated. In this manner, the auxiliary power unit exhaust duct **722** extends around the BLI fan **712** thereby an auxiliary power unit exhaust flow through the auxiliary power unit exhaust duct **722** is prevented from interfering with the boundary layer ingestion fan **712**.

[0099] In this manner, referring to FIG. **9**, in an exemplary embodiment, the APU and BLI system **700** by including a first auxiliary power unit exhaust duct portion **724** and a second auxiliary power unit exhaust duct portion **726** that extend through structural members **328** to the nacelle **306** provides a mechanism for de-icing the nacelle **306** of the boundary layer ingestion fan **712**. In this manner, the higher temperatures of an auxiliary power unit exhaust flow traveling through the first auxiliary power unit exhaust duct portion **724** and the second auxiliary power unit exhaust duct portion **726** to different portions of the nacelle **306** are configured to de-ice the nacelle **306**. Essentially the first auxiliary power unit exhaust duct portion **724** and the second auxiliary power unit exhaust duct portion **726** allow some of the auxiliary power unit exhaust flow to be routed from the auxiliary power unit exhaust duct **722** to portions of the nacelle **306** thereby providing de-ice capabilities using this configuration of the auxiliary power unit exhaust duct **722**. As shown in FIG. **9**, the first auxiliary power unit exhaust duct portion **724** and the second auxiliary power unit exhaust duct portion **726** can extend to all portions of a nacelle **306**.
[0100] In one embodiment, the auxiliary power unit exhaust duct **722** includes an exit portion **728** that is located at a trailing edge **730** of the nacelle **306**. In one embodiment, the first auxiliary power unit exhaust duct portion **724** and the second auxiliary power unit exhaust duct portion **726** provide two separate exit portions **728** located at a trailing edge **730** of the nacelle **306**.
[0101] In an exemplary embodiment, the structural member **328** that the auxiliary power unit exhaust duct **722** of the APU **710** extends through is a guide vane of the BLI fan or aft engine **712**. By exhausting through guide vanes or structural members **328** of the BLI fan **712**, e.g., inlet guide vanes, the combined APU and BLI system **700** provides a radially consistent temperature profile to the fan blades **310**. It is contemplated that the auxiliary power unit exhaust duct **722** of the APU **710** can extend through any component of the BLI fan or aft engine **712** such as inlet guide vanes, outlet guide vanes, or other components of the BLI fan or aft engine **712**.
[0102] Referring to FIG. **9**, in an exemplary embodiment, the APU and BLI system **700** includes a thermal insulation portion **760** between the auxiliary power unit exhaust duct **722** and the structural member **328**, e.g., a guide vane of the aft engine or BLI fan **712**. In this manner, the BLI fan **712** is thermally insulated from higher temperatures of the auxiliary power unit exhaust flow exiting the auxiliary power unit exhaust duct **722**.
[0103] In one embodiment, the auxiliary power unit **710** corresponds to the auxiliary power unit **150** as described above with respect to FIG. **4**. As shown in FIG. **9**, an exit portion of the auxiliary power unit exhaust duct **722** allows for exhaust air to be exhausted or exited to atmosphere.
[0104] FIG. **10** illustrates another exemplary embodiment of the present disclosure. Referring to FIG. **10**, a combined APU and BLI system **800** for an aircraft **10** extending between a forward end **16** and an aft end **18** will now be described. As shown in FIG. **10**, the present disclosure allows for the installation of a combined APU and BLI system **800** proximate the aft end **18** of the aircraft **10**.
[0105] Referring to FIG. **10**, in an exemplary embodiment, the APU and BLI system **800** includes an auxiliary power unit **810** positioned proximate the aft end **18** of the aircraft **10** and also an aft engine or boundary layer ingestion fan **812** positioned proximate the aft end **18** of the aircraft **10**. The auxiliary power unit **810** includes an auxiliary power unit inlet duct or inlet **820** and an auxiliary power unit exhaust duct or outlet portion **822**.
[0106] In one embodiment, the aft engine or boundary layer ingestion fan **812** corresponds to the aft engine or boundary layer ingestion fan **300** as described above with respect to FIG. **5**. As described herein, the aft engine is configured as a boundary layer ingestion fan **300**, **812**.
[0107] Referring to FIG. **10**, in an exemplary embodiment, the boundary layer ingestion fan **812** is spaced away from the auxiliary power unit **810** with each being positioned proximate the aft end **18** of the aircraft **10**. The auxiliary power unit exhaust duct **822** extends radially outward to a tail of the aircraft **10**, e.g., the auxiliary power unit exhaust duct **822** extends radially outward to a vertical stabilizer **30** of the aircraft **10** as shown in FIG. **10**. In one embodiment, the auxiliary power unit exhaust duct **822** includes an exit portion **828** that is located at a trailing edge, e.g., at a trailing

edge of rudder flap **32**, of the tail of the aircraft **10** as shown in FIG. **10**.

[0108] Referring to FIG. **10**, in an exemplary embodiment of the present disclosure, the auxiliary power unit exhaust duct **822** of the APU **810** extending radially outward to a tail of the aircraft **10**, e.g., to vertical stabilizer **30**, enables the APU **810** to be positioned proximate the aft end **18** of the aircraft **10** while also adding the BLI fan **812** to a position proximate the aft end **18** of the aircraft **10**. In this manner, the auxiliary power unit exhaust duct **822** extends around the BLI fan **812** and thereby an auxiliary power unit exhaust flow through the auxiliary power unit exhaust duct **822** is prevented from interfering with the operation of the boundary layer ingestion fan **812**.

[0109] An aircraft of the present disclosure allows for the integration of an auxiliary power unit (APU) and a boundary layer ingestion (BLI) fan at the aft end of an aircraft. The embodiments of the present disclosure by allowing for the integration of the APU and the BLI fan at the aft end of an aircraft reduces the exhaust noise of the aircraft. Furthermore, embodiments of the present disclosure include a bypass portion of the auxiliary power unit exhaust duct that extends to the nacelle through the structural member, wherein an auxiliary power unit exhaust flow through the bypass portion to the nacelle is configured to de-ice the nacelle.

[0110] The embodiments of the present disclosure can also include temperature sensors at various locations of an integrated APU and BLI fan system. For example, in an exemplary embodiment, temperature sensors can be included at areas of the system to measure an air temperature just prior to fan blades of the BLI fan thereby allowing an increase or decrease of power to the fan based on such temperature readings. This configuration can prevent stalling of the BLI fan system.

[0111] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0112] While this disclosure has been described as having exemplary designs, the present disclosure can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the disclosure using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains and which fall within the limits of the appended claims.

Claims

1. An aircraft extending between a forward end and an aft end, the aircraft comprising: an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct; and a boundary layer ingestion fan positioned proximate the aft end of the aircraft, the boundary layer ingestion fan having a support shaft, wherein the auxiliary power unit exhaust duct extends through a portion of the support shaft of the boundary layer ingestion fan.

2. The aircraft of claim 1, further comprising a mixer in communication with the auxiliary power unit and the boundary layer ingestion fan such that the mixer receives and mixes a boundary layer airflow from the boundary layer ingestion fan and an auxiliary power unit exhaust flow from the auxiliary power unit exhaust duct.

3. The aircraft of claim 1, further comprising: a thermal insulation portion between the auxiliary power unit exhaust duct and the support shaft of the boundary layer ingestion fan.

4. The aircraft of claim 1, wherein the boundary layer ingestion fan defines a central axis and further comprises: a fan rotatable about the central axis and including a plurality of fan blades attached to a fan shaft; a nacelle encircling the plurality of fan blades; and a structural member extending from the support shaft of the boundary layer ingestion fan to the nacelle.

5. The aircraft of claim 4, wherein the auxiliary power unit exhaust duct includes a bypass portion that extends to the nacelle through the structural member, wherein an auxiliary power unit exhaust flow through the bypass portion to the nacelle is configured to de-ice the nacelle.

6. The aircraft of claim 4, further comprising: a motor having a drive shaft offset from the fan shaft; and a gear in communication with the drive shaft and the fan shaft to drive the boundary layer ingestion fan.

7. The aircraft of claim 1, wherein the auxiliary power unit exhaust duct extends through a center of the support shaft of the boundary layer ingestion fan along an axial direction of the boundary layer ingestion fan.

8. The aircraft of claim 1, wherein the boundary layer ingestion fan is incorporated into a tail section of the aircraft at the aft end of the aircraft.

9. The aircraft of claim 1, wherein a portion of the boundary layer ingestion fan makes up the aft end of the aircraft.

10. An aircraft extending between a forward end and an aft end, the aircraft comprising: an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct; and an aft engine configured to be mounted to the aircraft at the aft end, the aft engine defining a central axis and comprising: a fan rotatable about the central axis of the aft engine and including a plurality of fan blades attached to a fan shaft; a nacelle encircling the plurality of fan blades; and a structural member extending from a portion of the aft engine to the nacelle; wherein the auxiliary power unit exhaust duct extends through the structural member to the nacelle.

11. The aircraft of claim 10, wherein the aft engine further comprises: a power source having a drive shaft; and a support shaft extending through the fan shaft, wherein the structural member extends from the support shaft to the nacelle, and wherein the auxiliary power unit exhaust duct extends around the drive shaft and the support shaft through the structural member to the nacelle.

12. The aircraft of claim 10, wherein the auxiliary power unit exhaust duct includes an exit portion that is located at a trailing edge of the nacelle.

13. The aircraft of claim 10, wherein the structural member is an inlet guide vane.

14. The aircraft of claim 13, further comprising: a thermal insulation portion between the auxiliary power unit exhaust duct and the inlet guide vane.

15. The aircraft of claim 10, wherein the aft engine is configured as a boundary layer ingestion fan.

16. The aircraft of claim 10, wherein an auxiliary power unit exhaust flow through the auxiliary power unit exhaust duct within the nacelle is configured to de-ice the nacelle.

17. The aircraft of claim 11, wherein the auxiliary power unit exhaust duct comprises: a first auxiliary power unit exhaust duct portion that extends around the drive shaft in a first direction through a first portion of the structural member to a first portion of the nacelle; and a second auxiliary power unit exhaust duct portion that extends around the drive shaft in a second direction through a second portion of the structural member to a second portion of the nacelle, wherein the first auxiliary power unit exhaust duct portion and the second auxiliary power unit exhaust duct portion are bifurcated.

18. An aircraft extending between a forward end and an aft end, the aircraft comprising: an auxiliary power unit positioned proximate the aft end of the aircraft, the auxiliary power unit having an auxiliary power unit inlet duct and an auxiliary power unit exhaust duct; and a boundary layer ingestion fan positioned proximate the aft end of the aircraft between the aft end of the aircraft and the auxiliary power unit, the boundary layer ingestion fan spaced away from the auxiliary power unit, wherein the auxiliary power unit exhaust duct extends radially outward to a tail of the aircraft.

19. The aircraft of claim 18, wherein the auxiliary power unit exhaust duct includes an exit portion that is located at a trailing edge of the tail of the aircraft.

20. The aircraft of claim 18, wherein the auxiliary power unit exhaust duct extends radially outward to a vertical stabilizer of the aircraft.