PRESSURIZED CLOSED COOLING SYSTEM

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ABSTRACT

An aircraft air conditioning system includes an air supply system (engine bleed or cabin air compressor taking ambient air and pressurizing it at or above cabin pressure) and a cooling system (air cycle or vapor cycle cooling packs to reject heat outside the vessel). These systems can exist as independent systems or combined into a single unit. Air supply and cooling are powered from either engine bleed air or electric power. In order to increase the airflow through the cabin, some cabin air is re-circulated and mixed with fresh air from the air supply system.
PROVIDING A FRESH AIR FLOW THROUGH AN ECS PACK

PROVIDING A RECIRCULATION AIR FLOW FROM THE AIRCRAFT CABIN

COOLING THE RECIRCULATION AIR FLOW

MIXING THE RECIRCULATION AIR WITH THE FRESH AIR FLOW

DELIVERING THE MIXED AIR FLOW TO THE AIRCRAFT CABIN

FIG. 3
PRESSURIZED CLOSED COOLING SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to air cooling systems and, more specifically, to apparatus and methods for using and cooling cabin recirculation air to improve system performance and operability of air cooling systems.

[0002] Conventional transport aircraft typically utilize bleed air from the engine (or the auxiliary power unit: APU) to supply fresh, cool or hot air to the cabin in order to maintain the proper cabin pressure and temperature. The heating function comes naturally as the bleed air provided by the engines to pressurize the cabin is generally significantly above the required cabin temperature. Cooling requires special equipment that can reject the heat outside the vessel in order to reduce the air supply temperature low enough to regulate cabin temperature. The Environmental Control Systems (ECS) are typically using Air Cycle Systems (ACS) or Vapor Cycle Systems (VCS). These systems traditionally use fresh air provided by the engine or the APU and cool it to a low enough temperature to compensate the temperature increase due to the heat loads in the cabin (it might be necessary to more than compensate heat loads during initial temperature pull down of the cabin).

[0003] When recirculation air is used in these traditional systems, it is being mixed with the low temperature air supply (which can be sub-freezing) before being distributed to the cabin. The only purpose of the recirculation air is to increase the ventilation rate in the cabin but there is no contribution to the cooling effect.

[0004] Referring to FIG. 1 there is shown a schematic diagram of a conventional system 16 using an air cycle machine 14 to reject heat (but work similarly with a vapor cycle system). Fresh air 12 is injected into the system 16 at an injection location designated by 1 and is compressed by a compressor 22 (which can be rotated by the turbine 24 or the optional motor 26) of the air cycle machine 14 before it can be cooled down by ambient air in a heat exchanger 20 and further cooled by expansion in a turbine 24 of the air cycle machine 14. The fresh air 12 may be cooled in a pre-cooler or a heat exchanger (not shown) before being compressed by the compressor 22. A water separator device 28 is added to keep humidity at an acceptable level. The cooler and drier fresh air is now mixed at station I with the air from the cabin 10 before being distributed back into the cabin 10.

[0005] U.S. Pat. No. 4,487,034, issued to Cronin et al., describes a machine that combines cabin air compressors and a vapor cycle compressor. Recirculation air may be cooled via vapor cycle cooling, generally relying on an all-electric air conditioning system for aircraft cabin pressurization and cooling.

[0006] U.S. Pat. No. 5,956,960, issued to Niggeman, describes an integrated system which uses two auxiliary power unit (APU)-like machines for pressurization and a vapor cycle system (VCS) pack for cooling. Recirculation air is used only to get some power on the turbine of the APUs and this air is then dumped overboard. Recirculation air is not used for cabin pressurization or cooling.

[0007] U.S. Pat. No. 6,681,592, issued to Lents et al., describes a motorized four-wheel machine that combines pressurization and cooling. Recirculation air is used in this machine in a traditional way, by mixing subfreezing ECS air with recirculation air before it goes to the cabin. In this patent, the recirculation air is not actively cooled by the ECS pack.

[0008] As can be seen, there is a need for an improved apparatus for pressurizing and cooling the cabin of an aircraft while reducing power consumption, volume, weight and cost of the system.

SUMMARY OF THE INVENTION

[0009] In one aspect of the present invention, a pressurized cooling system for a vehicle, comprises a recirculation air flow coming from the vehicle; a fresh air flow being delivered to a cooling subsystem; and at least one injection location for mixing at least a portion of the recirculation air flow with the fresh air flow, wherein the portion of the recirculation air flow is either cooled prior to mixing with the fresh air flow or the portion of the recirculation air flow is mixed with the fresh air flow prior to the fresh air flow being delivered to the cooling subsystem.

[0010] In another aspect of the present invention, a pressurized cooling system for an aircraft comprises a recirculation air flow coming from the aircraft; a fresh air flow being delivered to a cooling subsystem; a cabin air compressor for pressurizing the fresh air flow into a pressurized fresh air flow; a first injection location for providing a fluid connection between the recirculation flow and the fresh air flow prior to the fresh air flow reaching the cabin air compressor; and at least one additional injection location for mixing at least a portion of the recirculation air flow with the pressurized fresh air flow, wherein the portion of the recirculation air flow is either cooled prior to mixing with the fresh air flow or the portion of the recirculation air flow is mixed with the fresh air flow prior to the fresh air flow being delivered to the cooling subsystem.

[0011] In yet another aspect of the present invention, a method for providing cooling to an aircraft cabin comprises providing a fresh air flow through a cooling subsystem; providing a recirculation air flow from the aircraft cabin; cooling the recirculation air flow; mixing the recirculation air flow with the fresh air flow to provide a mixed recirculation air flow; and delivering the mixed recirculation air flow and fresh air flow to the aircraft cabin.

[0012] These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic drawing showing a conventional air cooling system;
[0014] FIG. 2A is a schematic drawing showing an air cooling system having multiple points of injection according to the present invention;
[0015] FIG. 2B is a schematic drawing an air cooling system having multiple points of injection according to another embodiment of the present invention; and
[0016] FIG. 3 shows steps for performing a method according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The following detailed description is of the best currently contemplated modes of carrying out the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention, since the scope of the invention is best defined by the appended claims.
Broadly, the present invention provides a pressurized closed cooling system wherein the recirculation air from the cabin of a flight vehicle structure, such as a fixed-wing aircraft or a helicopter, for example, may be cooled. Cooling the recirculation air may provide an additional cooling capacity beyond that of the traditional “fresh” air supply provided by the environmental control system (ECS) and generated by the engines (bleed air) or the ambient air, such as in bleed less engines using cabin air compressors. The cooling system of the present invention may be useful in any cabin pressurization and/or environmental control system, such as those found in commercial aircraft.

Conventional ECSs may combine pressurization and cooling in a single ECS pack or in multiple ECS packs. The present invention may dissociate the cooling function from the pressurization function. The cooling function may act as a closed cooling circuit with a rather stable flow/pressure/temperature environment using cabin recirculation air. For example, the pressurization function may be carried out by a cabin air compressor while the cooling function may use an air cycle machine. The pressurized cooling system of the present invention, as described below, may use any number of injection locations, the selection of which may help maintain flow to the cabin, cabin pressure and air temperature in the cabin as efficiently as possible. The pressurized cooling system may be designed to “push” air through the cabin with enough flow and minimum pressure to compensate for the cabin leaks and still maintain the cabin at its required pressure. As described in detail below, the pressurized cooling system may develop and/or maintain pressure via any one or more of the following: recirculation flow from the cabin, cabin air compressors, air cycle machine compressors and ram air. Therefore, unlike conventional systems, there is no need for complex variable geometries that are required to cover a wide range of pressure and flow capabilities, which is especially a problem when dealing with electrical pressurization systems. As discussed in greater detail below, the pressurized cooling system of the present invention can use a very simple air pressure generator (such as an electric compressor or a low pressure engine bleed port) and can perform cooling with better efficiency than conventional systems.

The present invention may dissociate the cooling process from the pressurization process in Environment Control Systems, unlike traditional air cycle ECS systems. In one embodiment of the present invention, a closed cooling loop (taking air from the cabin, cooling it and distributing it back to the cabin) may be used with the possibility to inject, somewhere in this loop, some pressurized air that would be needed to meet fresh air certification requirements and, at a minimum, maintain the cabin pressure by compensating for cabin leaks. Due to, for example, the fresh air certification requirements representing an important part of the work an ECS system, another embodiment of the present invention may use a stream of fresh air (pressurized and cooled before being distributed to the cabin) with the possibility to inject, somewhere in the pressurizing and cooling systems, some air from the cabin (recirculation).

In some embodiments of the present invention, the circulation flow can optionally be cooled before being injected into the fresh air stream and the injection location can be single or a combination of locations that can be dynamically adjusted in order to optimize the operation of the complete system. The injection locations can be different, in function of the cooling technology being used. To illustrate the invention as a non-limiting example, an air cycle solution which may have the advantage of providing more injection locations will be described in more detail.

According to one embodiment, a system of the present invention may be capable of taking fresh air below the cabin pressure and compressing it (as a first compressor). Subsequently, the compressed fresh air may pass through an air cycle machine, which, for the sake of the illustration, can be considered as a compressor (as a second compressor), a heat exchanger and an expansion turbine. The injection points according to embodiments of the present invention may include the following:

i. Injection before the first compressor (below or at cabin pressure) which may have the potential of raising the pressure and reducing the temperature in the inlet of the first compressor as well as increasing the corrected flow;

ii. Injection between the first and second compressors (below or above cabin pressure) with the same advantages as before and the added possibility to use the fresh air flow to increase the recirculation flow pressure and therefore create the recirculation flow, when the pressure between the two compressors is above cabin pressure;

iii. Injection between the second compressor and the heat exchanger (at or above cabin pressure) with the advantage to reduce air temperature before the heat exchanger without increasing the corrected flow in the first or the second compressors. This may be particularly relevant when air is close to cabin pressure and the expansion turbine is bypassed;

iv. Injection after the expansion turbine (at or above cabin pressure) with the advantage of reducing the corrected flow in the first and second compressor as well as heat exchanger and turbine. When the air pressure out of the expansion turbine is above the cabin pressure, this injection location can be used to increase the recirculation flow pressure and create the recirculation flow. When recirculation is not cooled prior to being injected into the fresh air flow, this configuration may correspond to the prior art configuration.

It should be noted that options i), ii) and iii) may have the advantage of cooling both the fresh air and the recirculation air with the same set of devices. Using multiple injection locations can be very useful to optimize system performance (least input power) while maintaining optimum operating condition on the various components (corrected flow).

Referring to FIG. 2A, there is shown a schematic drawing of a pressurized cooling system 40 when a supply air pressure is below, at or above a cabin pressure according to the present invention. The present invention pertains to the use of a recirculation air flow 48 from the cabin 42 and injected at different locations (labeled I, II, III, IV and V) in the pressurized cooling system 40. The following description describes air cooling system 40 using an air cycle machine 44. The air cooling system 40 of the present invention, however, may also use vapor cycle machines in place of, or in addition to, the air cycle machine 44. While multiple injection locations are shown and described with respect to one exemplary embodiment, other embodiments of the present invention may only need a limited number (could be only one) of recirculation air injection locations in the air pressurized cooling system 40.
[0029] A plurality of possible air injection locations I, II, III, IV and V is shown, each one or more of which may be used in the air cooling system 40. Each of the injection locations I, II, III, IV and V (wherein I is the prior art injection location, as described above) will be discussed in further detail below. The various operating modes may allow different flow path combinations depending on the most desirable configuration as a function of operating conditions (i.e., ground operation, in flight operation, and the like) of the system.

[0030] Still referring to FIG. 2A, in general, the pressurized cooling system 40 may include an air supply system 110 to supply fresh air 100 (from engine bleed or a cabin air compressor pressurizing ambient air) and a cooling subsystem 46, such as an ECS pack (which may include an air cycle machine 44 or vapor cycle cooling packs) to reject heat from the fresh air 100 to outside the aircraft.

[0031] Some air in the cabin 42 may be re-circulated as recirculation air 48 and mixed with fresh air 100 from the air supply system 110. The recirculation air 48 may be mixed with fresh air 100 at one or more injection locations I, II, III, IV and V, as described in more detail below, to provide a mixed air. The term “mixed air” as used herein, describes the resultant air when recirculation air 48 is mixed with fresh air 100. The mixing can be achieved by using simple mixers or more elaborate injectors that can add to the mixing function a pressure raise to the lower pressure flow. The mixed air may be part of an incoming airflow 51, the conditioned air 49, or a compressed incoming airflow 53, each of which is described in more detail below.

[0032] The mixed air may be fed to the ECS pack 46; alternatively, the fresh air 100 may be fed directly to the ECS pack 46, which may include a compressor 52 for compressing the incoming airflow 51, the fresh air 100 and a turbine 56 for providing expansion cooling of a compressed incoming airflow 53 from the compressor 52. The compressor 52 may be powered by an electric motor 60. A heat exchanger 54 may also be part of the ECS pack 46. Heat exchanger 54 may be used, among other purposes, to reject heat from the compressed incoming air flow 53 before delivering the cooled compressed incoming air flow 55 to the turbine 56. A conditioned air 49 from the ECS pack 46 may pass through a water extractor 58 and be delivered to the cabin 42.

Injection Location II

[0033] Air cooling systems 40 that include the injection location II may allow for the optimization of the size of the ECS pack 46 as well as for the reduction in pressure (engine bleed) and electrical input power to perform pressurization and cooling of the cabin 42. It might even be possible to partially or completely shut down the active cooling from the ECS pack 46 by bypassing the air cycle machine 44 which can improve further ECS permeability and reduce input power (high cruise altitude case).

[0034] When the present invention utilizes recirculation air injection location II, the conditioned air 49 coming out of an ECS pack 46 does not have to be as cold as systems that do not use injection location II. Injection location II may cool the recirculation air 48 before mixing it with a fresh air flow 100 that has passed through the ECS pack 46 and before distributing it to the cabin 42. Cooling of the conditioned air 49 at injection location II may be accomplished through the recirculation flow heat exchanger 50. The heat exchanger 50 may reject the heat either a) directly to ambient air (in which case the heat exchanger 50 would be an air/air heat exchanger); b) to a cooled liquid (in which case the heat exchanger 50 would be an air/liquid heat exchanger), wherein the cooled liquid may be obtained from a second air/liquid heat exchanger (not shown); or c) to a conventional vapor cycle system as would be known to one skilled in the art.

Injection Location III

[0035] Injection location III may be useful for both ground and flight however, it could be particularly interesting for ground operation (hot day, when lot of cooling is required) when the fresh air 100 coming from ambient, APU or engine bleed has a temperature and a water content which are higher than the recirculation air flow 48 coming from the cabin 42. In these situations, embodiments of the present invention utilizing air injection location III may result in reduced power requirements for the air cooling system 40 as compared to conventional systems.

[0036] When the present invention utilizes recirculation air injection location III, fresh air flow 100 may be mixed with recirculation air flow 48 before passing through the ECS pack 46. Recirculation air flow 48 may pass from the cabin 42 to the air cycle machine 44, where the incoming air flow 51 may be pressurized by the compressor 52 of the air cycle machine 44. This compressed air may pass through the heat exchanger 54 before returning the cooled compressed air 55 to the turbine 56 of the air cycle machine 44. The cooled and expanded air may then be passed through the water extractor 58 before return to the cabin 42. By mixing fresh air flow 100 with recirculation air flow 48 upstream of the ECS pack 46, the air temperature and water content of the incoming air flow 51 entering the ECS pack inlet 51 may be reduced at sizing condition.

Injection Location IV

[0037] Injector location IV may be located upstream of a location where conditioned air 49 exits from the cooling subsystem 46, but after the compressor 52 acts on the fresh air flow 100. Injection location IV may be particularly useful when enough cooling capacity may be achieved with only the heat exchanger 54 (such as at high altitude cruise condition). This configuration may allow either bypass of the air cycle machine 44 completely or bypass of the turbine 56 while using the compressor 52 (which may be motorized by an electric motor 60) to pressurize the fresh air flow 100 (e.g. when pressure 100 is below cabin pressure). In both cases, power savings may be realized by not running the air cycle machine 44 or the turbine 56.

[0038] The present invention may utilize recirculation air injection location IV when a) the cooling of the fresh air flow 100 and the recirculation air flow 48 may be achieved by rejecting heat directly to ambient through the heat exchanger 54; and/or b) the pressure of the fresh air flow 100 at the ECS pack inlet 51 is below the cabin pressure. In the latter case, the compressor 52 of the air cycle machine 44 may be used to increase the pressure of the fresh air flow 100 in order to reach or exceed the pressure of the cabin recirculation air flow 48 before the introduction of recirculation air 48 at injection location IV.

Injection Locations III & IV

[0039] In an embodiment of the present invention, both injection locations III and IV may be utilized to affect the flow to pressure ratio at which the ECS pack 46 is being used. This
embodiment may improve the surge margin and the efficiency of the air cycle machine over conventional designs.

Injection Location V

[0040] Referring now to FIG. 2B, injection locations I, II, III and IV are shown and operate in a manner similar to that described above with reference to FIG. 2A, except that the embodiment of FIG. 2B includes the option of using injection locations I, II, III and IV in conjunction with injection location V, as described below. The embodiment of the present invention, as described below with reference to FIG. 2B, may be useful in situations where the fresh air flow is significantly below cabin pressure and some work has to be performed by one or more cabin air compressors, having a compressor motorized by an electric motor. This configuration may be particularly useful in bleed-less configurations, where the fresh air flow is ambient air which may be at a low pressure (for example, when at high altitude cruise). Inlet injection V may reduce overall power input to the two compressors 52 and 62 by allowing an optimum split of the power between the two compressors 52, 62 in order to stay within the highest efficiency operating conditions of each compressor 52, 62. The resulting pressurized fresh air flow may then be delivered to the ECS pack 46.

[0041] Injection location V may be used to provide a fluid connection between the recirculation air flow 48 and the fresh air flow 100 before the fresh air flow 100 enters a cabin air compressor 70. By mixing the recirculation air flow 48 with the fresh air flow 100, the pressure of the recirculation air flow 48 may be used to partially pressurize the resulting mixed air delivered to the second compressor 62.

Combination Injection Locations

[0042] While the above description has discussed the separate injection locations I, II, III, IV and V, these locations may be used either separately, as discussed above, or simultaneously in order to meet pressurization and cooling performance while improving the complete system efficiency over a wide range of operating conditions. For example, an aircraft (not shown) may include all five locations discussed above, each controlled with valves 66 to regulate air flow there through. The valve 66 may be adjusted to permit recirculation air flow to flow into any combination of injection locations I, II, III, IV and V.

[0043] Referring now to FIG. 3, there is shown a method 200 for providing cooling to an aircraft cabin according to an exemplary embodiment of the present invention. The method 200 may include a step 210 of providing a fresh air flow through an ECS pack. The method 200 may include a step 220 of providing an air flow of recirculation air from the aircraft cabin. The method 200 may include another step 230 of cooling the recirculation air. The recirculation air may be cooled by an air cycle machine, a vapor cycle machine, a heat exchanger or a combination of these. The method 200 may include a step 240 of mixing the recirculation air with the fresh air flow and a step 250 of delivering the mixed air flow to the aircraft cabin. The mixing of the recirculation air and the fresh air may occur a) before both air flows pass through the cooling machine (e.g. air cycle machine); b) after the fresh air is compressed and before the compressed fresh air passes through a heat exchanger (air cycle); c) after the recirculation air is cooled by a heat exchanger and the fresh air passes through the ECS pack (cooling turbine for air cycle or evaporator for vapor cycle); d) after the fresh air is cooled by the ECS pack and before distribution to the cabin or e) before the fresh air and the recirculation air pass through a cabin air compressor.

[0044] The embodiments described above with reference to the drawings may provide several benefits over the conventional cooling and pressurization systems. By cooling the recirculation air, there is provided an additional cooling capacity beyond that of the traditional "fresh" air supply provided by the air conditioning system and generated by the engines (bleed air) or the ambient air (bleed less engines or cabin air compressors). This additional cooling capacity can benefit the aircraft by allowing lower energy usage and/or lighter environmental control system components.

[0045] It should be understood, of course, that the foregoing relates to exemplary embodiments of the invention and that modifications may be made without departing from the spirit and scope of the invention as set forth in the following claims.

We claim:

1. A pressurized cooling system for a vehicle, comprising:
   a recirculation air flow coming from the vehicle;
   a fresh air flow being delivered to a cooling subsystem; and
   at least one injection location for mixing at least a portion of the recirculation air flow with the fresh air flow, wherein the portion of the recirculation air flow is either cooled prior to mixing with the fresh air flow or the portion of the recirculation air flow is mixed with the fresh air flow at a location upstream of a conditioned air flow being delivered from the cooling subsystem.

2. The pressurized cooling system according to claim 1, further comprising:
   at least another injection location, in addition to the at least one injection location, the at least another injection location mixing at least a second portion of the recirculation air flow with the fresh air flow after the fresh air flow passes through a compressor of an air cycle machine.

3. The pressurized cooling system according to claim 1, wherein the cooling subsystem includes an environmental control system (ECS) pack having an air cycle machine.

4. The pressurized cooling system according to claim 3, further comprising a water extractor disposed downstream of the air cycle machine.

5. The pressurized cooling system according to claim 3, wherein:
   the air cycle machine includes a compressor and a turbine; and
   the at least one injection location includes a first injection location mixing the portion of the recirculation air flow with the fresh air flow after the fresh air flow passes through the compressor.

6. The pressurized cooling system according to claim 1, further comprising at least one cabin air compressor for receiving and pressurizing the fresh air flow.

7. The pressurized cooling system according to claim 6, wherein the at least one injection location includes a second injection location mixing the portion of the recirculation air flow with the fresh air flow before the fresh air flow is delivered to the at least one cabin air compressor.

8. The pressurized cooling system according to claim 1, wherein the at least one injection location includes a third injection location mixing the portion of the recirculation air flow with the fresh air flow before the fresh air flow is delivered to the cooling subsystem.
9. The pressurized cooling system according to claim 1, further comprising a recirculation flow heat exchanger wherein the at least one injection location includes a fourth injection location mixing the portion of the recirculation air flow after the portion of the recirculation air flow has passed through the recirculation flow heat exchanger with the fresh air flow after the fresh air flow has passed through a cooling subsystem.

10. The pressurized cooling system according to claim 9, further comprising at least one of a fifth injection location and a sixth injection location, wherein:
   - the fifth injection location mixing the portion of the recirculation air flow with the fresh air flow before the fresh air flow is delivered to the cooling subsystem; and
   - the sixth injection location mixing the portion of the recirculation air flow with the fresh air flow after the fresh air flow passes through a compressor.

11. A pressurized cooling system for an aircraft comprising:
   - a recirculation air flow coming from the aircraft;
   - a fresh air flow being delivered to a cooling subsystem;
   - a cabin air compressor for pressurizing the fresh air flow into a pressurized fresh air flow;
   - a first injection location for providing a fluid connection between the recirculation flow and the fresh air flow prior to the fresh air flow reaching the cabin air compressor; and
   - at least one injection location for mixing at least a portion of the recirculation air flow with the fresh air flow, wherein the portion of the recirculation air flow is either cooled prior to mixing with the fresh air flow or the portion of the recirculation air flow is mixed with the fresh air flow at a location upstream of a conditioned air flow being delivered from the cooling subsystem.

12. The pressurized cooling system according to claim 11, wherein the at least one injection location includes a second injection location for mixing the portion of the recirculation air flow with the pressurized fresh air flow before the pressurized fresh air flow is delivered to the cooling subsystem.

13. The pressurized cooling system according to claim 11, wherein the at least one injection location includes a third injection location mixing the portion of the recirculation air flow with the pressurized fresh air flow after the pressurized fresh air flow passes through a compressor of an air cycle machine.

14. The pressurized cooling system according to claim 11, further comprising a recirculation flow heat exchanger, wherein the at least one additional injection location includes a fourth injection location mixing the portion of the recirculation air flow after the portion of the recirculation air flow has passed through the recirculation flow heat exchanger with the pressurized fresh air flow after the pressurized fresh air flow has passed through the cooling subsystem.

15. A method for providing cooling to an aircraft cabin, the method comprising:
   - providing a fresh air flow through a cooling subsystem;
   - providing a recirculation air flow from the aircraft cabin;
   - mixing the recirculation air flow with the fresh air flow to provide a mixed recirculation air flow; and
   - delivering the mixed recirculation air flow and fresh air flow to the aircraft cabin.

16. The method according to claim 14, wherein the step of cooling the recirculation air flow occurs before the step of mixing the recirculation air flow with the fresh air flow.

17. The method according to claim 14, wherein the step of cooling the recirculation air flow occurs after the step of mixing the recirculation air flow with the fresh air flow.

18. The method according to claim 17, wherein the step of mixing the recirculation air flow with the fresh air flow occurs before the fresh air flow passes through the cooling subsystem.

19. The method according to claim 17, wherein the step of mixing the recirculation air flow with the fresh air flow occurs after the fresh air flow is compressed by a compressor of an air cycle machine in the cooling subsystem.

20. The method according to claim 15, further comprising:
   - pressurizing the fresh air flow with a cabin air compressor; and
   - mixing at least a portion of the recirculation air flow with the fresh air flow prior to the step of pressurizing the fresh air flow with a cabin air compressor.

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