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Recirculation air motor driven ACM

Abstract

A conditioning system for recirculation air of an aircraft cabin includes an air cycle system in fluid communication with the aircraft cabin and configured to receive a recirculation airflow from the aircraft cabin and a mixing chamber disposed in fluid communication between the air cycle system and the aircraft cabin. The mixing chamber is configured to mix the recirculation airflow received from the air cycle system with a conditioned airflow received from an environmental control system pack of the aircraft.

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Background/Summary

BACKGROUND
(1) The present disclosure relates generally to an aircraft environmental control system (ECS) and more particularly to recirculation air in an ECS.
(2) Commercial aircraft include recirculation fans to circulate cabin air. The recirculation fans simply move the cabin air while also adding some heat. Cooling of the aircraft cabin, including cooling of the recirculation air, is provided by the ECS. Conventional aircraft include a bleed system in which compressed air is extracted from the engine core through a high pressure or low pressure bleed port and delivered to ECS air conditioning packs to provide conditioned air for the aircraft cabin. Use of bleed air for cabin cooling in modern gas turbine engines can have a dramatic impact on fuel consumption. ECS packs can be required to cool air far below aircraft cabin temperature requirements (e.g., −40 degrees Fahrenheit) to minimize the amount the air needed to

be delivered to the aircraft cabin and thereby minimize the amount of bleed air extracted. Conditioned air from ECS packs is mixed with a predetermined and much larger amount of cabin recirculated air to warm the conditioned air to a comfortable temperature for the aircraft cabin. There is a need to further reduce the amount of bleed air extracted for cabin cooling to further reduce fuel consumption.

SUMMARY

(3) In one aspect, a conditioning system for recirculation air of an aircraft cabin includes an air cycle system in fluid communication with the aircraft cabin and configured to receive a recirculation airflow from the aircraft cabin and a mixing chamber disposed in fluid communication between the air cycle system and the aircraft cabin. The mixing chamber is configured to mix the recirculation airflow received from the air cycle system with a conditioned airflow received from an environmental control system pack of the aircraft.

(4) In another aspect, a conditioning system for recirculation air of an aircraft cabin includes a compressor, a turbine, and a heat exchanger. The compressor has a compressor inlet and a compressor outlet. The compressor inlet is in fluid communication with the aircraft cabin. The compressor is disposed to receive a recirculation airflow from the aircraft cabin. The turbine has a turbine inlet and a turbine outlet. The turbine outlet is in fluid communication with the aircraft cabin. The aircraft cabin is disposed to receive the recirculation airflow from the turbine. The heat exchanger is in fluid communication with each of the compressor and the aircraft cabin and configured to transfer thermal energy between a cabin discharge airflow received from the aircraft cabin and the recirculation airflow received from the compressor.

(5) In yet another aspect, a method of supplying conditioned air to an aircraft cabin includes conducting, in a cooling operation, a recirculation airflow received from the aircraft cabin through an air cycle system including a compressor, a heat exchanger, and a turbine; and conducting, in the cooling operation, the recirculation airflow received from an outlet of the air cycle system to a mixing chamber. The mixing chamber is configured to mix the recirculation airflow with a conditioned airflow received from an environmental control system pack of the aircraft to produce a cabin airflow for delivery to the aircraft cabin.

(6) The present summary is provided only by way of example, and not limitation. Other aspects of the present disclosure will be appreciated in view of the entirety of the present disclosure, including the entire text, claims and accompanying figures.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a schematic diagram of a conditioning system including a motor-driven air cycle system for recirculation air of an aircraft cabin.

(2) FIG. **2** is a flow chart of a method for providing for supplying conditioned air to an aircraft cabin.

(3) While the above-identified figures set forth embodiments of the present invention, other embodiments are also contemplated, as noted in the discussion. In all cases, this disclosure presents the invention by way of representation and not limitation. It should be understood that numerous other modifications and embodiments can be devised by those skilled in the art, which fall within the scope and spirit of the principles of the invention. The figures may not be drawn to scale, and applications and embodiments of the present invention may include features, steps and/or components not specifically shown in the drawings.

DETAILED DESCRIPTION

(4) The present disclosure is directed to a conditioning system for recirculation air of an aircraft cabin that can be used to provide supplemental cooling of the aircraft cabin. FIG. **1** is a schematic

diagram of a conditioning system including a motor-driven air cycle machine (ACM) for recirculation air of an aircraft cabin. The motor-driven air cycle machine can be used in place of a conventional recirculation fan to provide the aircraft cabin recirculation flow plus supplemental cooling capacity. The supplemental cooling provided by the conditioned recirculation air can reduce the ECS cooling capacity. This can allow lower ECS flow rates or higher ECS outlet temperatures, which may improve engine efficiency. The disclosed system can improve cooling performance or may allow for a smaller ECS system, while also eliminating the need for a recirculation fan.

(5) FIG. **1** shows conditioning system **10** configured to provide aircraft cabin **12** recirculation flow plus supplemental cooling. Cabin outlet **14**, cabin inlet **16**, air cycle system **18**, air cycle machine **19**, compressor **20**, compressor inlet **22**, compressor outlet **24**, motor **26**, shaft **28**, turbine **30**, turbine inlet **32**, turbine outlet **34**, heat exchanger **36**, first and second heat exchanger inlets **38** and **40**, first and second heat exchanger outlets **42** and **44**, controller **46**, bypass line **48**, bypass inlet **50**, bypass outlet **52**, valve **54**, mixing chamber **56**, first and second mixing chamber inlets **58** and **60**, mixing chamber outlet **62**, ECS outlet **64**, recirculation airflow F.sub.R, conditioned ECS airflow F.sub.ECS, cabin airflow Fc, and cabin discharge airflow F.sub.CD are shown. Aircraft cabin **12** is in fluid communication with mixing chamber **56** and air cycle system **18**. Air cycle system **18** includes air cycle machine **19**, heat exchanger **36**, and, optionally, bypass line **48**. Air cycle machine **19** includes compressor **20**, turbine **30**, motor **26**. Air cycle system **18** is configured to receive recirculation airflow F.sub.R from aircraft cabin **12** and deliver a conditioned recirculation airflow F.sub.R to mixing chamber **56**. Mixing chamber **56** is configured to receive and mix the conditioned recirculation airflow F.sub.R from air cycle system **18** and conditioned ECS airflow F.sub.ECS from an ECS pack (not shown) to provide conditioned cabin airflow Fc. Heat exchanger is configured to receive cabin discharge airflow F.sub.CD from aircraft cabin **12** and recirculation airflow F.sub.R from compressor outlet **24**. Heat exchanger **36** is configured to transfer thermal energy from recirculation airflow F.sub.R to cabin discharge airflow F.sub.CD to cool recirculation airflow F.sub.R. Bypass line **48** connects compressor outlet **24** to mixing chamber **56**, thereby bypassing heat exchanger **36** and turbine **30**. Bypass line **48** is configured for use in heating recirculation airflow F.sub.R.

(6) Air cycle machine **19** is a motor-driven air cycle machine including compressor **20**, turbine **30**, and motor **26**. Compressor **20** and turbine **30** are disposed on shaft **28**. Compressor **20** can be a variable speed compressor. Motor **26** is configured to drive compressor **20**. Turbine **30** can provide additional driving force for compressor **20**. Motor **26** can be an electric motor. Motor **26** is in electronic communication with controller **46**. Controller **46** is configured to regulate a rotational speed of compressor **20**. The speed of compressor can be adjusted to meet varying cooling demands of aircraft cabin **12** based on, for example, an air temperature in aircraft cabin **12**, a temperature of the ECS conditioned airflow FECS, a temperature of conditioned cabin airflow FC, a temperature of recirculation airflow FC at turbine outlet **34**, or any combination thereof. Controller **46** can be in electronic communication with one or more temperature sensors (not shown).

(7) Compressor **20** can be a variable speed centrifugal compressor configured draw recirculation airflow FR from aircraft cabin **12** and to compress recirculation airflow FR. Other types of compressors, including axial compressors and single-stage compressors are contemplated. Compressor **20** is configured for fluid communication with aircraft cabin **12** and at least one of heat exchanger **36** and mixing chamber **56** (via bypass line **48**) depending on a mode of operation as discussed further herein. Compressor **20** includes compressor inlet **22** and compressor outlet **24**. Compressor inlet **22** is arranged to receive recirculation airflow FR from aircraft cabin **12**. Compressor outlet is configured to deliver the compressed recirculation airflow FR to heat exchanger **36** or to mixing chamber **56** via bypass line **48**. In a cooling operation, bypass line **48** is closed via valve **54**, such that all compressed recirculation airflow FR from compressor **20** is

delivered to heat exchanger **36**. If heating of aircraft cabin **12** is required, valve **54** can be opened to allow flow of the compressed recirculation airflow through bypass line **48** to mixing chamber **56**, thereby bypassing heat exchanger **36** and turbine **30**.

(8) Heat exchanger **36** is in fluid communication with compressor outlet **24** and aircraft cabin **12**. Heat exchanger **36** is an air-to-air heat exchanger. Heat exchanger **36** is arranged to receive cabin discharge airflow FCD from aircraft cabin **12** and to receive compressed recirculation airflow FR from compressor **20**. A flow of cabin discharge airflow FCD can be constant. Cabin discharge airflow FCD is an airflow that is removed from aircraft cabin **12** and exhausted from the aircraft. Heat exchanger **36** is configured to place the compressed recirculation airflow FR in thermal communication with cabin discharge airflow FCD to cool the compressed recirculation airflow FR.

(9) Heat exchanger **36** includes a first fluid flow path for conveying the compressed recirculation airflow FR and a second fluid flow path for conveying the cabin discharge airflow FCD. The first and second fluid flow paths are fluidly isolated and arranged in thermal communication. The first fluid flow path includes fluidly connected first heat exchanger inlet **38** and first heat exchanger outlet **42**. The second flow path includes fluidly connected second heat exchanger inlet **40** and second heat exchanger outlet **44**. First heat exchanger inlet **38** is fluidly coupled to aircraft cabin **12** and configured to receive cabin discharge airflow FCD from aircraft cabin **12**. Second heat exchanger inlet **40** is fluidly coupled to compressor **20** and configured to receive the compressed recirculation airflow FR from compressor **20**. Heat is transferred from compressed recirculation airflow FR to cabin discharge airflow FCD in heat exchanger **36**, thereby lowering a temperature of the compressed recirculation airflow FR. The cooled compressed recirculation airflow FR is delivered from second heat exchanger outlet **44** to turbine **30**. The heated cabin discharge airflow FCD exits heat exchanger **36** at heat exchanger outlet **42** and can be exhausted overboard, for example, through and cabin outflow valve or thrust recovery outflow valve.

(10) As illustrated, heat exchanger **36** and compressor **20** are fluidly coupled to aircraft cabin **12** via cabin outlet **14**, which can be a cabin outflow passage configured to deliver a cabin airflow which is divided between cabin discharge airflow FCD and recirculation airflow FR. It will be understood by one of ordinary skill in the art that separation of cabin discharge airflow FCD and recirculation airflow FR can occur at aircraft cabin **12** or between cabin outlet **14** and compressor **20** and heat exchanger **36**.

(11) Cabin discharge airflow FCD is a preferred example of a heat sink for recirculation airflow FR, however, other heat sinks are contemplated. For example, in alternative embodiments, heat exchanger **36** can be configured to receive a ram airflow in place of cabin discharge airflow FCD for cooling the compressed recirculation airflow FR. Use of ram air can increase drag and, therefore, may be less preferrable. Use of cabin discharge airflow FCD as a heat sink can reduce the overall ram air usage in flight thereby reducing drag. Additionally, the heat added to cabin discharge airflow FCD in heat exchanger **36** may also provide for higher thrust recovery through an outflow nozzle as cabin airflow FCD is exhausted.

(12) The cooled compressed recirculation airflow FR is expanded through turbine **30**. Expansion of recirculation airflow FR through turbine **30** can drive compressor **20**. Air cycle system **18** can be configured to provide recirculation airflow FR at turbine outlet **34** at a pressure substantially approximating or equal to a pressure of recirculation airflow FR at compressor inlet **22**. Recirculation airflow FR cools as it expands. Because some thermal energy has been removed by heat exchanger **36**, expansion of recirculation airflow FR cools recirculation airflow FR to a temperature below a temperature of recirculation airflow FR at compressor inlet **22**.

(13) The cooled recirculation airflow FR is delivered to mixing chamber **56** where it is mixed with ECS conditioned airflow FECS to provide supplemental cooling for conditioned cabin airflow FC. Mixing chamber **56** is fluidly coupled to turbine outlet **34**, ECS outlet **64**, and aircraft cabin **12**. ECS outlet **64** can be fluidly coupled to one or more ECS packs (not shown). Mixing chamber **56** includes first and second mixing chamber inlets **58** and **60** and mixing chamber outlet **62.** First

mixing chamber inlet **58** is configured for fluid communication with each of turbine outlet **34** and bypass outlet **52** and configured to receive recirculation airflow FR. Second mixing chamber inlet **60** is fluidly coupled to ECS outlet **64** and configured to receive conditioned ECS airflow FECS. Mixing chamber outlet **62** is fluidly coupled to cabin inlet **16** and configured to deliver conditioned cabin airflow FC to aircraft cabin **12**.

(14) The supplemental cooling provided by air cycle system **18** can reduce the required ECS cooling capacity. For example, the same cooling requirements can be achieved with lower conditioned ECS airflow FESC flow rates or with higher temperature conditioned ECS airflow FECS.

(15) Controller **46** can be used to regulate a speed of compressor **20** to provide a desired supplemental cooling capacity. As previously discussed, controller **46** can be in electronic communication with one or more temperature sensors (not shown) configured to sense an air temperature of any of a plurality of locations or airflows of conditioning assembly **10** or aircraft cabin **12**, including but not limited to a temperature of the ECS conditioned airflow FECS, a temperature of conditioned cabin airflow FC, and a temperature of recirculation airflow FC at turbine outlet **34**. Controller **46** can be configured to regulate the speed of compressor **20** based on one or more sensed temperatures.

(16) Bypass line **48** is a fluid conduit configured to deliver a heating fluid to conditioned ECS airflow FECS to accommodate heating demands of aircraft cabin **12**. Bypass line **48** is fluidly coupled to compressor outlet **24** and mixing chamber **56**. Valve **54** can be configured to selectively open or close bypass line **48** to recirculation airflow FR. Valve **54** can be regulated by controller **46**. During a cabin heating operation, valve **54** can be opened to allow the compressed recirculation airflow FR from compressor **20** to bypass heat exchanger **36**. Recirculation airflow FR absorbs heat as it is compressed by compressor **20**. Bypass line **48** is configured to deliver the heated compressed recirculation airflow FR to mixing chamber **56** to provide supplemental heating to conditioned ECS airflow FECS to accommodate heating demands of aircraft cabin **12**.

(17) FIG. **2** is a flow chart of method **68** for supplying conditioned air to an aircraft cabin. FIG. **2** shows cooling operation **70** and heating operation **72**. During cooling operation **70**, conditioning system **10** provides supplemental cooling.

(18) In step **74**, recirculation airflow FR received from aircraft cabin **12** is conducted though air cycle system **18**. Motor **26** can be used to drive air cycle machine **19**, which draws recirculation airflow FR from aircraft cabin **12**. Recirculation airflow FR is compressed by compressor **20**, cooled by heat exchanger **36**, and expanded through turbine **30** to produce cooled recirculation airflow FR. Recirculation airflow FR at turbine outlet **34** has a lower temperature than the recirculation airflow FR received from aircraft cabin **12**. In step **76**, the cooled recirculation airflow FR received from an outlet (turbine outlet **34**) of air cycle system **18** is conducted to mixing chamber **56**. In step **78**, mixing chamber **56** mixes the cooled recirculation airflow FR received from air cycle system **18** with conditioned ECS airflow FECS received from an ECS pack via ECS outlet **64** to produce conditioned cabin airflow FC for delivery to aircraft cabin **12**. Step **80** includes controlling a rotational speed of compressor **20** based on at least one of an air temperature of aircraft cabin **12**, an air temperature of conditioned cabin airflow FC, an air temperature of recirculation airflow FR at turbine outlet **34**, an air temperature of conditioned ECS airflow FECS, or a combination thereof. Step **80** can occur at any time to regulate a cooling capacity of recirculation airflow FC.

(19) During heating operation **72**, conditioning system **10** provides supplemental heating. Step **82** includes controlling valve **54** configured to regulate flow of recirculation airflow FR through bypass line **48**. Controller **46** can open or close valve **54** to allow recirculation airflow FR to bypass heat exchanger **36** and turbine **30** based on at least one of an air temperature of aircraft cabin **12**, an air temperature of conditioned cabin airflow FC, an air temperature of recirculation airflow FR at turbine outlet **34**, an air temperature of conditioned ECS airflow FECS, or a combination thereof.

Step **72** can occur at any time to provide supplemental heating conditioned cabin airflow FC. In step **84**, recirculation airflow FR received from aircraft cabin **12** is conducted to compressor **20** of air cycle system **18** where recirculation airflow FR is compressed and thereby heated. In step **86**, the heated compressed recirculation airflow FR received from compressor outlet **24** is conducted to mixing chamber **56** via bypass line **48**, thereby bypassing heat exchanger **36** and turbine **30**. In step **88**, mixing chamber **56** mixes and expands the heated recirculation airflow FR received bypass line **48** with conditioned ECS airflow FECS received from an ECS pack via ECS outlet **64** to produce conditioned cabin airflow FC for delivery to aircraft cabin **12**.

(20) The disclosed motor-driven air cycle machine can be used in place of a conventional recirculation fan to provide the aircraft cabin recirculation flow plus supplemental cooling capacity. The supplemental cooling provided by the conditioned recirculation air can reduce the ECS cooling capacity. This can allow lower ECS flow rates or higher ECS outlet temperatures, which may improve engine efficiency. The disclosed system can improve cooling performance or may allow for a smaller ECS system, while also eliminating the need for a recirculation fan. A conventional ECS (not shown) uses ram air as a heat sink, which increases drag. Use of cabin discharge airflow as a heat sink can reduce the overall ram air usage in flight thereby reducing drag. Additionally, the heat added to the cabin discharge airflow in the heat exchanger of the air cycle system may also provide for higher thrust recovery through a cabin outflow valve or thrust recovery outflow valve as the cabin discharge airflow is exhausted.

(21) Any relative terms or terms of degree used herein, such as “substantially”, “essentially”, “generally”, “approximately” and the like, should be interpreted in accordance with and subject to any applicable definitions or limits expressly stated herein. In all instances, any relative terms or terms of degree used herein should be interpreted to broadly encompass any relevant disclosed embodiments as well as such ranges or variations as would be understood by a person of ordinary skill in the art in view of the entirety of the present disclosure, such as to encompass ordinary manufacturing tolerance variations, incidental alignment variations, transient alignment or shape variations induced by thermal, rotational or vibrational operational conditions, and the like. Moreover, any relative terms or terms of degree used herein should be interpreted to encompass a range that expressly includes the designated quality, characteristic, parameter or value, without variation, as if no qualifying relative term or term of degree were utilized in the given disclosure or recitation.

Discussion of Possible Embodiments

(22) The following are non-exclusive descriptions of possible embodiments of the present invention.

(23) A conditioning system for recirculation air of an aircraft cabin includes an air cycle system in fluid communication with the aircraft cabin and configured to receive a recirculation airflow from the aircraft cabin and a mixing chamber disposed in fluid communication between the air cycle system and the aircraft cabin. The mixing chamber is configured to mix the recirculation airflow received from the air cycle system with a conditioned airflow received from an environmental control system pack of the aircraft.

(24) The conditioning system of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

(25) The conditioning system of the preceding paragraphs, wherein the air cycle system includes a compressor in fluid communication with the aircraft cabin, the compressor configured to receive the recirculation airflow from the aircraft cabin; a motor configured to drive the compressor; a heat exchanger in fluid communication with the compressor, the heat exchanger configured to receive the recirculation airflow from the compressor; and a turbine in fluid communication with the heat exchanger, the turbine configured to receive the recirculation airflow from the heat exchanger.

(26) The conditioning system of any of the preceding paragraphs, wherein the heat exchanger is in

fluid communication with the aircraft cabin, the heat exchanger configured to receive a discharge airflow from the aircraft cabin and configured to transfer thermal energy between the recirculation airflow and the discharge airflow.
(27) The conditioning system of any of the preceding paragraphs can further include a recirculation airflow bypass line arranged in fluid communication between the compressor and the mixing chamber, the recirculation airflow bypass line configured to receive the recirculation airflow from the compressor, the mixer configured to mix the recirculation flow received from the recirculation bypass line with the conditioned airflow received from the environmental control system pack.
(28) The conditioning system of any of the preceding paragraphs can further include a valve configured to regulate the flow of the recirculation airflow through the bypass line.
(29) The conditioning system of any of the preceding paragraphs can further include a controller in electronic communication with the motor, the controller configured to regulate a rotational speed of the compressor.
(30) The conditioning system of any of the preceding paragraphs, wherein the conditioned airflow received from the environmental control system pack of the aircraft is a conditioned bleed air from a compressor section of a core engine of the aircraft.
(31) A conditioning system for recirculation air of an aircraft cabin includes a compressor, a turbine, and a heat exchanger. The compressor has a compressor inlet and a compressor outlet. The compressor inlet is in fluid communication with the aircraft cabin. The compressor is disposed to receive a recirculation airflow from the aircraft cabin. The turbine has a turbine inlet and a turbine outlet. The turbine outlet is in fluid communication with the aircraft cabin. The aircraft cabin is disposed to receive the recirculation airflow from the turbine. The heat exchanger is in fluid communication with each of the compressor and the aircraft cabin and configured to transfer thermal energy between a cabin discharge airflow received from the aircraft cabin and the recirculation airflow received from the compressor.
(32) The conditioning system of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:
(33) The conditioning system of the preceding paragraphs can further include a motor electrically coupled to the compressor and configured to drive the compressor.
(34) The conditioning system of any of the preceding paragraphs can further include a controller in electronic communication with the motor, the controller configured to modulate a rotational speed of the compressor.
(35) The conditioning system of any of the preceding paragraphs, wherein the heat exchanger further includes first and second fluid flow paths. The first fluid flow path includes a first inlet in fluid communication with the compressor outlet and a first outlet in fluid communication with the first inlet and the turbine. The second fluid flow path includes a second inlet in fluid communication with the aircraft cabin, the second inlet configured to receive the cabin discharge airflow and a second outlet in fluid communication with the second inlet an exhaust outlet. The first fluid flow path and the second fluid flow path are fluidly isolated and arranged in thermal communication.
(36) The conditioning system of any of the preceding paragraphs can further include a bypass line, the bypass line having a bypass inlet in fluid communication with the compressor outlet and a bypass outlet in fluid communication with the aircraft cabin, wherein the aircraft cabin is disposed to receive the recirculation airflow from the bypass outlet.
(37) The conditioning system of any of the preceding paragraphs can further include a valve configured to modulate flow of the recirculation airflow through each of the heat exchanger and the bypass line.
(38) The conditioning system of any of the preceding paragraphs can further include a mixing chamber having a first chamber inlet in fluid communication with each of the turbine outlet and the

bypass outlet, a second chamber inlet in fluid communication with an environmental control system pack of the aircraft, and a chamber outlet in fluid communication with the aircraft cabin. The mixing chamber is disposed to fluidly connect each of the turbine outlet and bypass outlet to the aircraft cabin.
(39) A method of supplying conditioned air to an aircraft cabin includes conducting, in a cooling operation, a recirculation airflow received from the aircraft cabin through an air cycle system including a compressor, a heat exchanger, and a turbine; and conducting, in the cooling operation, the recirculation airflow received from an outlet of the air cycle system to a mixing chamber. The mixing chamber is configured to mix the recirculation airflow with a conditioned airflow received from an environmental control system pack of the aircraft to produce a cabin airflow for delivery to the aircraft cabin.
(40) The method of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations additional components, and/or steps:
(41) The method of the preceding paragraphs can further include conducting, in a heating operation, the recirculation airflow received from the aircraft cabin to the compressor of the air cycle system, and conducting, in the heating operation, the recirculation airflow received from an outlet of the compressor to the mixing chamber via a fluid conduit bypassing the heat exchanger and the turbine.
(42) The method of any of the preceding paragraphs, wherein the heat exchanger is configured to transfer thermal energy between the recirculation airflow received from an outlet of the compressor and a cabin discharge airflow received from the aircraft cabin.
(43) The method of any of the preceding paragraphs can further include driving a compressor of the air cycle system with an electric motor.
(44) The method of any of the preceding paragraphs can further include controlling a rotational speed of the compressor based on at least one of an air temperature of the aircraft cabin, an air temperature of the cabin airflow provided by the mixing chamber, an air temperature of the recirculation airflow received from the air cycle system outlet, and an air temperature of the conditioned airflow received from the environmental control system pack.
(45) While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A conditioning system for recirculation air of an aircraft cabin, the conditioning system comprising: an air cycle system in fluid communication with the aircraft cabin and configured to receive a recirculation airflow from the aircraft cabin, the air cycle system comprising: a compressor in fluid communication with the aircraft cabin, the compressor configured to receive the recirculation airflow from the aircraft cabin; a motor configured to drive the compressor; a heat exchanger in fluid communication with the compressor, the heat exchanger configured to receive the recirculation airflow from the compressor; and a turbine in fluid communication with the heat exchanger, the turbine configured to receive the recirculation airflow from the heat exchanger; and a mixing chamber disposed in fluid communication between the air cycle system and the aircraft cabin, the mixing chamber configured to mix the recirculation airflow received from the air cycle system with a conditioned airflow received from an environmental control system pack of the

aircraft, wherein the conditioned airflow from the environmental control system pack is isolated from the recirculation airflow from the air cycle system upstream of the mixing chamber.
2. The conditioning system of claim 1, wherein the heat exchanger is in fluid communication with the aircraft cabin, the heat exchanger configured to receive a discharge airflow from the aircraft cabin and configured to transfer thermal energy between the recirculation airflow and the discharge airflow.
3. The conditioning system of claim 1, and further comprising a recirculation airflow bypass line arranged in fluid communication between the compressor and the mixing chamber, the recirculation airflow bypass line configured to receive the recirculation airflow from the compressor, the mixer configured to mix the recirculation flow received from the recirculation bypass line with the conditioned airflow received from the environmental control system pack.
4. The conditioning system of claim 3, and further comprising a valve configured to regulate the flow of the recirculation airflow through the bypass line.
5. The conditioning system of claim 1, and further comprising a controller in electronic communication with the motor, the controller configured to regulate a rotational speed of the compressor.
6. The conditioning system of claim 1, wherein the conditioned airflow received from the environmental control system pack of the aircraft is a conditioned bleed air from a compressor section of a core engine of the aircraft.
7. A conditioning system for recirculation air of an aircraft cabin, the conditioning system comprising: a compressor having a compressor inlet and a compressor outlet, the compressor inlet in fluid communication with the aircraft cabin, wherein the compressor is disposed to receive only a recirculation airflow from the aircraft cabin; a turbine having a turbine inlet and a turbine outlet, the turbine outlet in fluid communication with the aircraft cabin, wherein the aircraft cabin is disposed to receive the recirculation airflow from the turbine; and a heat exchanger in fluid communication with each of the compressor and the aircraft cabin and configured to transfer thermal energy between a cabin discharge airflow received from the aircraft cabin and the recirculation airflow received from the compressor.
8. The conditioning system of claim 7, and further comprising a motor electrically coupled to the compressor and configured to drive the compressor.
9. The conditioning system of claim 8, and further comprising a controller in electronic communication with the motor, the controller configured to modulate a rotational speed of the compressor.
10. The conditioning system of claim 7, wherein the heat exchanger further comprises: a first fluid flow path comprising: a first inlet in fluid communication with the compressor outlet; and a first outlet in fluid communication with the first inlet and the turbine; and a second fluid flow path comprising: a second inlet in fluid communication with the aircraft cabin, the second inlet configured to receive the cabin discharge airflow; and a second outlet in fluid communication with the second inlet and an exhaust outlet; wherein the first fluid flow path and the second fluid flow path are fluidly isolated and arranged in thermal communication.
11. The conditioning system of claim 7, and further comprising a bypass line, the bypass line having a bypass inlet in fluid communication with the compressor outlet and a bypass outlet in fluid communication with the aircraft cabin, wherein the aircraft cabin is disposed to receive the recirculation airflow from the bypass outlet.
12. The conditioning system of claim 11, and further comprising a valve configured to modulate flow of the recirculation airflow through each of the heat exchanger and the bypass line.
13. The conditioning system of claim 12, and further comprising a mixing chamber having: a first chamber inlet in fluid communication with each of the turbine outlet and the bypass outlet; a second chamber inlet in fluid communication with an environmental control system pack of the aircraft; and a chamber outlet in fluid communication with the aircraft cabin; wherein the mixing

chamber is disposed to fluidly connect each of the turbine outlet and bypass outlet to the aircraft cabin.
14. A method of supplying conditioned air to an aircraft cabin, the method comprising: conducting, in a cooling operation, a recirculation airflow received from the aircraft cabin through an air cycle system, the air cycle system comprising a compressor, a heat exchanger, and a turbine; and conducting, in the cooling operation, the recirculation airflow received from an outlet of the air cycle system to a mixing chamber; wherein the mixing chamber is configured to mix the recirculation airflow with a conditioned airflow received from an environmental control system pack of the aircraft to produce a cabin airflow for delivery to the aircraft cabin wherein the conditioned airflow from the environmental control system pack is isolated from the recirculation airflow from the air cycle system upstream of the mixing chamber.
15. The method of claim 14, and further comprising: conducting, in a heating operation, the recirculation airflow received from the aircraft cabin to the compressor of the air cycle system; conducting, in the heating operation, the recirculation airflow received from an outlet of the compressor to the mixing chamber via a fluid conduit bypassing the heat exchanger and the turbine.
16. The method of claim 14, wherein the heat exchanger is configured to transfer thermal energy between the recirculation airflow received from an outlet of the compressor and a cabin discharge airflow received from the aircraft cabin.
17. The method of claim 14, and further comprising driving a compressor of the air cycle system with an electric motor.
18. The conditioning system of claim 14, and further comprising controlling a rotational speed of the compressor based on at least one of an air temperature of the aircraft cabin, an air temperature of the cabin airflow provided by the mixing chamber, an air temperature of the recirculation airflow received from the air cycle system outlet, and an air temperature of the conditioned airflow received from the environmental control system pack.